CAPE TOWN, SOUTH AFRICA - JULY 2024

PROCEEDINGS OF THE 9TH WORLD CONGRESS

ON CONSERVATION AGRICULTURE

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DECLARATION

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PROMOTE AND ENHANCE AWARENESS AND ADVOCACY OF CONSERVATION AGRICULTURE (CA)

Conservation Agriculture (CA) is a sustainable farming approach emphasizing minimal soil disturbance, cover, and crop rotation. Despite its numerous benefits, CA adoption rates remain low in many regions. To address this, a multifaceted strategy is essential to promote and enhance awareness and advocacy of CA globally.

To advocate for CA effectively, it is crucial to highlight its environmental, economic, and social benefits. CA practices can significantly improve soil health, increase biodiversity, and reduce greenhouse gas emissions. Additionally, CA can enhance water retention and reduce erosion, leading to more resilient agricultural systems. Economically, CA can lower production costs and increase yields over time, providing a more stable income for farmers.

Efforts to promote CA should include comprehensive education and outreach programs targeting farmers, agricultural extension workers, policymakers, and the public. These programs can utilize various platforms, such as workshops, seminars, webinars, and social media campaigns, to disseminate information and success stories. Collaborating with local agricultural organizations, universities, and research institutions can further amplify these efforts.

Policy advocacy is a critical component of promoting CA. By integrating CA practices into agricultural policies, governments can create an environment encouraging widespread adoption. Establishing strong relationships with policymakers at local, national, and international levels is essential. This involves presenting evidence-based research on the benefits of CA, organizing policy dialogues, and participating in relevant forums and conferences.

Governments can introduce incentive programs, such as subsidies, tax breaks, and grants, to encourage farmers to adopt CA practices. These incentives can offset initial costs and provide financial support during the transition. Agricultural extension services are vital in disseminating knowledge and providing technical support to farmers. By incorporating CA into these services, governments can ensure that farmers receive the necessary training and resources to implement CA practices effectively.

Investing in research and development is crucial for advancing CA practices. Governments can fund research projects, support innovation, and facilitate knowledge exchange between researchers, practitioners, and farmers. Establishing monitoring and evaluation frameworks can help track the progress of CA adoption and assess the impact of policies and programs. This data can inform future policy decisions and ensure continuous improvement.

We can create a global movement towards sustainable agriculture by intensifying advocacy efforts and actively lobbying for policy integration. Conservation Agriculture has the potential to transform agricultural systems, enhance food security, and contribute to climate change mitigation. We must work together to promote and support CA for a more sustainable and resilient future.

INCREASE FINANCIAL INVESTMENT, FUNDING, AND MARKET OPPORTUNITIES FOR CONSERVATION AGRICULTURE (CA) THROUGH APPROPRIATE PARTNERSHIPS, MECHANISMS, AND INCENTIVES WHILE PROVIDING DECENT JOBS AND EMPOWERING WOMEN AND YOUTH

To maximize its potential, it is essential to increase financial investment, funding, and market opportunities through strategic partnerships, effective mechanisms, and targeted incentives. Additionally, these efforts should focus on creating decent jobs and empowering women and youth, ensuring inclusive and equitable growth.

Strong Public-Private Partnerships can mobilize resources and expertise to support CA initiatives. Governments, private companies, and non-governmental organizations (NGOs) can collaborate to fund research, provide technical assistance, and develop infrastructure.

International organizations should also be educated to establish grants and loans to support CA projects, particularly in developing countries. Developing microfinance programs and credit facilities tailored to smallholder or commercial farmers can provide the necessary capital for farmers to adopt CA practices, purchase equipment, and invest in sustainable inputs.

Focus must be placed on the agricultural value chain to create market opportunities for CA products. This includes improving processing, storage, and transportation infrastructure to reduce post-harvest losses and enhance market access. Certification and labelling schemes might be needed to differentiate CA products, which could attract consumers willing to pay a premium for sustainably produced goods, thereby increasing farmers' incomes.

We can create a sustainable and inclusive agricultural system by increasing financial investment, funding, and market opportunities for CA through appropriate partnerships, mechanisms, and incentives. Empowering women and youth and providing decent jobs are essential components of this strategy, ensuring that the benefits of CA are shared equitably and contribute to the overall development of communities. Involving youth in promoting Conservation Agriculture (CA) is essential for its future well-being. CA topics should be integrated into school and tertiary curriculums to educate students about sustainable farming practices from an early age. We should encourage the formation of youth clubs and organizations focused on CA.

These groups can lead local projects, awareness campaigns, and community outreach. Establishing scholarships and grants to entice the young into pursuing studies or projects related to CA could empower our young people and benefit their communities. Pairing young people with experienced farmers and CA practitioners who can provide guidance and support will give our young people valuable practical experience.

Training in public speaking and advocacy to effectively communicate the benefits of CA to diverse audiences would also be essential. These strategies will empower young people to become champions of Conservation Agriculture, ensuring a sustainable and resilient future for agriculture.

C

RECOGNIZE, RESPECT, AND USE FARMERS AS KEY DRIVERS AND INNOVATORS OF CONSERVATION AGRICULTURE (CA)

Farmers are at the heart of agricultural systems and play a crucial role in the success of Conservation Agriculture (CA). Their firsthand experience, knowledge, and innovative practices are invaluable assets that can drive the widespread adoption and adaptation of CA. To fully harness this potential, it is essential to recognize, respect, and actively involve farmers as critical drivers and innovators of CA.

A farmer-centered CA innovation systems approach places farmers at the core of the innovation process. This approach acknowledges that farmers are passive recipients of technology and knowledge and active contributors who can develop, test, and refine CA practices. By leveraging their insights and experiences, we can create more effective and context-specific solutions.

Engaging farmers in participatory research and development (R&D) is a crucial strategy to support a farmer-centred innovation system. This involves collaborative research by partnering with farmers to conduct on-farm trials and experiments. Farmers can test new CA techniques and provide feedback on their effectiveness and practicality. The collaboration also fosters knowledge exchange between farmers, researchers, and extension workers. This can be achieved through farmer field schools, demonstration plots, and farmer-to-farmer learning networks. It is essential to document successful CA practices developed by farmers and disseminate this knowledge through various channels, such as publications, videos, and social media.

The establishment of mentorship programs and linkages where experienced farmers can guide and support their peers in adopting CA could further enhance the successful adoption of CA.

We can create a more sustainable and resilient agricultural system by recognizing, respecting, and using farmers as key drivers and innovators of Conservation Agriculture. Farmers' knowledge, creativity, and adaptability are invaluable assets that can lead to the successful implementation and scaling up of CA practices. Supporting a farmer-centred CA innovation systems approach will enhance learning and adaptation and empower farmers to take ownership of sustainable agricultural practices.

INCREASE SUPPORT FOR SMALL-SCALE FARMERS

Small-scale farmers are the backbone of many agricultural economies, yet they often face significant challenges in adopting sustainable practices such as Conservation Agriculture (CA). To enhance their productivity and sustainability, it is crucial to prioritize promoting sustainable agricultural mechanization, developing affordable machinery, and establishing comprehensive support plans. These efforts should include funding and maintenance to foster sustainable CA adoption among small-scale farmers with the help of sustainable mechanization service providers.

Sustainable agricultural mechanization involves using machinery and equipment that enhance productivity while minimizing environmental impact. For small-scale farmers, mechanization can reduce labour intensity, increase efficiency, and improve crop yields. However, access to appropriate and affordable machinery remains a significant barrier.

Developing affordable, efficient machinery tailored to the needs of small-scale farmers is essential. This involves designing equipment that is easy to use, maintain, and repair. Collaboration with local manufacturers to develop and produce affordable machinery is also necessary. These partnerships can ensure that the equipment is context-specific and meets the unique needs of small-scale farmers. Establishing innovation hubs where engineers, farmers, and researchers can collaborate to design and prototype new machinery might be worthwhile. These hubs can serve as centres for testing and refining equipment before it is scaled up for broader use.

Access to funding is critical for small-scale farmers to invest in sustainable mechanization. Comprehensive support plans should include microfinance programs and credit facilities that provide low-interest loans and flexible repayment terms for purchasing machinery. Governments and NGOs can offer subsidies and grants to reduce the financial burden on small-scale farmers. These incentives can cover a portion of the cost of machinery and related expenses.

However, ongoing maintenance and technical support are essential to ensuring the longevity and efficiency of agricultural machinery. Support plans for sustainable mechanisation should include maintenance service centres that provide regular check-ups, repairs, and spare parts for machinery. These centres could provide opportunities for local entrepreneurs or cooperatives. Technical assistance could be provided through local extension services and/or mobile units that visit farms to offer on-site support and troubleshooting.

Another possibility is equipment rental services that allow small-scale farmers to access machinery without significant upfront investments. Cooperatives, private companies, or community groups can manage rental services. Shared ownership models, where groups of farmers collectively purchase and share machinery, could reduce costs, and ensure that equipment is used efficiently.

Building the capacity of service providers is essential for delivering high-quality support to small-scale farmers. It would involve providing training and certification programs for service providers to ensure they have the necessary skills and knowledge to support farmers effectively.

By prioritizing sustainable agricultural mechanization, developing affordable machinery, and establishing comprehensive support plans, we can significantly enhance the adoption of Conservation Agriculture among small-scale farmers. These efforts will improve agricultural productivity and sustainability and contribute to the economic empowerment and resilience of farming communities.

PROMOTE ACCESSIBLE PRACTICAL LITERATURE, EXTENSION, AND RURAL ADVISORY SERVICES

A lack of accessible information and support can hinder the adoption of CA practices. To address this, it is essential to renew initiatives that create practical literature on CA, share knowledge and experience, and showcase its feasibility across various systems and regions. These efforts should ensure that information is easily accessible to the public, particularly small-scale farmers, and rural communities.

Practical literature gives farmers the knowledge and tools to implement CA practices effectively. This literature should be clear, concise, and tailored to the specific needs of different farming systems and regions.

Collaborative development between farmers, researchers, extension workers, and agricultural organizations is critical in developing practical literature. This collaborative approach ensures that the content is relevant, accurate, and user-friendly.

The literature should be in various formats, including printed manuals, booklets, posters, and digital resources such as e-books and online guides. This ensures that information is accessible to farmers with different preferences and levels of literacy.

It might be necessary to create a single central hub where literature from around the globe is hosted. Translating the research into multiple languages could also be beneficial. Documenting and sharing case studies and success stories is an effective way to showcase the feasibility of CA.

These stories can highlight the experiences of farmers who have successfully adopted CA practices and the positive impacts on their farms.

Extension services are vital in supporting farmers and promoting the adoption of CA practices. To enhance the effectiveness of these services, extension workers need comprehensive training on CA principles and practices. This ensures that they have the knowledge and skills to support farmers effectively.

Governments must again realise the vital importance of the extension services in each country. Rural advisory services complement extension services by offering personalized support to farmers. One-on-one consultations where advisors visit farms to provide tailored advice and support in a personalized approach can address specific challenges and opportunities individual farmers face.

Where applicable the deployment of mobile advisory units that travel to remote areas can provide information and support through on-site training, distributing literature, and facilitate knowledge exchange.

We can promote the widespread adoption of sustainable agricultural practices by renewing initiatives to create practical literature on CA, sharing knowledge and experience, and showcasing its feasibility across various systems and regions. These efforts will empower small-scale farmers, enhance agricultural productivity, and contribute to the overall sustainability of farming systems.

F

INCREASE PUBLIC EDUCATION AND AWARENESS OF CONSERVATION AGRICULTURE (CA) BENEFITS

Public awareness and understanding of CA remain limited. To address this, providing clear and precise information about CA is essential to enhance public understanding of its positive impacts on food security. This can be achieved through a multifaceted approach that includes educational campaigns, community engagement, and the use of various media platforms.

Educational campaigns are crucial in raising awareness about CA and its benefits. These campaigns can target different audiences, including farmers, consumers, policymakers, and the public. Clear and concise messages that highlight the key benefits of CA, such as improved soil health, increased crop yields, and reduced environmental impact, are essential.

We need to tailor the campaigns to specific audiences, such as focusing on the economic benefits of CA for farmers, the health benefits for consumers, and the environmental benefits for policymakers.

Collaborations between agricultural organizations, NGOs, educational institutions, and government agencies are critical to amplify and maximise the campaigns' reach and impact. Community engagement can foster a sense of ownership and encourage the adoption of CA practices.

By providing clear and precise information about Conservation Agriculture and enhancing public understanding of its positive impacts on food security, we can promote the widespread adoption of sustainable farming practices. These efforts will contribute to a more resilient and sustainable agricultural system, benefiting farmers, consumers, and the environment.

ESTABLISH A CA HALL OF FAME TO REWARD CA PRACTITIONERS

Recognizing and rewarding the efforts of Conservation Agriculture (CA) practitioners is essential for promoting sustainable farming practices and inspiring others to follow suit. One effective way to achieve this is by establishing a CA Hall of Fame.

This initiative can honour outstanding contributions to CA, provide a platform for sharing valuable knowledge, and foster a community of practice. Revisiting the 8th World Congress on Conservation Agriculture (WCCA) proposal to create a CA Hall of Fame and a directory of specialists, scientists, and practitioners can facilitate access to valuable knowledge and drive the adoption of CA practices globally.

The primary purpose of the CA Hall of Fame is to recognize and celebrate the achievements of individuals and organizations who have made significant contributions to CA. This recognition can serve as a powerful motivator for practitioners and highlight the importance of sustainable agriculture.

By honouring CA practitioners, the Hall of Fame can also promote sharing of best practices, innovations, and success stories. This can help disseminate valuable knowledge and inspire others to adopt CA practices.

The CA Hall of Fame can foster a sense of community among CA practitioners, scientists, and advocates. This community can collaborate, share experiences, and support each other in advancing CA.

The 8th World Congress on Conservation Agriculture (WCCA) proposed the creation of a CA Hall of Fame and a directory of specialists, scientists, and practitioners—this proposal aimed to facilitate access to valuable knowledge and recognise the contributions of CA champions. The proposal also recommended creating a directory of CA specialists, scientists, and practitioners.

This directory would be valuable for accessing expertise, networking, and collaboration.

To ensure transparency and fairness, it is essential to establish clear criteria for induction into the CA Hall of Fame. These criteria can include:

- Impact: The extent to which the individual's or organization's work has positively impacted CA adoption and sustainability.
- Innovation: Introducing innovative practices, technologies, or approaches that have advanced CA.
- Leadership: Demonstrated leadership in advocating for and promoting CA at local, national, or international levels.
- Collaboration: Contributions to fostering collaboration and knowledge sharing within the CA community.

An annual induction ceremony can be organized to honour new inductees. To maximise visibility and participation, this event can be held in conjunction with major agricultural conferences, such as the WCCA.

ENHANCE RESEARCH AND DEVELOPMENT

Research and development (R&D) is critical in advancing Conservation Agriculture (CA) by generating new knowledge, improving practices, and addressing emerging challenges. To maximize the impact of R&D in CA, it is essential to expand the capabilities of researchers and scientists to conduct studies and effectively disseminate their findings to the agricultural industry. This can be achieved through increased funding, capacity building, collaboration, and the use of modern communication tools.

Adequate funding is crucial for conducting high-quality research in California. To expand research capabilities, the government needs to increase the financing of CA research through grants and subsidies. Governments can allocate specific budgets for CA projects within agricultural research programs. We must encourage private companies, particularly those in the farming and environmental sectors, to invest in CA research. Public-private partnerships can mobilize additional resources and expertise.

CA research benefits from interdisciplinary collaboration that brings together experts from various fields, including agronomy, soil science, ecology, and economics. Establishing research networks and consortia that facilitate collaboration among researchers, institutions, and organizations is invaluable. Collaborative research projects that involve multiple institutions and disciplines can address complex challenges in CA and generate comprehensive solutions.

By expanding the capabilities of researchers and scientists to conduct studies on CA and effectively disseminating findings to the agricultural industry, we can advance the adoption of sustainable farming practices. These efforts will contribute to improved food security, environmental sustainability, and the overall resilience of agricultural systems.

SUMMARY OF ABSTRACTS

PROF JOHANN STRAUSS

The 9th World Congress on Conservation Agriculture (CA), held in Cape Town, South Africa, stood as a testament to the transformative potential of sustainable farming practices in a rapidly changing world. With representatives from every corner of the globe, the congress underscored the urgency of adapting agricultural systems to address global challenges such as soil degradation, climate change, food insecurity, and biodiversity loss. More than just a gathering of experts, it became a powerful call to action, inspiring the scientific community to embrace conservation agriculture as a proven pathway toward sustainable development.

Conservation agriculture is rooted in three key principles: minimal soil disturbance, permanent soil cover, and diversified crop rotations. These practices have long been celebrated for restoring soil health, conserving water, and increasing resilience to extreme weather. Yet, as this congress illustrated, CA is much more than a set of principles; it is a movement driven by innovation, farmer ingenuity, and the tireless efforts of researchers to adapt and refine these systems for diverse environments.

A central theme of the congress was the exponential growth of CA worldwide. From its modest beginnings, it now covers nearly 20% of the world's cropland, with adoption continuing to rise. Much of this success has been farmer-led, often born out of necessity. Farmers have turned to no-till practices and cover cropping as practical solutions in regions plagued by drought or erosion. South America, a CA pioneer, showcased inspiring examples of how collaborative efforts among farmers, researchers, and policymakers can transform agricultural landscapes.

In Brazil, large-scale soil health assessments using enzyme bioanalysis have provided critical insights into sustainable soil management. Farmers now have access to tools that integrate biological indicators like enzyme activity into routine soil testing, empowering them to monitor and improve soil quality effectively.

CA has become a lifeline for smallholder farmers confronting erratic rainfall and depleted soils in Africa. Studies presented at the congress demonstrated the profound impact of reduced nitrogen inputs and cover crops on microbial diversity and soil functionality. South African research highlighted how CA can enhance soil health even in challenging conditions, offering a glimmer of hope for regions grappling with food insecurity.

Australia's story exemplifies the delicate balance between innovation and caution. While no-till farming is widely practised, the system's heavy reliance on herbicides has raised concerns. Innovative digital technologies offer promising solutions, such as targeted weed mapping and precision herbicide applications. Yet, the congress emphasised the need for systemic approaches to reduce herbicide dependence, ensuring long-term sustainability.

The Canadian Prairies provided an inspiring example of how CA can revitalise degraded soils and increase carbon sequestration. Farmers in Saskatchewan have embraced conservation tillage and continuous cropping, significantly increasing soil organic matter. However, the research also revealed gaps in adopting diverse crop rotations, underscoring the need for further education and incentives to fully realise CA's potential.

Mechanisation emerged as a critical enabler for scaling CA practices, particularly for smallholder farmers in low- and middle-income countries. However, as the congress highlighted, introducing new machinery is not enough. Success depends on creating market environments that support mechanisation service providers and ensure equitable access to technology. Examples from Mexico, Zimbabwe, and Bangladesh demonstrated the importance of integrating mechanisation into broader rural development strategies, focusing on empowering women farmers often left behind in the mechanisation wave.

Perhaps the most profound discussions centred on the soil microbiome, described as the heart of healthy agricultural ecosystems. Advances in microbiome research revealed its critical role in nutrient cycling, organic matter regeneration, and resilience against environmental stressors. Studies from diverse regions showed how no-till practices and diverse rotations enrich microbial communities, reducing the need for synthetic inputs and fostering long-term productivity. In South Africa, researchers highlighted the importance of understanding microbial interactions within the plant-soil continuum, offering practical insights for designing regenerative farming systems.

While the success stories were uplifting, the congress did not shy away from addressing the challenges facing CA. Herbicide resistance, monocropping, and legislative barriers remain significant obstacles. In some regions, misguided policies have even reversed CA adoption, as seen in parts of South America. The congress called for coordinated global action to align policies, education, and research with the principles of CA, ensuring its benefits reach all farmers.

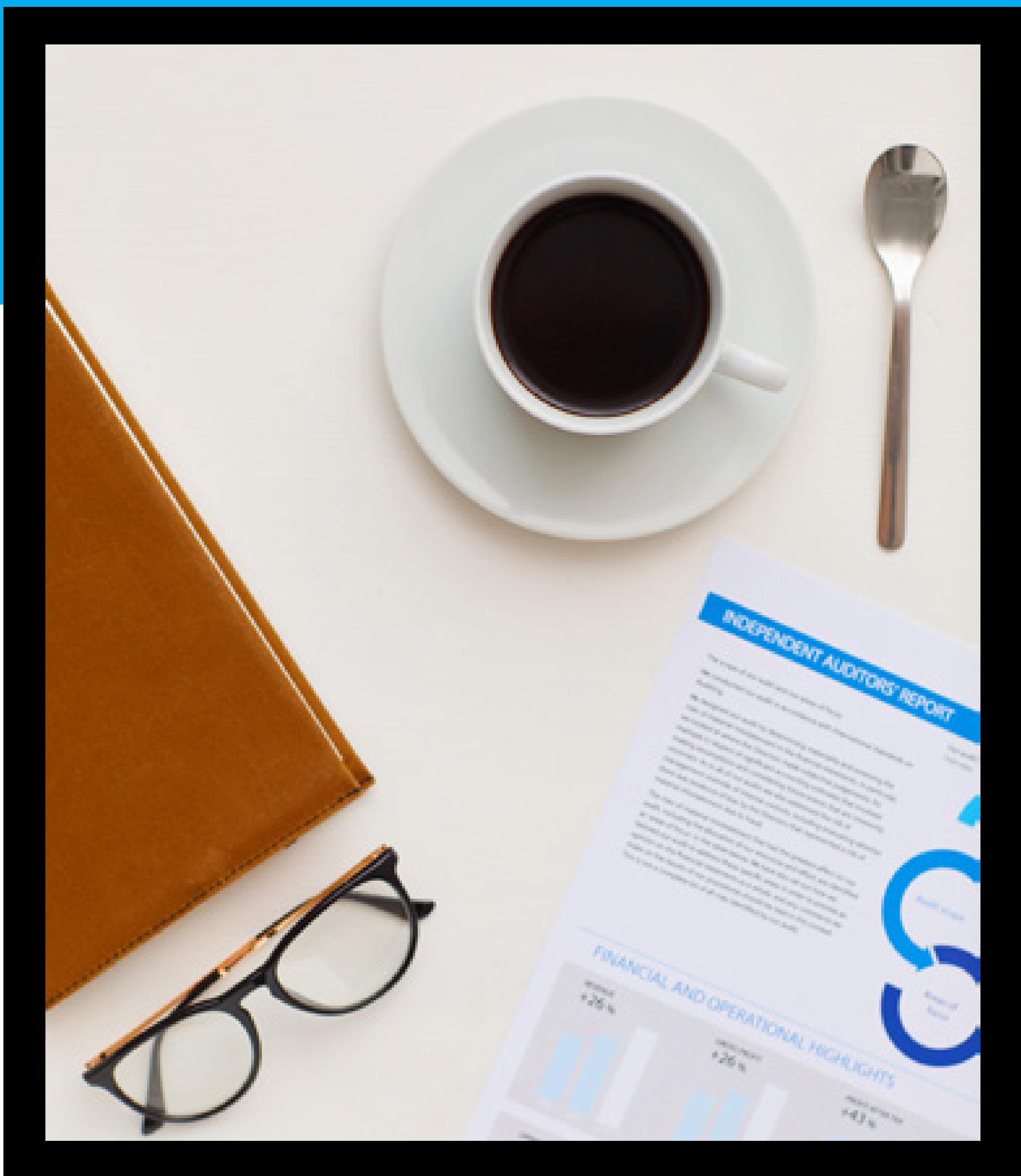
The role of science in this journey cannot be overstated. The congress emphasised that research must move beyond controlled environments to real-world applications, where CA systems are adapted to diverse environmental and socio-economic contexts. Scientists were urged to prioritise interdisciplinary collaborations, integrating insights from soil science, ecology, economics, and social sciences to address the multifaceted challenges of sustainable agriculture.

Amid these discussions, the congress exuded a sense of hope and urgency. Speakers reminded attendees that CA is more than a technical solution; it is a philosophy that aligns agricultural practices with the rhythms of nature. It represents a shift from exploitation to stewardship, from short-term gains to long-term resilience. As one presenter eloquently stated, "Mother Nature always wins; don't farm against her." Achieving the target of 700 million hectares under CA by 2050 will require unprecedented collaboration among farmers, researchers, policymakers, and the private sector. It will demand investment in education and extension services, innovative financing mechanisms, and incentives to reward farmers for the public goods they generate, from carbon sequestration to biodiversity conservation.

As the scientific community reflects on the insights from this congress, it is clear that conservation agriculture offers a powerful tool for addressing the interconnected crises of our time. It is a call to action for researchers to push the boundaries of innovation, for policymakers to create enabling environments, and for farmers to lead the way in transforming our food systems.

The 9th World Congress on Conservation Agriculture was a celebration of past achievements and a clarion call for the future. It reminded us that the solutions to our most significant challenges already exist in the soil beneath our feet. Through collective action, guided by the principles of CA, we can cultivate a future where agriculture thrives in harmony with the planet, feeding the world while restoring the Earth. Let us embrace this vision with the urgency and determination it demands.

KEYNOTES


INDEPENDENT AUDITORS' REPORT
FINANCIAL AND OPERATIONAL HIGHLIGHTS

THE DRIVERS AND SYSTEMS OF SUCCESSFUL ADOPTION OF CA IN DIFFERENT PARTS OF THE WORLD AND THE RELATION OF CA TO OTHER SUSTAINABLE FARMING CONCEPTS

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The World Congress series for Conservation Agriculture (CA) has reached with this Congress its 9th repetition. This is a remarkable achievement in a world where people's attention spans are getting shorter and shorter, and the concept of change seems to be an end in itself and the driving force for programme planning of institutions and organizations. Like butterflies flying from flower to flower, searching for the sweetest nectar, we constantly chase new buzzwords and terms. Even some who have shaped and promoted CA are changing this winning horse in the race against world hunger and degradation for allegedly "better ones" before even reaching the finish line.

Conservation Agriculture has undergone remarkable and unprecedented development. When the term was defined by the Food and Agriculture Organization of the United Nations, FAO, it was still a fairly unknown and untested farming concept, just becoming popular in the Southern Cone of South America and being used by some few pioneers in other parts of the world. This changed with the first World Congress celebrated in 2001 in Madrid, when a global movement of Conservation Agriculture started. Some international agricultural research institutions and several national and international development organizations began working on Conservation Agriculture systems and promoting them in their projects, resulting in exponential adoption worldwide.

Extrapolating the adoption data of the last census from 2018/19, we should now have about 250-270 million hectares of annual cropland under CA, which is nearly 20% of the global cropland, with an additional growing area of orchards and plantation crops also adopting CA. Although CA came into practical farming much later than organic farming, it has far outgrown organic agriculture globally. Yet, contrary to organic farming, Conservation Agriculture is primarily unknown in the general population. Despite the impressive growth rate, we are still far from reaching the goal of 700 million ha by 2050, as was postulated in Switzerland in the Declaration of the Last World Congress on Conservation Agriculture in 2021.

This forces us to reflect on the drivers and mechanisms for the successful adoption of CA so far and discover ways to enhance them for further accelerated adoption. As global soil and land degradation and deforestation continue and climate change with extreme weather conditions accelerate, we have no time to lose to make our land management systems climate-smart and sustainable.

We can trace the origin of no-till farming as the core principle of CA to the Dust Bowl in North America in the 1930s. As a result of that devastating erosion, soil tillage was found to be a major contributor. Research started to find ways to protect tilled soil, and the easiest way was to cover the soil with crop residues. It was found that this could reduce the danger of soil erosion considerably, provided that more than 30% of the soil surface was covered.

Below that 30% level, the soil erosion increased exponentially. This led to the concept of conservation tillage, which we still use today. However, even under conservation tillage, soil erosion is still higher than natural soil formation, making tillage farming unsustainable in the long term. In 1943, Edward Faulkner published the book Plowman's Folly, where he stated:

"No one has ever advanced a scientific reason for plowing". "There is simply no need for plowing in the first instance. And most of the operations that customarily follow the plowing are entirely unnecessary, if the land has not been plowed". "There is nothing wrong with our soil, except our interference"; and "It can be said with considerable truth that the use of the plow has actually destroyed the productiveness of our soils."

All these statements from the early 1940s have proven true and were confirmed in the 2007 book Dirt, The Erosion of Civilizations by David Montgomery.

In the late 1940s, the first no-till seed drill was developed by Purdue University, and in the early 1950s, it was commercially produced. However, it was only in 1962 that the Young brothers in Kentucky started to farm their land without tillage. Today's farm is the oldest one that has not been tilled since then. Ten years later, water erosion problems made crop farming on recently cleared land impossible in southern Brazil. And it was again a farmer, Herbert Bartz, who converted his farm to no-till when he saw all his just seeded crops and topsoil flowing downhill one night in a rainstorm.

In southern Brazil, this began a farmers' movement slowly spreading to neighbouring countries and reaching local research institutions to develop a cropping system without tillage, which was later named Conservation Agriculture. We see that the drivers in those cases were erosion control from wind and water. Also, erosion control is still an important driver for adopting CA in other parts of the world. In China, for example, CA was promoted in the Hebei province surrounding Beijing to protect the city from dust storms during the 2008 Olympic games, as they frequently hit Beijing. In 2009, the Chinese government adopted the promotion of CA as a national policy.

Another driver for CA adoption was drought. As no-till technology became feasible, farmers from arid areas started adopting no-till to save water since each tillage operation caused water loss from the soil. For example, this was a strong driver in Western Australia, the Middle East, Canada, northern Kazakhstan, Mongolia, and Sub-Saharan Africa. No-till systems were established in those countries, and after the first World Congress on CA, many of these no-till systems were developed in CA by adding the other two CA principles of soil cover and crop diversity.

A third important motivation for farmers to investigate no-till systems was economics. This triggered, for example, the development of no-till in the USA and some European countries, such as the UK, where no-till was becoming popular as a technique but not as a system. Unfortunately, this adoption of no-till practice did not consider the other two principles of CA and ended with the straw burning ban in the early 1990s. However, reduced tillage systems, combining operations, using PTO equipment for faster impact, or reducing the tillage intensity and depth became popular for their cost saving. However, since these systems did not provide the benefits of a continuous long-term CA system and created new problems which did not exist with full tillage using the plough while still presenting most of the tillage-related soil problems, most of these developments were dead ends. Still, today, Europe is lagging in the adoption of CA. On the other hand, even in countries such as North Korea, one of the most substantial incentives farmers mentioned to adopt CA was the significant cost reduction, fuel use, and yield increases. For farmers worldwide, the bottom line is the strongest driver to adopt CA.

In all the successful cases of early adoption of CA, it was driven by farmers, helping their fellow farmers and getting organized around CA, such as the "Friends of the Earth" or "Earthworm-Clubs" in Brazil. As CA is a concept and not a ready-made recipe, it needs local adaptation of the practices, and farmers, with their experience in local conditions and flora, are the best developers and promoters. Many pioneer farmers did innovative on-farm research, learning from mistakes and improving the system while helping other farmers avoid these mistakes. Research only joined later, and in some cases, researchers spent more effort trying to prove that CA could not work than helping their farmers adapt and optimize the system for their conditions. Unfortunately, this is still the case in some countries, leading to general confusion for policymakers. Some researchers are still searching for "trade-offs" and downsides of CA, misinterpreting the definition of CA voluntarily or due to ignorance to obtain the desired negative results. Recently, a researcher from a recognized official agricultural research institution even claimed that carbon content could be increased by deep ploughing and not by no-till soil. But when a researcher declares that CA, in theory, cannot work and a farmer proves that, in practice, it does work, who do you think is right? Promoting CA through farmers is the most successful and safe way to achieve adoption. For this reason, participatory learning, such as through the system of Farmer Field Schools or organized farmers' groups, also worked best in development projects to adopt CA. However, this process is painfully slow. It took Brazil about 20 years before CA developed into a significant cropping system, spreading to neighbouring countries.

Considering the alarming speed of global soil degradation, biodiversity decline and climate change, we have no time to wait for farmers' movements only to bring about the large-scale adoption of CA worldwide. Policy support is becoming an important factor in countries that show accelerated national adoption. Countries where policymakers have become convinced to declare CA an essential element of their agricultural development strategy, such as China, Kazakhstan, and several African countries, are showing accelerating and high adoption rates. In other countries, such as in some European countries, even the growing number of interested farmers is hindered in adoption not only by the lack of support but also by legislation that makes CA adoption difficult or impossible. I have worked in countries where farmers could lose their land if they did not plough.

Supportive national and local policies can motivate pioneer farmers to adopt CA. But more importantly, development policies can mainstream CA in education and vocational training systems, producing knowledgeable and skilled staff in national extension systems to support farmers in the transition. They can stimulate research programmes to concentrate on CA systems rather than spending money and effort on tillage research. They can design supportive policies, such as providing financial support such as credit schemes for investing in new CA equipment and technologies and changing subsidy schemes to pay for cover crop seeds or environmental services mediated through CA instead of paying by production area or for commodities. By doing this, they can also stimulate a market for CA technologies and incentivise the machinery industry to provide them to their farmer clients. As the economics of CA are usually much better than in conventional tillage-based production systems, farmers generally do not need subsidies as direct payments. Instead, what is required is some incentive to overcome any possible initial risks in the transition to an unknown system, to help in case of unexpected yield dips, which can happen during the learning curve, or just to recognise the CA farmers' efforts to not only efficiently and sustainably produce food and raw materials, but also for being good stewards of functioning ecosystems.

On the downside, the lack of supportive policies for CA not only does not accelerate the adoption but can also reverse the successful adoption of CA, as we have seen in two of the leading CA pioneer countries in South America. In both cases, misguided incentives to produce certain export crops, based on national policies that never understood or supported CA, have lured CA farmers into monocropping, facilitated by agroindustry promoting their production input packages and using only the no-till practice while forgetting the cover and diversity CA principles. The result is the creation of herbicide resistance, soil compaction, erosion and, in the absence of professional guidance, the return to inefficient and degrading tillage production systems, which is more an action of desperation than a long-term solution, as we know. This example is a reminder that CA is not just Green Revolution agriculture without tillage.

While the three reasons mentioned above were the early drivers of CA adoption, several more can be added today, providing even more reasons for policymakers to support CA adoption. Some interesting results have surfaced in the 5 decades of experience with CA systems worldwide and the 3 decades of intensive scientific research on these systems, giving even more reasons for accelerated adoption of CA.

CA was found to build and conserve the soil and regenerate many ecosystem functions and resources, such as soil organic matter, soil structure and health, biodiversity below and above the soil surface, and clean freshwater resources. More recently, it was even discovered that crops grown under CA would be richer in some vitamins, trace elements, and secondary ingredients, the lack of which in our actual food could be the reason for some of the non-transmittable diseases common in modern societies.

Complemented with other modern technologies for crop production, CA can be highly productive, helping to fight global hunger while at the same time regenerating natural resources and ecosystems. This was why FAO decided in 2009 to make the "sustainable intensification of crop production" its first strategic objective. With CA, it was possible to have highly productive yet fully sustainable agricultural production simultaneously. CA also proved to be the best strategy to respond to the challenges of climate change: it makes cropping systems resilient against drought and torrential rains, against heat and cold and all this without having to prepare for these events. At the same time, CA increases the soil carbon pool and reduces greenhouse gas emissions from agriculture, which could be called "climate-smart agriculture". Those two terms were directly derived from the experience with CA cropping systems and are synonymous with CA, not alternative. CA is the only known operational concept for productive, sustainable, climate-smart agriculture. No wonder in 2011, the FAO published its Save and Grow guide for policymakers to help support smallholders in adopting CA systems for sustainable livelihood development.

Despite this, there have been many attempts to so-called think "beyond" CA, or to look for alternatives and to search for sustainable farming systems as reflected by terms such as "Ecoagriculture", "Agroecology", or more recently "Regenerative Agriculture". Many of these terms are not clearly defined, allowing everyone to use them with a different interpretation. In many cases, such "ecological" farming systems are nothing more than organic farming, not using synthetic inputs but still degrading the environment with tillage. If they reflect sustainable farming systems, they do so by including CA. This is, for example, the case with Regenerative Agriculture. The term was created in the 1980s by Robert Rodale, who researched organic farming systems without tillage in the USA. Therefore, in some Rodale literature on regenerative agriculture, we find references to the principles that are the basis for CA since regenerative organic agriculture differs from just organic agriculture as it uses no-tillage. Rodale adds two more principles, such as permanent living roots and crop-livestock integration, preferably with mob grazing. Rodale mentions the reduction and avoidance of synthetic inputs for "Regenerative Organic Agriculture".

But also, the original CA definition refers to that point, stating that "external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes". Experience with CA has shown that it is well-compatible with organic farming, as the regeneration of the natural processes and control mechanisms reduces the need for synthetic inputs over time. Again, regenerative agriculture is no "alternative" to CA but a complementary system optimized for those agroecological zones, where the climate allows permanent living roots and livestock integration. The three principles of CA remain the universally valid concept for sustainable land management. They are the foundation and structural elements for the sustainability of any production system. In contrast, all the other components and concepts are complementary to improve the performance of the production system and provide for higher production intensity in terms of biological and environmental outputs. Also, the social components, an important element of the Agroecology movement, are not an alternative to CA but an intrinsic element. While the empowerment of subsistence farmers without CA as a farming concept has rarely improved the livelihoods of those farmers and the sustainability of their production systems, the adoption of CA has, in many cases, for example, in Paraguay, but also in several African countries, improved the livelihood, making the farming sustainable and resilient and with this empowering the small-scale farmers.

CA is not a "panacea" as it does not resolve all the existing problems of mankind. But in agriculture and development, it is undoubtedly a magic "silver bullet" hitting multiple targets in one shot. In fact, of the 17 sustainable development goals of the United Nations, CA contributes directly and indirectly to 11. This should be reason enough to concentrate our efforts on promoting CA and accelerating its adoption everywhere where agriculture manages land. Instead of creating new buzzwords and inventing new concepts, still searching for the ultimate sustainable agriculture, hoping for the "betters" while already having the "good" at hand, we should use the "good" we already have and accept that with CA we have a feasible, operational, readily available, and universally applicable concept for sustainable land management which can at the same time feed the world, protect the environment and help achieve the desirable social goals. But it is also not useful to be satisfied with the concept of "sustainable land management practices", wasting time and resources with approaches that only look at single good or best practices that are far from ever reaching real sustainability. The actual confusion created by the scientific world is neither helping the planet resolve its alarmingly growing problems nor providing clear guidance on which way to go for policymakers and farmers. Let's now, more than ever, mainstream CA in all our efforts to make the world a better place. There is no such thing as a sustainable land management practice. We need the three principles of CA applied together to reach real sustainability. There are also no alternatives to these three principles derived from nature and conform to Conservation Agriculture.

Before ending, let me remind you of the six enabling conditions which were proposed in the last World Congress on Conservation Agriculture and which, to reach the proposed goal of 700 million hectares under CA cropland by 2050, are now more urgent than three years ago:

1. Catalysing the formation of additional farmer-run CA groups in countries and regions that do not yet exist.
2. Greatly speeding up the invention and mainstreaming of a growing array of genuinely sustainable, locally adapted CA-based technologies.
3. The CA Community should be incorporated in the primary global efforts to shift to sustainable food management and governance systems at local levels.
4. Assuring that CA farmers are justly rewarded for their generation of public goods and environmental services.
5. Mobilizing recognition, institutional support and additional funding from governments and international development institutions to support good quality CA programme expansion.
6. Building global public awareness of the steps being taken by our CA Community to make food production and consumption sustainable.

RELIANCE ON HERBICIDES – THE ACHILLES HEEL OF CONSERVATION AGRICULTURE IN AUSTRALIA

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INTRODUCTION

Conservation agriculture (CA) is based on three key principles: retaining crop residue, using diverse rotations, and minimising tillage. In Australia, upwards of 85% of farmers use no-tillage seeding and crop residue retention is widespread. The diversity of rotations varies, with reduced diversity in the drier cropping areas where cereals, particularly wheat (Triticum aestivum), dominate. Precision agriculture is at various stages of implementation on Australian farms, with most cropping machinery capable of accurate auto-steer guidance by GPS and variable rate application of inputs. The use of variable rate fertiliser application is increasing slowly.

PRAGMATIC APPLICATION OF CONSERVATION AGRICULTURE IN AUSTRALIA

Farmers using no-tillage in Australia tend to use a pragmatic approach to applying these CA principles (Kirkegaard et al., 2014). For example, occasional tillage is used in specific situations like lime incorporation to ameliorate acidic subsoils, burial of weed seeds, particularly when resistant to key herbicides, or mixing clay into hydrophobic, sandy topsoil. Most farms aim to maintain crop residues wherever possible, with some aiming to maximise this practice using a stripper front on the harvester and disc seeding.

Although cereals dominate grain production, canola (Brassica napus) has been widely adopted, largely due to good grain prices and canola varieties with herbicide-tolerant traits, enabling a comprehensive herbicide package. In the past, poor competitive ability and relatively few herbicide options limited the inclusion of legumes in the rotation, except on some soil types and in the higher rainfall areas. However, additional herbicides have been registered for legumes in Australia, providing farmers with good weed control options for these crops. The area of legumes is still relatively small compared with cereals and canola, although an effort is underway to demonstrate their broader system and economic benefits.

THE WEED CONTROL CHALLENGE

Despite much research on integrated weed management (IWM) over the years, weed control for large-scale cropping in Australia is dominated by herbicides in the no-tillage system. For example, in Western Australia, fields receive an average of 6.3 herbicide applications yearly (Harries et al., 2000). The main weed control benefit of using more diverse rotations is that different herbicide modes of action can be used rather than less herbicide. However, a relatively recent non-chemical weed control innovation has been called harvest weed seed control (HWSC) (Walsh and Powles, 2022). Typically, weed seeds that remain on the plant at harvest are cut by the harvester, threshed with the crop and end up in the chaff fraction, which is usually spread out the back of the harvester. With HWSC, the chaff fraction may be managed in a variety of ways, like directed into a mill on the harvester to crush/kill the weed seeds, dropped in the wheel tracks to confine the seeds or collected in a cart pulled behind the harvester and dumped for livestock feed. Many farms now incorporate some form of HWSC in their system; despite this, herbicide use continues to increase.

The reliance on herbicides for cropping in Australia means the system is vulnerable to major threats, such as loss of social license to use some key herbicides and weeds evolving herbicide resistance or adapting their life cycles to evade constant herbicide use. There is also an example of wild radish (Raphanus raphanistrum) adapting to HWSC, where long-term use has been selected for plants that shed their seed pods before harvest (Ashworth et al., 2024).

The Australian Herbicide Resistance Initiative (AHRI) was formed in 2020 to combat the major challenge of herbicide-resistant weeds in Australian grain production. Despite significant advances in our knowledge of herbicide resistance mechanisms and their management, the latter largely relies on herbicide innovations (new chemistry or novel herbicide rotations/mixes), a notable exception being the development of HWSC.

VISION FOR LOW RELIANCE ON HERBICIDES

The new vision for AHRI is to develop a cropping system with less reliance on herbicides. This simple statement is extremely difficult to achieve, as our large-scale no-tillage cropping system suits herbicides well. However, the paradigm is changing with rapid advances in digital technology and data science/machine learning. For example, weeds can now be detected with cameras/sensors (and associated algorithms) mounted on boom sprayers and then individually sprayed, allowing targeted herbicide application. However, this is still an herbicide response!

AHRI's approach will be to utilise the new technology to inform our cropping and weed management rather than as the means of just applying herbicides for weed control. We will aim to develop maps of weed locations, both predicted weed emergence for the next season and utilising available weed detection technology in-season to develop near real-time maps. The prediction maps would allow a more strategic/long-term approach. For example, if farmers or agronomists knew where the weeds would likely emerge in the upcoming season, they could apply site-specific tactics to minimise expected weed emergence and growth (crop competition, targeted fertilisers, targeted pre-emergent/ residual herbicides, etc.). Furthermore, weed control could be limited to relatively small areas of the field, allowing (re-) evaluation of all available control tactics, some of which were not viable at the whole field level.

Similarly, in-season/real-time weed maps based on weed detection could allow for targeted tillage or post-emergence herbicide. The overlaying of these in-season maps to see where weeds persisted could also be used to quickly detect and manage patches of herbicide-resistant weeds before they spread throughout the field.

Accurate weed maps would also provide a measure of the success or failure of the various weed control tactics over time, thereby providing crucial feedback for decision-making. The presentation will discuss some of these recent adaptations to the Australian cropping system and elaborate on AHRI's vision for reduced herbicide dependence.

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KEYWORDS

Conservation agriculture, Herbicide resistance, No-till, Weed control,

CONSERVATION AGRICULTURE UNDER MEDITERRANEAN CONDITIONS IN THE WESTERN CAPE

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INTRODUCTION

My brother JP and I farm in Moorreesburg, a small town about 80 km north of Cape Town. Our area, known as the Swartland region, has a Mediterranean climate with an average annual rainfall of 350 to 400 mm. Most of this rain, around 80%, falls during the winter months from April to October. Climate change has increased our risks, leading to more frequent dry years and rising temperatures. In our driest year, we received only 110 mm of rain during the growing season and harvested 1.1 tons of wheat.

DEVELOPING OUR CA STORY

Our family began farming in 1864. Since 1971, my father has practised monoculture wheat farming for nearly 25 years due to the government's single-channel wheat pricing system, making it the most profitable option. I met my wife in 1990 while studying Cost and Management Accounting in Cape Town. Given our area's low rainfall and soil types, she came from a fruit farm near Franschhoek and couldn't understand our monoculture system.

In 1994, the government introduced a free market system for wheat, putting profitability under pressure. Politicians, focused on votes and food security, often push for maximum food production, harming soil health as farmers use more chemicals to increase yields. A higher turnover isn't always best for the soil or the bank. I had been on the farm for two years when the free market system was implemented. We switched to crop rotation, starting with cash crops like wheat, canola, and lupins in 1995. However, the weather risk was too high for us. 1997 was the last year we burned stubble. An elderly farmer gave us a matchbox full of medic seeds, saying it was essential for a sound crop rotation system. In 2000, we started using medic clover legumes and applying lime on a 2-hectare grid system. After five years, our only issue was ryegrass. In 2006, Dr Powles from Australia visited the Langgewens research farm and advised us on improving our crop rotation system. I want to thank the Western Cape Department of Agriculture for effectively managing the research farms and allowing farmers to benefit from their relevant trials.

Since 2010, we have been farming with a modern three-year rotation system. In the first year, we plant wheat. In the second year, we plant cover crops, including black oats, radish, rye, clovers, and bitter lupins, which are used for grazing sheep and cattle. In the third year, we grow medic clover legume pastures to build nitrogen levels. We maintain just enough livestock to survive during dry years.

The benefits of our system include a. Spraying a specific chemical only once every three years. b. Using fertiliser composed of 60% chicken manure pellets and 40% MAP. c. Not needing to replant medics. d. Reduced pressure from wheat diseases. e. More time to manage stubble with animals. f. Using tine planters for the past 25 years and recently incorporating disc seeders, which perform excellently in high stubble fields. g. Eliminating the need for a chopper on a combine harvester, thus saving fuel.

Our fertiliser program since 1971 has changed dramatically, as seen in Table 1.

Table 1. Fertiliser application over time We also ensure that pH levels stay close to 6 (KCl) and that the calcium and magnesium ratio remains constant. We use the calcium

Years	N-levels applied	P applied	Ton/ha average
1971 - 1994 Monoculture wheat	80 up to 120 kg/ ha	15-20	2-3
1995 - 2000 Cash crops	120 down to 80 kg/ ha	15	3-4
2001 – 2010 Wheat + medics	80 down to 60 kg/ ha	15	3-4
2011- 2024 Wheat + cover crops + medics	60 down to 9 kg/ ha Average 30N	15	3.5-4.5

levels + mm of rainfall following planting the crop to manage nitrogen topdressing. On-farm trials showed a difference in wheat yield response to fertiliser levels (Table 2) today compared to 30 years ago. Table 2. The difference in yield over 30 years

30 years ago		**Today**	
Fertiliser	**Yield**	**Fertiliser**	**Yield**
none	1	none	2.7
80 N – start	2	9 N – average start	3
120 N – total	3	30 N – average total	4

Timing is crucial for successful farming. My former neighbour once said that if he had been born two weeks earlier, he would have been on time for everything. Over the years, the most important lesson I've learned is continually improving soil health. Ultimately, you will benefit. Mother Nature always wins; don't farm against her. Financially, our new farming methods have made us more profitable than before. This system has allowed us to expand our farmland to ten times its original size. I am grateful for this and thankful to those who believed in us financially, shared their knowledge and skills, and provided the products that meet our specific needs for our rotation system. Thank you.

SCALING OF REGENERATIVE CONSERVATION AGRICULTURE VIA SUSTAINABLE AGRICULTURAL MECHANIZATION

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Mechanization is widely viewed as an engine for agricultural transformation, although options for smallholder farmers are often limited. Mechanization alternatives are even scarcer for women farmers who are frequently left in charge of rural households when younger family members migrate to urban centres for more remunerative employment options.

CIMMYT takes a systems approach to improving the mechanization of smallholder agriculture and determining whether machinery may be scaled to its full potential. The challenge is not to develop new machinery or equipment to transform food systems but to develop conducive market environments for scaling mechanization in target countries and farming communities.

CIMMYT has systematically analyzed the main obstacles to large-scale adoption of farm mechanization to support rural development initiatives in low- and middle-income countries. The evidence from mechanization projects implemented in Mexico, Zimbabwe and Bangladesh shows that lack of finance to set up Mechanization Service Provider Models (MSPMs) and insufficient collaboration between value chain actors to foster and strengthen Mechanization Service Provider entrepreneurs are common limiting factors that hamper scaling efforts.

It is also important to consider that mechanization replaces long-standing traditional or dominant practices ingrained in farming communities and is often difficult to change. Therefore, it is crucial to understand what practices will be scaled down to create space for the machinery or equipment introduced in a specific context.

CIMMYT used the Scaling Scan framework to understand better the enabling environment required to adopt MSPMs. The Scaling Scan is an easy-to-use and accessible tool that collects quick and structured feedback from local stakeholders about ten issues, or "ingredients," that matter in scaling: technology/practice, Awareness and demand, Business cases, Value chain, Finance, Knowledge and skills, Collaboration, Evidence and learning, and Public sector governance.

The Scaling Scan results show a pattern in which technology/practice and knowledge & skills score very high, suggesting that most scaling efforts focus on fine-tuning innovation and training end-users. At the same time, insufficient attention is paid to the ingredients of a conducive market environment for scaling mechanization, such as Finance, Value chain and Business cases.

A successful mechanization project must have a systemic and evidence-based scaling strategy to develop or enable financing mechanisms, functioning value chains and business models for various actors, including farmers, manufacturers and service providers.

CIMMYT has worked in partnership with the German Agency for International Development GIZ and FAO to steer the former's investments in mechanization projects and develop and co-manage a network of mechanization experts, practitioners, and service providers with the latter in 15 countries in Africa and Asia.

Valuable lessons from CIMMYT's experience scaling agricultural mechanization services in different countries indicate that mechanization projects are still engineer-dominated and that a lack of business models, finance, and public sector governance often hampers scaling efforts.

From the start, practitioners and researchers should consider that the best-performing technology in the field is not always the most scalable. The Scaling Scan is an effective tool that can guide users to systemically assess the critical ingredients of an enabling environment for scaling that effectively identifies bottlenecks and helps build consensus needed for meaningful action.

SENSE AND NON-SENSE IN SOIL HEALTH: THE ROLE OF A FUNCTIONAL MICROBIOME IN REGENERATIVE AGRICULTURE

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Modern crop production is facing significant challenges in the 21st century, where a balance between demand for food and the conservation of the land that the crops depend on is required. Within the global agricultural sector, crop production forms the backbone of food production due to the direct human consumption of grains as staple food sources and as feed for livestock. As a result, food security depends entirely on successfully cultivating sufficient food.

At present, 98% of global food production is directly or indirectly linked to soil-borne crops. However, despite the massive growth in crop production seen after the "green revolution" of the previous century, which averted hunger for millions of people, mainly through monocultures and the application of chemical fertilizer, the system turned out to be self-destructive. Conventional agricultural practices have led to soil degradation, with 30% of global arable land being degraded. This degradation is partly due to extensive "agro-inputs," tillage and monocropping.

Global soil degradation is not only driven by overuse in agriculture but also by the unpredictability of climate change. With countries like the United States of America (USA) owing 8-12% of their greenhouse gas (GHG) release since the 1980s directly to crop agriculture, the system further perpetuates its destruction. Global food security now depends on a change in management practices, given that the existing predictions show that global agriculture will have to increase its output by ≈70% by the year 2050 to provide sufficient food for the human population.

The production of food and food crops has also become increasingly challenging in South Africa over the last two decades. This can mainly be attributed to the increase in fertilizer prices and the decline in soil quality. As it is, only 15% of South African soils are considered arable, and of these, around 60% are low in organic matter. Farmers are looking for alternative ways to produce food more sustainably to maintain yields. Conservation agricultural (CA) practices gained traction over the last 10 years as one of these solutions. CA and variations on this principle aim to lower synthetic inputs, integrate livestock, and minimize or altogether remove tillage within their fields. Farmers are embracing the idea of using the microbiome to improve soil quality or health towards a more sustainable food production system.

Soil health is challenging to define as soil is a highly complex environment influenced by various factors such as climate, soil chemistry, texture, nutrient availability, and moisture, all contributing to distinct niches that microorganisms inhabit. Changes in soil characteristics can lead to disruptions in the structure of soil microbial communities, resulting in changes in many of the functions performed by these communities. These shifts can profoundly affect the quality and function of the soil, and understanding the role of the microbiome is critical for farmers to harness these communities to move towards more sustainable food production.

A plant microbiome functions along a plant-soil continuum, including microbial communities in various plant components, bulk soil, and rhizosphere. These communities engage in various microbial interactions, including beneficial, antagonistic, and neutral symbionts. Root exudates regulate the rhizosphere community composition, selectively promoting or inhibiting individual microbial species, contributing to the host's development, nutrient acquisition, and disease suppression.

Several studies have shown that increasing plant diversity through crop rotation or cover crops can increase soil microbial activity and improve nutrient cycling. This does not necessarily relate to an increase in diversity or biomass, and maintaining functional groups is more important to the effective cycling of nutrients in the system than increasing diversity or biomass. Microbial-driven processes in soil are not confined to a single organism. Instead, they use functional redundancy or require the cooperation of several pathways within a complex metabolic network to perform ecosystem services. Therefore, establishing functional groups of microbes or even categorising microbes into functional profiles such as stress-tolerant, defensive, nitrogen (N)-fixing, and phototrophic taxa may be useful in microbiome studies and describing soil communities

Several biochemical transformations are vital for the cycling of essential nutrients mediated by the soil within the soil. These biochemical transformations include the cycling of nutrients, nutrient transformation, reallocation and assimilation. Apart from cycling nutrients, microbes facilitate the uptake of nutrients by plants through mobilisation (secreting chelating agents), solubilisation (mineral dissolving compounds), and mineralisation.

Nitrogen is one of the main plant growth-limiting elements, essential in various plant and microbial metabolic processes. The microbial and chemical processes involved in N cycling are often negatively altered by environmental or anthropogenic factors. Additionally, high levels of atmospheric CO_2 reduce ammonia oxidation while promoting the activities of denitrifiers, while N mineralisation rates are affected by mulching practices and the quality of organic residues. Excessive N fertilisation drives soil acidification through enhanced nitrification, and certain crop rotations favour ammonification processes while suppressing microbial denitrification. Microbial role players are intricately involved in the various processes that make up the N cycle, especially fixing atmospheric N. What has been very clear is that increased nitrogen inputs have a detrimental impact on the microbiome function.

Grain crop production plays a vital role in food security in South Africa and contributes between 25 - 33% of the national gross agricultural output. The most cultivated crops include barley, maize, millet, oats, rye, sorghum and wheat.

Given that South Africa is the main producer of maize for the Southern African Development Community (SADC), this crop is widely cultivated for food and animal feed and, to a lesser extent, for malting and bioethanol production processes. The production of maize is constrained by various stresses, including disease, drought, insect damage, and nutrient deficiency, all of which reduce yield and grain quality.

In a recent study, we investigated the effect of CA practices on the soil microbiome and function in maize production. Different farms using cover crop and crop rotation practices were compared to conventional farming (CV) practices in a maize-growing area. The microbiome was studied using a combination of high-throughput amplicon sequencing and qPCR methods for genes that encode key enzymes in the nitrogen cycle.

Results have shown that CA practices with reduced N-input have a marked influence on soil bacterial diversity, community structure and function. The CA microbiomes showed higher diversity and had distinct microbial communities compared to the samples from farms using conventional practices. In addition, we also observed that farms from different areas had distinct communities associated with the rhizosphere of the maize plants.

There was a marked increase in microbial groups involved in the biological nitrogen cycling in samples from CA farms, compared to conventional practices where these groups were suppressed. This is especially true for groups involved in nitrogen fixation (nifH) and nitrification (amoA and nirxB). The biological nitrification in CV samples seems to be suppressed entirely. It was also interesting to note that microbial groups involved in denitrification were elevated in the CA samples compared to the CV samples. This is most likely the result of the no-till practices combined with an increase in SOM in these fields.

Conservation agriculture management practices have a pronounced effect on the soil microbial communities in the rhizosphere of maize plants. No-till practices and reduced N-inputs lead to higher biological function, resulting in better soil health. A healthy, functional microbiome plays a pivotal role in a sustainable agricultural system and should be considered as part of the management plan of regenerative farms.

LARGE-SCALE SOIL HEALTH ASSESSMENTS IN BRAZIL USING SOIL ENZYMES

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In alignment with global health concerns about agricultural soils, Brazil has adopted the Soil Bioanalysis (SoilBio) approach since July 2020. This pioneering initiative integrates two key soil enzymes—arylsulfatase (ARYL) and beta-glucosidase (GLU)—into routine soil testing (Mendes et al., 2024).

In the past 20 years, Embrapa´s research group on Bioindicators of Soil Quality (SQ), has been dedicated to the selection of robust SQ/Soil Health (SH) bioindicators to be used in commercial routine soil analyses in Brazil. The main objective was to provide a simple, effective, and practical tool that allows SH monitoring at a farm scale. Based on this, farmers would know precisely what, why, how, and when to evaluate SQ/SH and, most importantly, how to interpret what is being assessed. Because of these studies, soil enzymes, arylsulfatase (ARYL) and β-glucosidase (GLU) (associated with the S and C cycles, respectively) were selected, and interpretative algorithms were developed.

These two soil enzymes were included in routine soil analysis and the calculation of Soil Quality Indices (SQIs), named soil bioanalysis technology (BioAS in Portuguese; SoilBio in English). In the SoilBio approach, soil quality is quantified by combining chemical (FERT) and biological (BIO) indicators in a framework that includes three soil functions: (1) nutrient cycling (based on the activities of GLU and ARYL), (2) nutrient storage (based on soil organic carbon, SOC and cation exchange capacity, CEC) and (3) nutrient supply (based on Ca^{+2}, Mg^{+2}, K, P, pH, H+Al; Al^{+3}, sum of bases and base saturation).

Based on a series of previous studies, the following important features were defined for the SoilBio protocol (i) the choice of the 0 to 10 cm depth as the diagnostic soil layer, sampled by the same procedure as for soil chemical fertility analyses and using air-drying and sieving (smaller than 2 mm) for the pretreatment of the soil sample; ii) time of soil sampling after harvest of the second crop, together with that for chemical analysis, facilitating the procedure for farmers (in Brazil, two summer cash crops, e.g. soybean and maize, are grown on most farms), and iii) use of the widely validated and accessible methodology developed by Tabatabai (1994), omitting toluene.

The list of advantages of using ARYL and GLU includes their sensitivity to detect management changes (Balota et al., 2004, Lisboa et al., 2012; Lopes et al., 2013; 2021; Mendes et al., 2019a; 2021, 2024; Peixoto et al., 2010; Santos et al., 2022); low seasonal variability (Lopes et al., 2018), ease of measurement, and cost-effectiveness (Mendes et al., 2019; 2024). After calibration of critical levels for different soils and environments, GLU and ARYL can be measured directly in air-dried soil samples (Mendes et al., 2019), a procedure that streamlines soil handling by seamlessly integrating these enzyme assessments into the standard soil sampling procedures typically conducted for chemical analyses. These enzymes also exhibit good correlation with crop yield and soil organic matter (SOM) content (Lopes et al., 2013; Mendes et al., 2019; 2021; Passinato et al., 2021), soil microbial community diversity (Passinato et al., 2021), low phytonematode populations (Silva, 2020), as well as with soil physical quality indicators (Anghinoni et al., 2021; Passinato et al., 2021).

Using GLU and ARYL in large-scale on-farm SH assessments in Brazil represents an opportunity to engage producers in soil testing beyond standard chemical analyses. To make SoilBio available to Brazilian producers, Embrapa offers training to commercial soil analysis laboratories (Rede Embrapa de BioAS, in Portuguese; Embrapa's SoilBio Network, in English). Standardization of methods and protocols, along with appropriate proficiency testing, guarantees the quality of the results obtained nationwide.

By 06/06/2024, SoilBio technology has been applied to 32,280 soil samples (0-10 cm) across various states in Brazil, resulting in an extensive database that includes enzymatic analyses, soil organic matter (SOM), soil fertility data, sample locations at the municipal level, crop types, and soil textures. The processing of this dataset allowed for constructing the first version of the Brazilian SH map. The application of geospatial modelling based on the SoilBio database, using municipalities as the mapping unit, has proven effective for mapping SH in Brazil, a country with 5,570 municipalities.

The categorical variable, SH condition, comprised five classes: healthy, deteriorating, unhealthy, recovering from degradation, and intermediary. We also explore potential relationships between SH patterns and soybean yield levels in municipalities within the top five Brazilian soybean-producing states. Of the 1089 Brazilian municipalities evaluated, 74% exhibited healthy or recovering agricultural soil environments.

Remarkably, within four of the top five soybean-producing states with more than 2,000 soil samples— Mato Grosso, Mato Grosso do Sul, Minas Gerais, and Paraná — significant correlations have been observed, associating reductions in soybean yield with increases in the percentages of unhealthy and deteriorating soils. Geospatial modelling based on the SoilBio database and municipalities as mapping units proved effective in mapping SH conditions in Brazil. The first version of the Brazilian SH has been sent to publication. It represents a groundbreaking approach to nationwide SH monitoring, contributing to improving sustainable management practices in agricultural landscapes.

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SUCCESSES AND SURPRISES: CONSERVATION AGRICULTURE IN THE CANADIAN PRAIRIES

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INTRODUCTION

Conservation agriculture on the Canadian Prairies has transformed soil health, primarily through widespread adoption of reduced- and no-tillage practices. The effect of conservation tillage on residue decomposition varies with climate and soil types across the Prairies. Saskatchewan is home to approximately 45% of Canada's cropland, where nearly 12 million hectares (58%) are managed using strict no-till and 95% of cropland is managed with conservation tillage (Statistics Canada, 2021). As a result, soil organic matter stocks have increased significantly (Awada et al., 2021), leading to improved soil health. Conservation tillage was accompanied by the adoption of continuous cropping that likewise contributed to increases in soil organic matter (SOM).

In 2024, Saskatchewan farmers seeded over 12 million acres of canola and over 9 million acres of spring wheat (Statistics Canada). Other cereals, including barley, durum wheat, and oats, as well as pulse crops (field peas, lentils, etc.), are common rotation crops. Despite the documented benefits of crop rotation as an integrated pest and disease management tool, the adoption of diverse crop rotations is not universal, and the benefits for soil health are not well documented. Crop shoots, root residues, and rhizodeposits are essential precursors to soil organic matter and provide carbon (C) and nutrients to fuel below-ground food webs. There is evidence of preferential stabilization of root-derived C in soil (Sokol et al., 2019), which holds promise as a tool to increase soil C sequestration. However, common crop species' contributions to SOM formation are not well characterized, particularly for roots and root-derived C.

We have been studying the impact of diverse rotations and the drivers of SOM formation from different crops in the field and greenhouse better to understand the contributions of crop rotation to soil health. Our work aims to quantify the effects of crop rotation diversity on soil health functions, C stored in different soil pools and to characterize shifts in microbial community diversity and composition to provide evidence-based information about the broader benefits of diverse crop rotations.

METHODS

We sampled bulk soil, roots, and rhizosphere soil from two long-term field experiments at sites in Saskatchewan and Alberta. First, in Town et al. (2022), we sampled mono-cropped wheat and both wheat phases of a wheat-canola-wheat-pea rotation at early vegetative (EV), anthesis (AN) and post-harvest (PH) stages in a 28-year-old experiment at Swift Current, SK described in Smith et al. (2017). In a second study (Town et al., 2023), we sampled mono-cropped canola as well as canola grown in two- and three-year rotations at full flowering in two consecutive growing seasons from a 12-year field experiment at three sites with different soil zones (Lacombe, AB, Scott, SK and Swift Current, SK described in (Harker et al., 2015). Both long-term experiments were managed using conservation tillage and prescription nutrient management based on site-specific soil testing.

We used amplicon-based high throughput DNA sequencing of the bacterial 16S rRNA and fungal ITS genes to profile microbial diversity and community composition in the soil, rhizosphere and roots of wheat and canola. In the wheat study, we also measured extracellular enzyme activities with the fluorometric plate method (Bell et al., 2013), microbial necromass (amino sugars (Indorf et al., 2011)), lignin concentration (Peltre et al., 2017) and mineralizable C (VandenBygaart et al., 2015) along with plant available nutrient pools. In the canola system, we measured soil nutrient fluxes using PRS® Probes and root exudates (organic acids; (Mamet et al., 2019)). In both studies, we measured the mass of C in particulate- (POM) and mineral-associated organic matter (MAOM) pools using the simple size fractionation method (Cambardella & Elliot, 1992).

We used a custom $13CO_2$ stable isotope plant labelling chamber system to track the quantity, transformations and ultimately, the stored forms of root-derived C to understand the mechanisms by which different crop species contribute to the formation of stable SOM. Field peas, spring wheat and canola were grown to maturity in pots (10 cm diameter, 60 cm high) containing two different soil types in the greenhouse. Plants were pulse labelled with $13CO_2$ twice a week from 9:30 a.m. to 2:30 p.m. until maturity. The $13CO_2$ was supplied proportional to the photosynthetic rate by maintaining a constant target CO_2 concentration of ~ 410 ppm at a 13C enrichment of 35 atom% to achieve a uniform and adequate incorporation of 13C into the plant tissues. Aboveground and root tissues were harvested separately, dried, and weighed. Soil and root samples were dried at 100 and 60°C, respectively.

A 10 g subsample was used to isolate POM and MAOM by size fractionation. Roots, soil, POM and MAOM fractions were ball-milled and analyzed for total C and N, atom% 13C and atom% 15N using a varioPYROcube couple to an isoprime PrecisION isotope ratio mass spectrometer (Elementar, UK). A tracer mass balance approach based on recovered tracer yields, as detailed by Rasmussen et al. (2019).

RESULTS

In the wheat-based system, a redundancy analysis of the suite of all soil functional attributes showed that wheat monocropping (in red) shifted soil function (Figure 1A) compared to rotation wheat (green and blue). There were no significant effects of diverse rotations on the alpha-diversity of bacterial (Figure 1B) or fungal (Figure 1C) communities in the soil, rhizosphere or wheat roots.

However, soil organic matter quality declined, as indicated by higher lignin concentration under continuous wheat cropping (not shown). These shifts in soil health and function were reflected in lower long-term average wheat yields 20% lower than wheat grown in rotation with canola and field pea.

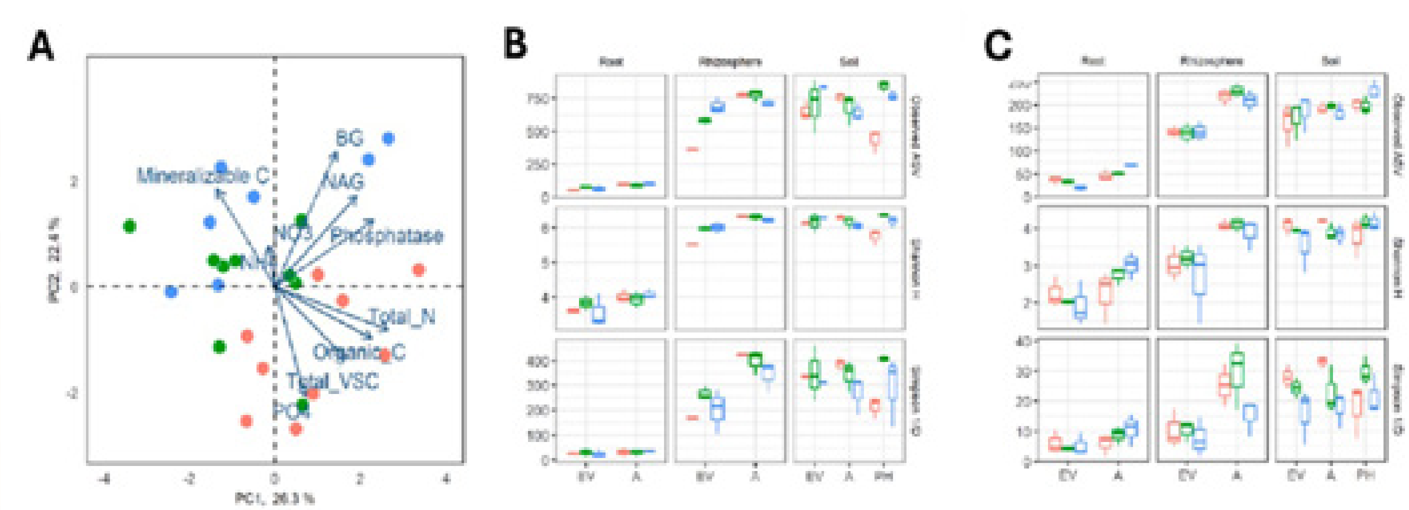

Figure 1. Redundancy analysis of soil functional attributes (A) and alpha diversity of bacterial (B) and fungal (C) communities in continuous wheat (red) and both wheat phases of a wheat-canola-wheat-field pea rotation. Figures adapted from Town et al. (2022).

In the canola-based system, fungi were more strongly affected by diverse rotations than bacteria, with greater abundance of root pathogens (Leptosphaeria maculans and Alternaria alternata) and Olpidium brassicae (Figure 2A) which dominated the fungal community in canola roots. At two of three sites, the composition of canola root exudate (organic acid) profiles differed between continuous and rotation canola profiles (Figure 2B).

Crop rotation did not affect the proportion of mass of POM-C or MAOM-C in either the wheat (not shown) or canola (Figure 3) field experiments. In the canola experiment, the quantity of MAOM-C stored was higher at Lacombe than at either Scott or Swift Current, showing that inherent soil properties and climate had a stronger effect than crop type on C storage in these pools.

When canola, wheat and field peas were compared in the greenhouse, canola and wheat contributed more C to both POM and MAOM pools than field peas, but the proportion stored as more persistent MAOM was highest for field peas. Slightly less plant C was measured in the POM and MAOM pools for the Central Butte soil than in the Goodale soil. However, in the Central Butte soil with more clay than the Goodale soil, a more significant amount of plant C was stored as MAOM vs. POM for all crop types.

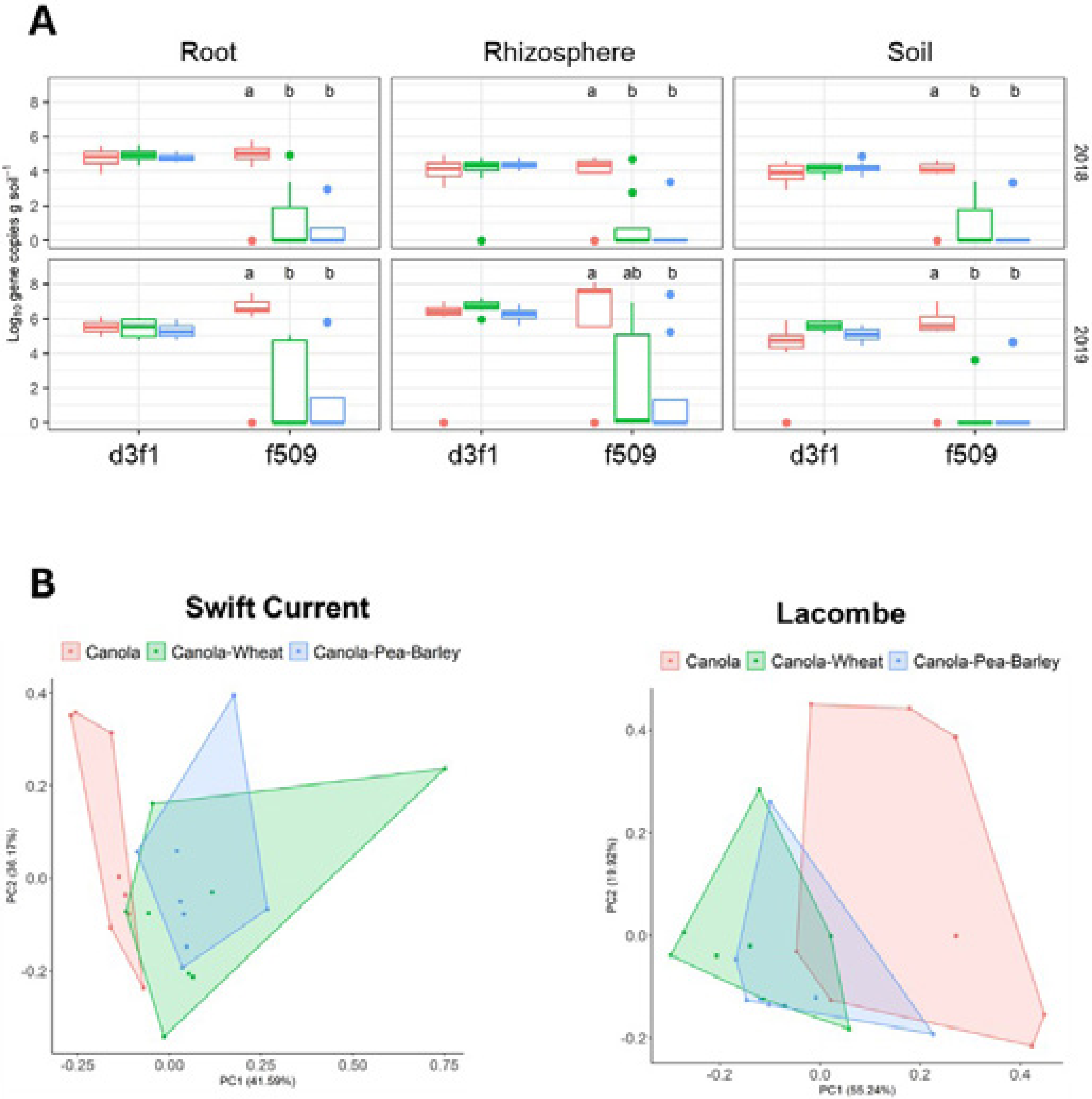

Figure 2. Continuous canola (red) had a higher abundance of the fungal root endophyte Olpidium brassicas at Lacombe (A) and altered organic acid exudate composition (B) in Swift Current and Lacombe sites compared to canola grown in diverse two- and three-year rotations (blue and green) after 12 years.

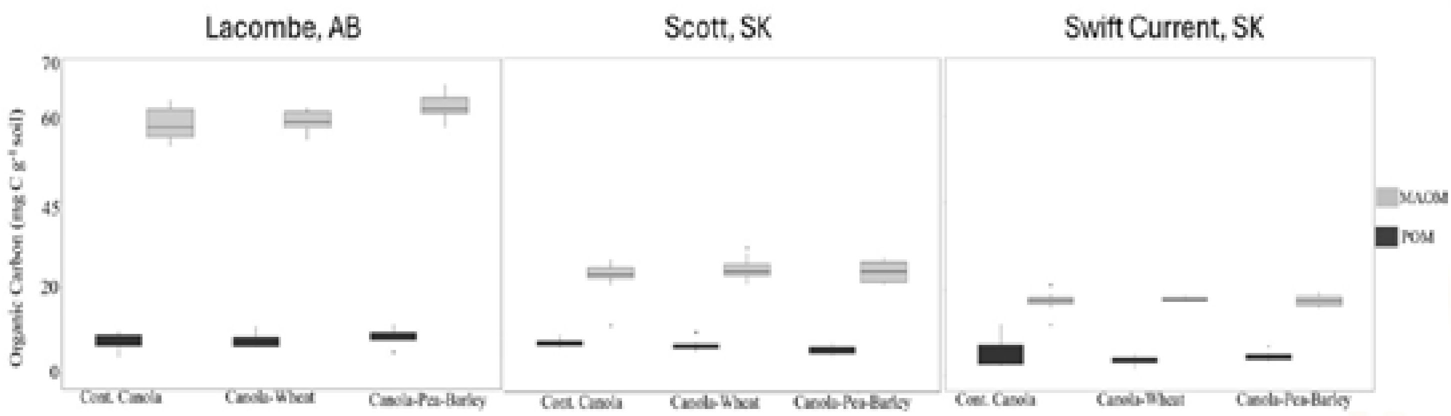

Figure 3. Particulate (POM-C) and mineral-associate organic (MAOM-C) carbon in soils after 12 years of canola monocropping or 2- and 3-year rotations.

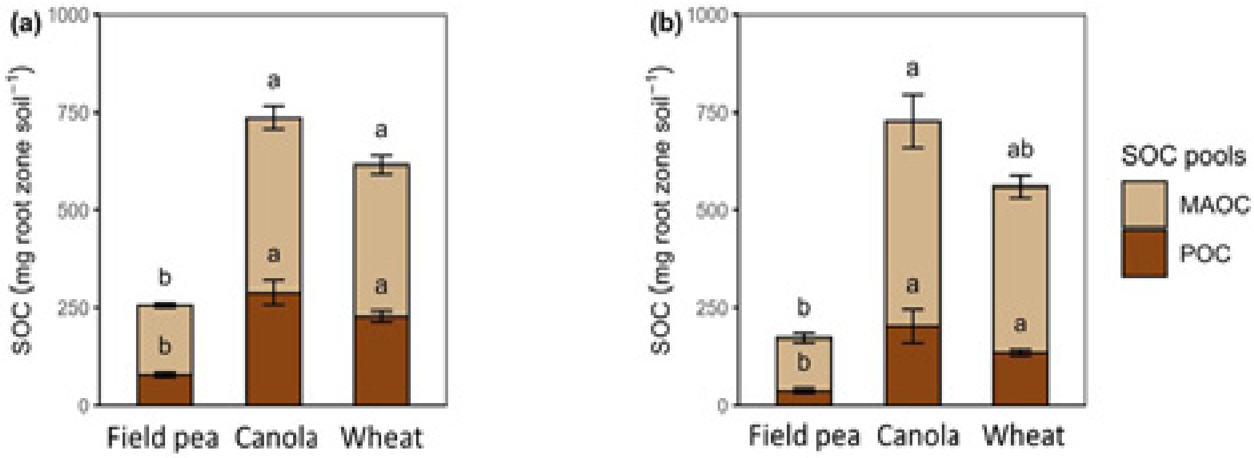

Figure 4. Quantity of root-derived carbon in particulate- (POC) and mineral-associated organic matter (MAOC) carbon pools after growing field pea, canola and wheat using $13CO_2$ stable isotope probing in the greenhouse in two loamy soils with different clay contents (a) Goodale (19% clay) and (b) Central Butte (23% clay).

CONCLUSIONS

The effects of long-term crop rotation diversity of wheat- and canola-based cropping systems showed that more diverse crop rotations did not lead to major increases in the diversity of soil or root-associated bacteria and fungi. Still, there were notable shifts in community structure and function. Diverse crop rotations contribute to soil health by reducing pathogen loads and shifting the structure of microbial communities in the soil, rhizosphere and roots. Growing a variety of crops that produce different amounts of above- and belowground residue with different residue and rhizodeposit characteristics results in shifts in microbial community structure and function. Over time, these changes lead to the formation of better-quality SOM, which is a foundation of good soil health.

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KEYWORDS

crop rotation, microbiome, soil nutrient cycling, organic matter

CONTEXT MATTERS: WHAT ROLE DOES ENVIRONMENTAL AND MANAGEMENT FACTORS PLAY IN PROMOTING SOIL HEALTH?

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Soil health reflects the ability of soil to function as a dynamic living system that supports plant, animal, and human life. Recognised as a fundamental concept, soil health is vital for promoting environmental health and food security. Consequently, there has been a heightened effort to develop and implement agricultural systems that restore and maintain healthy soils. Most frameworks that evaluate soil health integrate physical, chemical, and biological indicators to generate a soil health score. However, many of these assessments narrowly focus on microbial biomass and soil respiration and do not sufficiently consider the biological aspect of soil health. After all, soils cannot be healthy without a diverse biota community inhabiting them and performing key ecological processes. However, this is not the only challenge in assessing soil health in conservation agriculture.

Much of the existing research has been conducted in controlled, long-term trials. These trials are invaluable for understanding specific interactions and mechanisms over extended periods and are necessary because biological change and, by extension, soil health restoration is a gradual process. However, limited information on soil health restoration is available in real-world scenarios where conservation agriculture is practised in diverse management and environmental conditions.

Therefore, several on-farm studies were conducted in South Africa to examine how different environmental and management contexts influence soil health, emphasising the biological aspect of agricultural soils. This paper reports and discusses the results from three of these studies. The first study was undertaken over three consecutive summer growing seasons on a farm near Ottosdal in the North-West Province. The aim was to investigate the short-term influence of conservation agriculture on soil health.

In the first year, non-living factors like soil structure, sand content, and available nutrients (phosphorus and nitrogen) were the main drivers of differentiation between the agricultural systems (conservation, conventional, and uncultivated). However, biotic (living) factors, such as microbial community structure and organic matter, became more important as time passed. This shift highlights the dynamic nature of soil health, where both abiotic (non-living) and biotic properties interact and change over time. Furthermore, the study showed that total available phosphorus was consistently higher in cultivated crops due to using fertilisers, while organic matter and microbial biomass were higher in the uncultivated system. This suggests that agricultural practices, especially those involving minimal tillage, can enhance soil fertility but may also reduce organic matter content due to physical and chemical disturbances. Soil health status was also affected by crop sequence as part of the rotation. The cover crop followed by maize sequence showed potential for promoting soil health by increasing ecosystem maturity, food web connectivity, and fungal decomposition, leading to better nutrient cycling and pest regulation. Environmental context also played an important role. The study site's soil, characterised by high sand and low clay content, limited its capacity to store carbon. This made it challenging to build organic matter, which is linked to soil health status. The findings suggest that improvements in organic matter require multiple growing seasons and specific practices like planting cover crops and integrating livestock.

The second study was more strongly focused on the biological (ecological) aspect of soil health under different management and environmental contexts. To this end, two farms in the Eastern Free State were studied, which revealed some intriguing yet contrasting findings. At the first farm, the biological data aligned with the expected benefits of conservation agriculture and pasture systems compared to conventional agriculture systems. The pasture system showed a higher biological activity, likely due to continuous organic cover and minimal disturbance, which are known to increase organic carbon content.

These conditions appeared to support the soil biology, as evidenced by significantly higher respiration rates, indicating greater microbial activity. Additionally, the pasture system showed higher Maturity Index values, a nematode-based index used to assess soil ecosystem health. This suggests the presence of more sensitive nematode indicator species and healthier soils. The conservation system also had higher Maturity Index values than the conventional system, highlighting the potential of conservation agriculture to improve soil health. Therefore, the management systems employed at this farm were the primary factor influencing the biological status.

In contrast, at the second farm, the physical and chemical soil properties, or environmental context, played a key role in determining the biological status of the agricultural systems. Regardless of the management practices, factors such as organic carbon content and soil respiration were significantly influenced by clay content. Soil texture greatly affects soil biological, chemical, and physical properties.

For instance, the percentage of clay is a major factor in determining soil organic matter content. The adsorption of organic matter onto clay minerals helps preserve it by reducing its exposure to decomposing microorganisms. It is well known that the retention of organic matter is positively correlated with the decreasing size of soil particles. Consequently, fine-textured soils consistently have higher carbon content values than medium and coarse soils. A study on soil health across the Midwest, USA, found that soil texture accounted for over 60% of the variation in soil properties, having a much more significant effect than agricultural management practices.

The third and final study is still ongoing. It aims to validate a set of ecological tools for assessing soil ecosystem health in conservation and regenerative agricultural systems in South Africa. This study involves multiple farms across six different ecotopes, defined by their climatic and soil conditions, located in the North-West, Free-State, and KwaZulu-Natal provinces of South Africa. Early results suggest that while conservation and regenerative agriculture systems can potentially restore soil health, the environmental context may have a greater impact than the specific farming practices used. This finding highlights the importance of considering the environmental context when evaluating soil health restoration in agricultural systems. It suggests that it can be challenging to compare different environmental settings directly. Furthermore, this underscores the need to design, implement, and monitor more sustainable agricultural systems based on experimentation and results from individual farms.

In conclusion, the findings from these studies underscore the intricate interplay between environmental conditions and management practices in shaping soil health. For farmers, this means that while adopting conservation agriculture can significantly improve soil health, these benefits are highly dependent on the specific environmental context of their farms. Farmers need to consider their local soil characteristics, climate, and existing soil health when implementing new practices. Tailored approaches that incorporate cover crops, minimal tillage, and organic matter enhancement, adapted to the unique conditions of each farm, are vital for achieving sustainable soil health improvements. On-farm experimentation and continuous monitoring are also crucial in refining these practices and maximising their benefits, ultimately leading to more resilient and productive agricultural systems.

ORAL PRESENTATIONS

SUPPORTING ADOPTION OF CONSERVATION AGRICULTURE IN EUROPE – FIRST EXPERIENCES WITH A FARMER-BASED MOVEMENT IN GERMAN-SPEAKING EUROPEAN COUNTRIES

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INTRODUCTION

The adoption of CA in Europe is still lagging behind most other continents. Within German-speaking European countries, especially Germany, have the lowest adoption dynamics even though the farmers' community in Germany is well-trained. There are many reasons for this. In most countries that successfully adopted CA, farmers' movements were the main driver for the adoption and to trigger research and policy to support the movements.

However, German farmers are having difficulties learning about CA as most publications on CA are in English, Spanish, Portuguese, or French. On the other hand, education is still focused on conventional systems, whereas CA is mentioned only peripherally. German scientists had worked on no-till systems in the very early years. Still, they later lost interest, and there is hardly any German literature about mature CA systems and the latest state-of-the-art accessible for farmers.

Additionally, in German-speaking countries, official research is mainly focused on reduced tillage systems, not CA. Knowledge transfer of the trial results to farmers only happened sporadically. Therefore, farmers interested in CA systems and experts were organized in Switzerland, with the foundation of Swiss No-Till in 1995 and the German Association of Conservation Tillage in 1999, aiming for a practical exchange of knowledge of CA systems.

Younger generations, to some extent, can read international publications if they have the chance to do their studies at university. Still, non-academically educated farmers can hardly be internationally informed about CA. Therefore, to reach a wider audience, more information must be produced in German and spread via written papers, directly on the field, and face-to-face with other farmers.

Learning from the positive experience of the British Groundswell movement, a similar event called Soil Evolution was organized for the first time in 2022 in Germany, with CA farmers from Austria, Germany, and Switzerland participating.

MATERIALS AND METHODS

In 2019, the idea of a German version of the British Groundswell movement was born to make new scientific knowledge accessible to everyone. Together with Austrian and Swiss colleges, the German Association of Conservation Tillage (GKB) started to plan and organise the first "Soil Evolution—a festival of the soil" lasting over three days.

The concept of "Soil Evolution" is to bring machinery manufacturers, producers of seed, fertilizer and plant protection, presenting their products regarding CA systems together with scientists and farmers presenting their CA-knowledge through oral presentations and practical workshops. So finally, the visitors of "Soil Evolution" can see the technical options for CA systems and get to know practical experiences and knowledge from other colleges.

Oral presentations occur in tents on the festival grounds, sorted by thematic focus, e.g., soil, biodiversity, and conservation agriculture. Additional meeting points allow everybody to discuss several problems and questions about CA. In contrast, workshops, for example, show differences between CA and conventional systems but also share knowledge about plant protection, plant health, erosion, and soil. As the participants know, some farmers are not able to come for different reasons; every member of one of the three organizations, GKB, Boden, Leben or Swiss No-Till, could listen to the recorded oral presentations after the Event every time the Soil Evolution Homepage.

In summary, the "Soil Evolution" Festival is based on three pillars: oral presentations, workshops, and exhibitors. This assessment analyses experiences and findings from Soil Evolution 2022 in Germany and 2024 in Austria, which were organized by farmer-driven CA Organizations from Austria, Germany, and Switzerland.

RESULTS AND DISCUSSION

Since its foundation in 1999, GKB's priority aim has been to bring farmers and scientists together to work on CA and no-till systems on one hand and to help farmers interested in adopting those systems with their knowledge on the other. Therefore, the development of Soil Evolution was a logical step within the portfolio of GKB and its Austrian and Swiss equivalents.

Looking back to the first Soil Evolution Event in 2022, all participants were very pleased with the organisation and the concept of Soil Evolution. Although the visitor numbers were not as high as hoped for, together with the exhibitors, it was enough to call this first Event a success. Several conclusions could be drawn from Soil Evolution 2022: first, some visitors and exhibitors criticised the high number of oral presentations taking place simultaneously within the five presentation tents, which made it difficult for them to decide which they would listen to. Also, the short breaks between oral presentations were a point mentioned by several people. As a result, the number of oral presentations and their schedule were adjusted for Soil Evolution 2024, which has only three presentation tents with fewer presentations. Second, the feedback regarding different workshops was very positive and was the openminded atmosphere, which allowed us to discuss pros and cons, but also ways of working in CA systems.

Nevertheless, the organisation team decided to primarily support discussion between CA- and no-till farmers with farmers who are interested in adopting those systems. For this purpose, special talks, so-called "practical talks", were added for Soil Evolution 2024, mainly to promote the exchange of experiences and knowledge between experts and beginners. The number of 60 exhibitors already, which is quite double compared to 2022, emphasises the potential exhibitors see in the concept of this event and CA systems. Third, the participants learned from Soil Evolution 2022 that the interest in CA and no-till systems is very high, especially focusing on the transfer of knowledge and experiences from experts to beginners who want to adopt CA systems on their farms. Therefore, social media was used intensively for advertisement in 2024, especially to arouse the interest of young farmers.

The visitors' profile of Soil Evolution 2024 showed the huge success of this way of advertisement. Nevertheless, even more advertisement is necessary for future events to get more farmers interested and open-minded about the fields and presentations. It will take some time to make Soil Evolution an important and influential Event within agricultural Events in Europe, but still, this is the realistic aim of all participants. This target is based, among other things, on the increasing number of visitors, already 400 per day in 2022 compared to 800 participants per day in 2024. Also, the willingness of Swiss No-Till to be the host of Soil Evolution 2026 underlines the potential everybody could see in this Event.

CONCLUSIONS

Farmer-to-farmer exchange is the key to knowledge transfer regarding CA systems. Events like Groundswell in Great Britain or Soil Evolution in German-speaking European countries focus on the exchange of knowledge and experiences between farmers, but also between farmers and machinery manufacturers, seed producers and scientists. Therefore, they give everybody a chance to learn about CA systems and share experiences and difficulties, not only people with access to English, French, or Spanish publicized trials. Summing up, soil evolution has successfully achieved the aim of bringing farmers and scientists together and providing a platform of exchange.

KEYWORDS

Conservation Agriculture: Soil Evolution, Farmer Based, CA Learning, Knowledge transfer; Communication

SOIL HEALTH IN A CEREAL-OLEAGINOUS CROP ROTATION UNDER NO-TILLAGE IN A SEMIARID REGION IN SPAIN: NUTRIENT USE EFFICIENCY AND BIODIVERSITY

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INTRODUCTION

The European Union promotes soil and water protection and develops regulations and policies based on agricultural strategies, including soil management, to minimize contamination due to anthropogenic origin (Moreno-García et al., 2020). According to the Mission 'A Soil Deal for Europe', the main threats affecting agricultural soils in Spain are the loss of organic matter and nutrients and soil erosion. In addition, the use and management of soil in a traditional way (conventional agriculture, tillage), as well as the excessive use of fertilizers and pesticides, contributes to soil contamination, significant greenhouse gas emissions and losses of nutrients.

Additionally, agriculture produces around 20% of total greenhouse gas emissions and the agri-food system more than 30%, mainly due to the production and application of fertilizer and pesticides, soil use and its management (FAO, 2020). However, agriculture's primary goal is to feed a growing world population. Therefore, our efforts should be on reducing the impact of agriculture on the environment.

Precision irrigation and fertilization, direct sowing and no-till, application of organic matter, the retention of crop residues, cover crops, intercropping, crop rotations, the inclusion of diverse vegetation, and the promotion of soil biodiversity should be considered to deal with these threats and provide ecosystem services improving the health of our soils while increasing or maintaining crop yield and quality causing a minimal impact on the environment (Rose et al., 2021). Improving soil structure, increasing soil organic matter content and nutrient use efficiency positively impact soil health and ecosystem services provided by agricultural soils (Bünemann et al., 2018). Therefore, agricultural practices should consider an increase in food production and crop quality (Sánchez-Rodríguez et al. 2021) and a reduction in nutrient losses to water bodies and greenhouse gas emissions (Sánchez-Rodríguez et al. 2019).

However, our knowledge of these practices in certain conditions, such as semiarid environments, is still limited. For these reasons, this study aimed to assess the impact of different management strategies (no-tillage and direct sowing versus conventional agriculture) on soil nutrient content and availability to plants (soil fertility) and on soil organisms (insects) in a semi-arid region (south of Spain). Moreover, we are focused on the effect of contrasting soil typology: our study was developed on a Luvisol from a Quaternary fluvial terrace and a Cambisol with vertic properties developed on marls.

MATERIAL AND METHODS

For that, an experimental design with two different soil management systems (tillage and no-till) was set up 12 years ago, in which a cereal-oleaginous crop rotation is cultivated. Figure 1 shows the experimental design in which four blocks (approximately 6 ha each) are differentiated. Each block combines a soil management system (tillage or no-till) and a crop (wheat or canola).

Moreover, a grid of 203 points was set up to perform a soil characterization (basic soil properties at different depths) with at least 50 points in each block. In addition, there is a gradient in soil typology from the west, Stagnic Luvisols, to the east, Vertic Cambisols, of the experimental field. The Stagnic Luvisols on a Quaternary terrace has abundant rock fragments and a lower content in soil organic matter and clay contents (Figure 2) in comparison to the Vertic Cambisols, whose pH is higher due to the presence of calcium carbonate (from marls).

Figure 1. Experimental design in which a crop rotation is grown in two management systems (tillage and no-till) and two soil typologies (Stagnic Luvisols and Vertic Cambisols).

The sampling points used for crop nutrient uptake (N and P) and insects' diversity in the 2022-2023 season (12 years after the beginning of the field experiment) are shown in different colours in Figure 1 (25 per block, 100 in total). Crop nutrient uptake (N and P) was calculated after harvesting 1 m2 per sampling point. Then, the soil samples were dried, grounded, and burnt to calculate N or digested to calculate P concentration. Soil organisms' biodiversity (insects) was estimated through pitfall traps and microscopy in the spring of the same season and in the same sampling points detailed before. In this communication, we show the results of one of the two crops included in the rotation, wheat (season 2022-2023), except in the case of insects' diversity (both crops, wheat and canola).

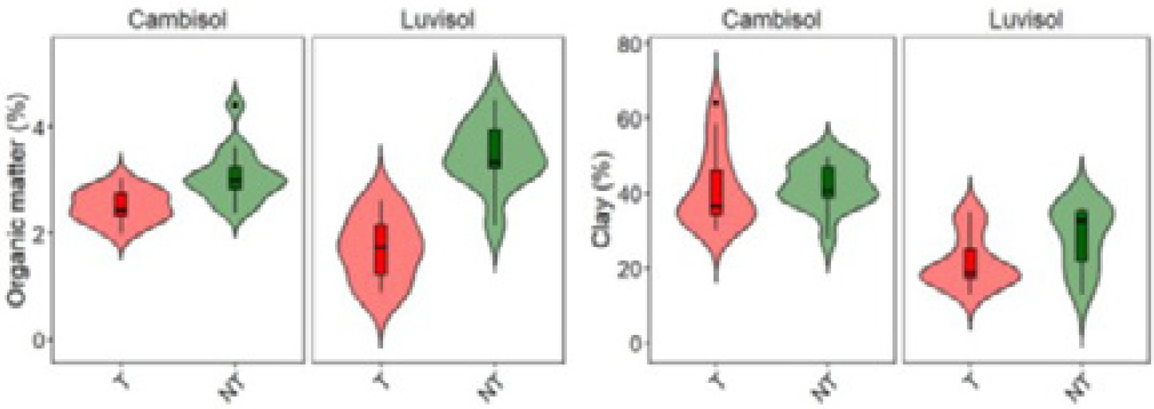

Figure 2. Violin and box plots of soil organic matter (0-5 cm soil depth) and clay contents (0-20 cm soil depth) as a function of soil management (T: tillage and NT: no-till) and soil typology (Cambisol and Luvisol).

RESULTS AND DISCUSSION

The low precipitation recorded in the season in which the analyses were done (50 % of the mean value in the reference period) could have affected nutrient use efficiency and soil biodiversity. Total N uptake was higher in the Cambisol than in the Luvisol but no significant differences were observed between tillage and no-till (Figure 3). However, the percentage of N translocated to the grain was higher under no-till in the Luvisol but not in the Cambisol, which also happened for P translocated to the grain. In this case, conservation agriculture (no-till and direct sowing) increased grain nutrient use efficiency and the resilience of agroecosystems. They reduced the requirement for chemical fertilizers in less fertile soil (Luvisol).

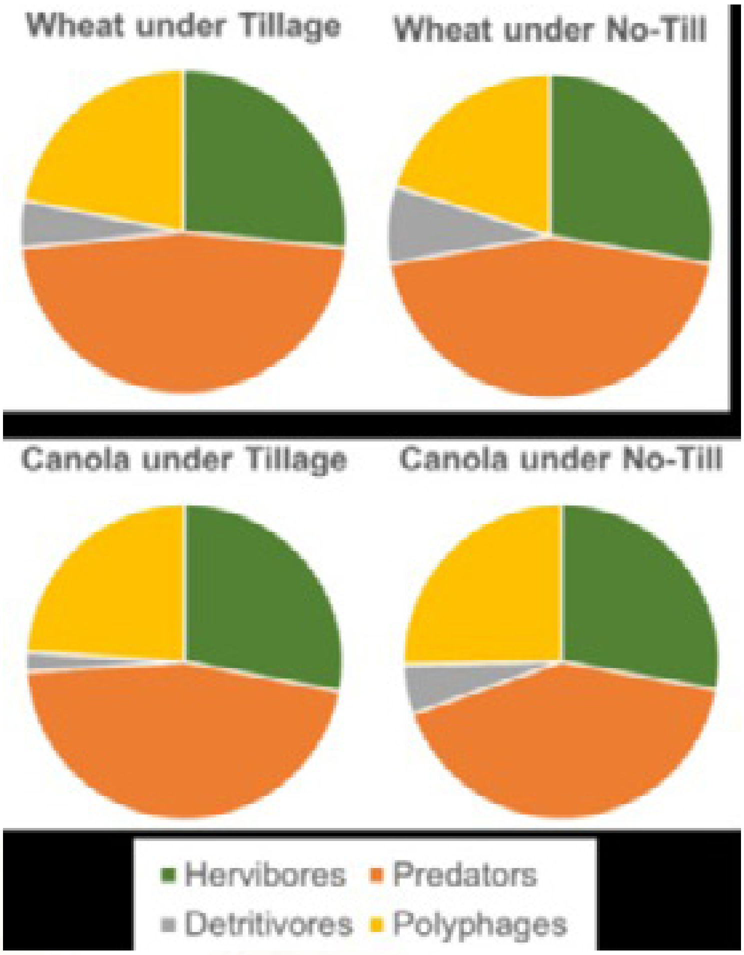

Figure 4. Number of insects species (%) grouped into functional groups as a function of the crop (upper part-wheat and bottom part-canola) and soil management (Tillage and No Till).

CONCLUSIONS

These results are an example of how no tillage improves the sustainability of agriculture in Mediterranean areas under different soil typologies, in this case, in the Luvisol (the most limiting soil typology studied here, in terms of fertility and productivity), reducing the requirements for fertilizers. In addition, the structure of soil insects was also modified, increasing the presence of detritivores with no-till. Our results highlight that understanding soil typology is fundamental to successful soil management because agroecosystems' response widely depends on that.

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LONG-TERM EFFECTS OF CONSERVATION TILLAGE PRACTICES ON SOIL QUALITY AND MAIZE YIELD IN MONZE, SOUTHERN PROVINCE, ZAMBIA

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INTRODUCTION

In much of southern Africa's smallholder dryland farming sector, there has been an increased risk of crop failure and declining yields due to infertile soils, unreliable rainfall, and inadequate management of the natural resource base (Thierfelder and Wall, 2009). Tillage practices profoundly influence soil's physical and chemical properties (Mangalassery et al., 2014; Aikins and Afuakwa, 2012). The common tillage practised by smallholder farmers in Zambia is conventional tillage practice, which is intensive as it involves moldboard ploughing, leaving the soil bare and loosening soil particles, making them susceptible to the erosive forces of wind and water. In Zambia, a mould plough, hand hoes, and disc harrow are mainly used for conventional tillage (CT), while a ripper and a no-till planter (Direct Seeder) are used for conservation options.

Conventional tillage (CT) has led to soil organic carbon decline (Melero et al., 2006), water runoff and erosion, and other manifestations of physical, chemical, and biological soil degradation (Kertész and Madarász, 2014). On the other hand, Conservation Tillage Practice (TP) involves minimum soil disturbance and reduces erosion by protecting the soil surface and allowing water to infiltrate instead of running off. Ripping and direct seeding are two conservation tillage practices used in Conservation Agriculture. Conservation tillage is known to increase soil organic carbon (SOC) content in the soil, while conventional TP leads to loss of SOC to the atmosphere. Conservation tillage helps to reduce many components of soil degradation, including soil organic matter decline and soil structural degradation (Derpsch, 2003).

PROBLEM STATEMENT

Conventional tillage contributes negatively to soil quality and maize yield in the Monze District of Southern Province, Zambia. It does not conserve moisture and soil nutrients to deliver better maize yields. A survey indicated that the average maize yield under conventional tillage is 1.6 tonnes/ha, which is low against a potential 8 tonnes/ha (Kalinda et al., 2010). Frequent turning of topsoil under conventional farming makes the soil loose and prone to erosion by wind and water, leading to nutrient loss and plough pan formation, hindering plant growth and moisture retention.

HYPOTHESIS

1. There are no differences in soil physical and chemical properties from CT, RT, and DS tillage practices.
2. There are no differences in soil quality and maize yields from CT, RT, and DS tillage practices.

MATERIALS AND METHODS

The study was conducted in Malende Agriculture Camp in Monze District, Southern Province of Zambia, using a randomised complete block design. Six on-farm sites were selected and managed by farmers under the strict supervision of the researcher and extension officer. The tillage practices investigated were Conventional Tillage (CT), Ripping Tillage (RT), and Direct Seeding (DS).

Soil samples were collected and analyzed for bulk density using the core-ring method, soil organic carbon using the Walkley and Black method, soil infiltration rates using a single-ring infiltrometer, and soil aggregate instability index using dry and wet sieving methods. Maize grain yield was recorded for each tillage practice. Statistical analyses were performed using STATISTIX software.

Soil Bulk Density Bulk density measures the compactness of the soil, which affects root growth and water infiltration. Lower bulk density indicates better soil structure and porosity. Soil samples were taken from the soil's top 0-10 cm layer using a core sampler. The samples were dried and weighed, and the bulk density was calculated.

Soil Organic Carbon Soil organic carbon (SOC) is a key indicator of soil health and fertility. It was measured using the Walkley-Black method, which involves oxidizing the organic carbon in the soil with potassium dichromate and sulfuric acid and titrating the excess dichromate with ferrous ammonium sulfate.

Soil Infiltration Rates The Soil infiltration rate is the rate at which water enters the soil. It was measured using a single-ring infiltrometer. The infiltrometer was inserted into the soil, adding water to the ring. The time it took for the water to infiltrate into the soil was recorded, and the infiltration rate was calculated.

Soil Aggregate Instability Index Soil aggregate stability measures the soil's resistance to erosion and its ability to retain water. It was measured using dry and wet sieving methods. Soil samples were sieved to separate the aggregates, which were then subjected to water and air to determine their stability.

RESULTS AND DISCUSSION

The study's results indicated that Ripping Tillage (RT) and Direct Seeding (DS) practices had a significantly positive effect on soil quality and maize grain yield compared to Conventional Tillage (CT).

Soil Bulk Density The bulk density for RT and DS was 1.53 g/cm^3 and 1.52 g/cm^3, respectively, while CT had a higher bulk density of 1.56 g/cm^3. Lower bulk density in RT and DS indicates better soil porosity and structure, enhancing root penetration and water infiltration.

Soil Organic Carbon RT and DS showed higher soil organic carbon (SOC) levels, with 63 kg/ha and 77.7 kg/ha, respectively, compared to 54.7 kg/ha in CT. Higher SOC levels improve soil fertility and structure, promoting crop growth and yield.

Soil Aggregate Instability Index The soil aggregate instability index was lower for RT and DS (2 and 1.9, respectively) compared to CT (4.4), indicating more stable soil aggregates under conservation tillage practices, which helps reduce soil erosion and improve water retention.

Soil Infiltration Rates Basic infiltration rates were higher in RT (0.058 cm/min) and DS (0.059 cm/min) than in CT (0.047 cm/min). Cumulative infiltration intake was also higher in RT (13.54 cm) and DS (13.32 cm) than in CT (12.33 cm), demonstrating better water infiltration and reduced runoff in conservation tillage practices.

Maize Grain Yield For the 2022/23 season, Maize grain yield was significantly higher under RT and DS (4.5 tonnes/ha) compared to CT (3.7 tonnes/ha). Higher yields under RT and DS are attributed to better soil quality, including higher SOC, lower bulk density, and better water infiltration rates.

CONCLUSIONS

The study concluded that conservation tillage practices (RT and DS) have significant advantages over conventional tillage (CT) in improving soil quality and maize grain yield. RT and DS practices resulted in higher organic carbon, better soil structure, improved water infiltration, and higher maize yields.

These findings suggest that conservation tillage practices can enhance soil health, increase agricultural productivity, and contribute to sustainable farming practices in Monze District, Southern Province of Zambia.

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KEYWORDS

Conservation Agriculture, Maize Yield, Soil Organic Carbon, Soil Quality, Tillage Practices, Zambia

WORLDWIDE TRENDS IN CONSERVATION AGRICULTURE AND CLIMATE CHANGE SCIENTIFIC PRODUCTION

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INTRODUCTION

Climate change is a significant contemporary challenge affecting present and future generations. Substantial scientific evidence supports the notion that Conservation Agriculture (CA) can effectively mitigate its effects. Because of that, the number of academic publications on these topics is rapidly increasing, making it challenging to stay abreast of the latest developments. In this context, bibliometric analysis is a valuable tool, encompassing methods employed to study or measure texts and information, especially within extensive datasets.

MATERIALS AND METHODS

To address the research question, “Is CA a viable strategy for mitigating climate change, supported by sufficient scientific evidence?” we initiated a systematic search process. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Protocol was applied in this study, involving key steps such as identification, screening, and inclusion.

The search encompassed two widely recognized databases, Web of Science and Scopus. The inclusion criteria were limited to journal articles published within the Q1 and Q2 quartiles. The eligibility criteria were no-tillage, vegetative cover and crop rotation related to climate change. 652 articles were subjected to bibliometric analysis using the Bibliometrix R-tool. No restrictions to publication date were selected.

RESULTS & DISCUSSION

CA became a trend of study related to climate change at the end of the XXth century since the first article was published in 1995. Analysing this period, 651 papers published were found in 69 different sources. In 2002, it started an exponential growth, which increased even more after 2012. This can be explained by the awareness of the Kyoto Protocol and the identification of agriculture as a key sector to sequester CO_2.

Results were grouped in 3 periods: 1995-2002; 2003-2012; 2013-2022. The studies found were 37, 189 and 426 (651). The number of authors by period was 126, 680 and 1876 (2493 in total). The international co-authorships of the papers evidence the collaboration of CA networks. By period: 8.11%, 28.04% and 37.79 %. Elsevier’s Soil&Tillage Research was the preferred journal with 192 publications, h-index of 70 and 13335 citations, followed by Agriculture, Ecosystem and Environment with 83 publications, h-index of 44 and 6322 citations.

CONCLUSION

The scientific community is highly interested in assessing CA’s important role in climate change mitigation.

KEYWORDS

No-tillage, Groundcovers, Crop rotations, bibliometric study

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CONSERVATION AGRICULTURE CAN BE AN EFFECTIVE FALL ARMYWORM CONTROL STRATEGY IN MAIZE-BASED CROPPING SYSTEMS IN SOUTHERN AFRICA

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INTRODUCTION

Since 2016, Fall Armyworm (FAW) (Spodoptera frugiperda (J.E Smith)) infestations have become prevalent and a common phenomenon in Southern Africa's maize-based cropping. If unchecked, infestation levels can cause more than 50% maize yield losses. To date, efforts to control the pest have focused on various agroecological approaches, including breeding tolerant varieties, push-pull systems, and using biocides, apart from chemical control. In this study, we tested how cropping systems, including conservation agriculture (CA) and legume intercrops, planting time, and indigenous control practices, influence maize crop damage by FAW and subsequent yields at two research stations in Malawi. This study evaluated the effects of conservation agriculture practices and other factors on FAW prevalence and subsequent maize yield.

MATERIALS AND METHODS

Field trials were established at Bvumbwe and Chitedze Research Stations, Malawi, in the 2020/21 and 2021/22 cropping seasons. The experiments tested how cropping systems (conservation agriculture (CA) and legume intercrops), planting time, and Indigenous control practices influence maize crop damage by FAW and subsequent yields.

RESULTS AND DISCUSSION

Results from 2020/21 from both stations suggested that the time of planting ($p<0.001$), cropping system ($p<0.001$) and the indigenous control treatments ($p<0.001$) all significantly influenced FAW damage to maize plants. Significant ($p<0.001$) linear declines in maize grain yield amounting to -130kg/ha (Bvumbwe) and -11 kg/ha (Chitedze) for every unit increase in % damage was apparent. Similar to first year, results from the second year (2021/22) at Chitedze Research Station also suggested the number of damaged plants was significantly influenced by the time of planting ($p<0.04$) and cropping system ($p<0.01$) while the indigenous FAW control treatments ($p=0.51$) were not significant. Therefore, using conservation agriculture (reduced soil disturbance and soil cover provision) led to a significant reduction in FAW damage to maize compared to farmers' conventional ridge and furrow systems. Furthermore, including cowpeas as intercrops in both the conventional ridge/ furrow and CA systems also significantly suppressed FAW damage to maize, leading to higher maize yield.

CONCLUSIONS

Results thus point to the fact that simple cultural management control methods such as reduced soil disturbance combined with soil cover provision using crop residues, legume intercropping, and early planting, as commonly recommended for CA, are all effective FAW control strategies in maize that farmers in FAW-prone environments can employ. The effects of Indigenous control methods were, however, season and location-dependent.

KEYWORDS

alternative systems, fall armyworm, yield loss,

MITIGATING LABOUR BOTTLENECKS AND IMPROVING PRODUCTIVITY OF SMALLHOLDER CA FARMERS IN SSA THROUGH MECHANIZATION

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INTRODUCTION

Southern Africa is warming at twice the global rate (Engelbrecht et al. 2015), making 44.8 million people food insecure. Due to climate change, sub-Saharan Africa could experience a potential 50% reduction in maize yield by 2040–2070 (Kaizzi et al. 2012; Stuch et al. 2020). Various climatic adaptation strategies, such as soil and water conservation practices, have been promoted to improve water use efficiency under rainfed agricultural production systems amidst increasing droughts and shifts in rainfall.

Under the Climate-proofed Presidential Inputs Scheme, the government of Zimbabwe has scaled a climate-smart/conservation agriculture (CA) practice called pfumvudza to three million Zimbabwean smallholder farmers. Under pfumvudza, farmers dig 1465 cubic size (150 mm) planting basins in 39 m x 16 m plots (basin spacing 0.75 m x 0.60 m for maize) ahead of rainy (planting) season. Pfumvudza farmers have increased their yields manifold compared to conventional farmers (Mujere et al. 2021). However, being a labour-intensive (50 person-days/ha) and back-breaking task, its adoption beyond the Inputs Scheme plots or Zimbabwe is limited. This study tested different low-cost CA machinery and compared their effectiveness against pfumvudza.

MATERIALS AND METHODS

The experiment was established at the University of Zimbabwe farm, Harare, from November 2022 to June 2023 (-17.7256040 latitude, 31.0193410 longitude). The field (clay-loam soil) receives 750–850 mm of rainfall/per annum, mainly from November to March. The experiment tested four CA maize establishment methods: T1 – ‘pfumvudza’ using hand hoes; T2– ‘mechanized pfumvudza’ using a basin digger (Model: EA52CC, Lucky Brand, Msasa, Harare), T3 - mechanized ‘ripping’ using two-wheel tractor single-row ripper (Model: Prochoice, Prochoice Solutions, Willowvale, Harare), and T4 – ‘No-till’ using two-wheel tractor multi-crop planter (Model: Kurima, Kurima Machinery and Technology, Southerton, Harare). All treatments were replicated three times in a 10.5 m x 19.8 m (T1 and T2) or 10.8 m x 19.8 m (T3 and T4) plots. Planting basins were dug in November 2022 for both basin treatments. Cubic size basins of 150 mm were targeted in the pfumvudza, while 150 mm diameter and 150mm deep basins in mechanized pfumvudza (basin spacing of 0.75 m x 0.60 m). The ripper prepared 100–120mm deep continuous furrows (90 cm rows) for hand planting while the planter completed furrow opening, planting seeds, fertilizing and covering seeds and fertilizer in a single pass. The calibrated planter planted 1 or 2 seeds/hill (25 cm hill spacing) and drilled fertilizer @200 kg/ha at a depth of 5 cm. Lime (2.31 kg/plot) and manure (208 kg/lot) were applied manually along the planter furrows.

Each planting basin or ripper hill (0.60 m hill spacing) was applied with 5 g lime, 450 g manure and 8 g basal fertilizer (N:P:K=7:14:7+8.5%S) and covered with some loose soil to avoid potential direct contact of fertilizer with seeds. Three maize seeds (PAN53, 99% germination capacity) were hand planted in pfumvudza, basin digger, and ripper plots on 1 December 2022 in each basin or hill and covered with 5 cm soil. Some incomplete furrow sections were left in the ripper and planter treatments, which were planted manually using hand hoes, and additional labour was added to the crop establishment labour requirement.

Three soil samples were collected/plotted from 150 mm depth at planting using a hand auger and oven-dried at 105 °C for at least 72 hours to determine soil moisture content. The plots were sprayed with glyphosate (6 l/ha) the day after planting. Plant emergence data were recorded 5–19 days after planting (DAP). Maize residues were spread (from the previous crop, 75 kg/plot) uniformly throughout the plots after planting.

The crops were hand-weeded at 30 and 70 DAP and thinned to a maximum of two seedings/hill for the basin digger and ripper at 42 DAP but to one/hill for the planter. Ammonium nitrate fertilizer (200 kg/ha/application) was top-dressed at 34 and 68 DAP following rains. Insecticides were applied twice using a knapsack sprayer (needed by the insect pressure). Labour and time data were recorded for all the operations till the second weeding. Crop establishment labour (CEL) requirement was calculated as the labour required for the operations from basin digging to thinning. The total labour (TL) included labour needed for weeding and spraying insecticides.

Furrow depth, width and backfill (depth of loose soil in-furrow after planting) were also measured from 10 locations/plots at planting. Seeding depths were calculated by measuring coleoptile depths of 10 thinned-out seedlings/plot. A ruler measured Basin and furrow dimensions in 25 locations/plots. Plant (25/plot) and ear (14/plot) heights were measured at 35 DAP and harvest on 19 May 2023. Crop data (plant population, cobs/plot, grains/cob, grain yield and grain moisture content by oven-dry method) were recorded. Grain yield was adjusted to 15% moisture content. Data were analysed for variance to check the significance of the inter-relationships.

RESULTS AND DISCUSSION

Analyses of variance showed that CEL, depths of furrow, loose soil, seeding depth, width of basin/furrow, days to 50% emergence, ear height, and yield varied significantly (a = 0.05) depending on the CA crop establishment methods. The TL varied greatly (21.89 person-h/ha for control, 15.95 person-h/ha for basin digger, 21.52 person-h/ha for ripper and 15.72 person-h/ha for planter). Still, they were not significantly different due to high variations of weeding labour requirements amongst replications resulting from highly varying weed pressures.

Compared to the pfumvudza, the basin digger, ripper and planter reduced CEL by 40%, 45% and 66%, respectively. However, total labour requirements were reduced by only 27%, 2% and 28%, respectively, for basin digger, ripper and planter, as they required additional labour to clear residues before machine operation and bring and spread them back after planting. Ripping is conventionally done at the onset of rains (when soil is still hard) so that furrows can accumulate rainwater for planting.

So, at ripping, the soil was dry and hard (12.7% moisture content), allowing ripping only a single row/pass without 2WT traction failure. This resulted in the lowest total labour saving by the ripper over pfumvudza. On the contrary, the planter could be set up with double rows as the operating depth was shallower, and it rained before planting, softening the soil (19.9% moisture content).

Soil disturbance areas were 12%, 7%, 15%, and 11% only for pfumvudza, basin digger, ripper and planter, respectively. Thus, all the crop establishment methods ensured low soil disturbance. The basin digger disturbed soil the least while having the deepest basins (116 mm) and finest soil tilth, which are highly desirable for good seed-soil contact, seed emergence, and early root growth. Only 108 mm depth was achieved in pfumvudza (and basins had up to 120–150 mm clods). The shallowest depth (87 mm) of soil disturbance was achieved in the case of the planter.

Despite of having shallow furrow depth and coarser soil tilth than the basin digger, the planter resulted in fast plant emergence (4 days in planter compared to about ten days in other treatments to reach 50% emergence). The planter would have benefitted from wetter soil and close to optimum seeding depth of 48.56 mm. The ripper resulted in a shallow seeding depth of 27.83 mm.

Plant populations/ha were high in the case of the pfumvudza (44516), basin digger (45360) and planter (43889) compared to ripper (39823). The manual basin produced large clods (up to 100–120 mm), which, as were used for covering seeds, would have caused reduced seed emergence due to poor seed-soil contact and resistance to emergence. In the case of the ripper, it was observed that there were incomplete furrow patches and high variations in-furrow and planting depths, resulting in a shallow planting depth of 27.83 mm, reducing emergence and final plant population.

Yield contributing factors (as indicated by high plant heights at 30 DAS, ear heights at harvest and grains/cobs) were highest for the planter, yielding 21–31% higher in the planter compared to other treatments.

CONCLUSION

CA has been promoted amongst smallholder farmers in sub-Saharan Africa, including Zimbabwe, where three million smallholder farmers are practising hand-hoe-based CA called pfumvudza. Pfumvudza is a labour-intensive and back-breaking task, reducing its adoption beyond the input-supported plots.

This study has shown that mechanization can reduce soil surface disturbance and labour requirements and increase maize yield significantly compared to manual CA. However, crop residues tended to hinder machine operations, which was solved by the temporary removal of residues. Being the least expensive (digger, US$122) or the most efficient (planter, US$3800) machine, they are recommended for CA programs. Improvement of their residue handling ability is also recommended to enhance their effectiveness.

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KEYWORDS

Pfumvudza, basin planting, basin digger, ripper, planter

THE FARMERS' PERCEPTIONS AND FACTORS INFLUENCING THE ADOPTION TO NO-TILL CA AMONG BEANS AND MAIZE FARMERS IN LESOTHO

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INTRODUCTION

Since the 1970s, Lesotho's maize and bean production has dropped from 1.5 to 0.50 Ton ha-1 (Knoema, 2021). Topsoil loss due to sheet and rill erosion from decades of conventional farming (CF) and nutrient mining from improper mineral fertilizer and manure amendments are responsible for the decline. Recent climate change trends and future projection models show Lesotho's sensitivity to climate change (LMS, 2017). Thus, a paradigm shift in adaptation is needed to create a climate-resilient pathway. Since 2005, the Government of Lesotho has promoted Conservation Agriculture (CA) as an innovative tillage practice that may mitigate CF's effects on crop production. Conservation agriculture boosts climate resilience, productivity, and rural livelihoods (Kolapo and Kolapo, 2023). Despite various practices supporting minimum soil disturbance, low initial yields, a lack of technical know-how, increased weeds, and climatic conditions limit minimum tillage adoption in sub-Saharan Africa (SSA).

Despite multiple CA promotion efforts and apparent benefits, CA adoption is static. Thus, this study examines Lesotho bean and maize farmers' no-till CA attitudes and factors influencing adoption. Understanding the factors affecting adoption intensity will help find corrective strategies for partial CA users and determine if partial CA adoption has any benefits.

The goal is to identify restrictions that may explain poor CA adoption. We seek to deepen the CA and smallholder agricultural conversation to help identify 'windows of opportunity' in space and time for CA efforts. Thus, this study examines Lesotho bean and maize farmers' no-till CA attitudes and factors influencing adoption.

MATERIALS AND METHODS

The study was conducted in Lesotho's seven districts—Butha-Buthe, Leribe, Berea, Maseru, Mafeteng, Mohale's Hoek, and Quthing—which are part of the lowlands and foothills agroecological zones (19 403 km2 of 30 557 km2), 63.69% of the national territory, most productive, and containing over 90% of crop production. Most crop production producers are in this western region hence they were chosen. Technology dissemination, socio-economic constraints, and farmer adoption perception underpin the study.
The extension enables technology diffusion, socio-economic position permits farmers to till or not, and education-based adoption views play a pivotal role. Survey using kobo-tool on an Android 10 tablet. Tablets had survey questions installed. The form requested the username, district, resource centre, and village. Nine hundred thirty-two homes in five villages were targeted. The snowball method selected the sample.
Cragg's Double Hurdle Model (Martinez–Espineira, 2006; Engel and Moffatt, 2014) was used to determine adoption factors and intensity. The strategy is best for this study since farmers face two questions while choosing adaptation strategies (Cragg, 1971). First, determine (i) if a farmer chooses adaptation methods (a binary choice) and (ii) their intensity (a continuous variable reflecting the fraction of land under adaptation strategies once chosen).

Cragg's Double Hurdle Model's central premise is that farmers make the two decisions in two stages. The first decision impacts the second, as the error term has a random distribution with mean 0 and standard deviation (δ)^2. As suggested by (Martinez–Espineira, 2006) and (Moffat, 2003), Cragg's Double Hurdle Model was utilized to determine adoption factors and intensity. The strategy is best for this study since farmers face two questions while choosing adaption options. The research used a quantitative design, meaning that it utilized numerical data, and was cross-sectional, meaning that data were collected at one point in time.

RESULTS AND DISCUSSION

The study found that gender ($p = 0.007$), education ($p = 0.045$), lower household income, yield, field area, and CA training strongly influenced No-Till adoption. Educated farmers can learn about innovations that improve their farms.

Knowledgeable farmers understand the danger climate change poses to the environment and agriculture, so they appreciate the need for action that requires sustainable farming practices. Farmer training was essential, highlighting the importance of extension services for farmers if nations are to meet climatic change mitigation and adaptation goals in agriculture. Age, household size, occupation, farming experience, soil fertility, credit, extension, and group membership. Although the priori anticipation was that farming expertise, credit, and extension would impact No-Till adoption, the study found otherwise. The sample size comprised more nonadopters than adopters, which may explain these results.No-till CA adoption was adversely correlated with farmer gender, indicating that male farmers disliked the method. These findings contradict (Chiputwa et al., 2011; Kahimba et al., 2014), who found that male farmers adopt no-till CA more than female farmers. Similarly, farmers with a primary education or less are 4.480 times more likely to adopt the principle than those with other education levels, contrary to (Ntshangase, Muroyiwa, and Sibanda, 2018), who found that an additional year of education is associated with no-till CA acceptance. Thus, farmers with incomes below M 1000.00 and between M 1000 and M 2000 are 0.370 and 0.351 times more likely to accept the principle than those with greater incomes. These findings contradict (Kahimba et al., 2014; Ntshangase et al., 2018; Sheikh et al., 2003), who argue that farmers with higher incomes indicate a greater ability to purchase CA inputs and higher rates of no-till adoption. As subsistence farmers were interviewed in this study, this contradiction may be true for commercial farms since socio-economic and educational status influence CA adoption (Esabu and Ngwenya, 2019).

Furthermore, farmers who experience yield increase are 13.603 times more likely to adopt the principle than those who report no change in yield, and (Ntshangase, Muroyiwa, and Sibanda, 2018) suggest that CA's benefits—soil moisture conservation, soil structure, and soil fertility—cause higher yields. However, field area affects zero-soil disturbance CA principle acceptance since farmers' probability of adoption falls by 0.952 per unit acre. This highlights the reality that farm labour on larger plots of land may be more laborious than the household can provide. According to (Lugandu, 2013), small-farm producers are likelier to use no-till technology.

However, (Nyanga,2012) suggests that larger farms may influence technology adoption. Access to training on CA is a highly significant predictor ($p < 0.001$) of the adoption of the zero-soil disturbance CA principle. This, therefore, means that farmers who have been trained are approximately 0.162 times as likely to adopt the principle compared to those who have not received training on CA. These findings align with the expectations of (Nyanga, 2012), who stipulate that training on CA increases farmers' chances of adopting no-till CA. Most adopters (70.82%) believe that training has influenced their decision to adopt no-till practices. In comparison, slightly lower (52.71%) opine that access to extension services does influence their decision to adopt no-till practices. On the contrary, a substantial minority (47.56%) believe that the promotion of conservation agriculture (CA) has influenced their decision, as is (52.11%), who do not consider access to credit as a significant factor in their decision to adopt practices related to minimum soil disturbance.

CONCLUSION

The study concluded that gender, education level, lower household income, yield, field size and training on CA influence the adoption of No-Till. The results are in harmony with other previous studies' findings, which reported that these variables affect the adoption of No-Till. The government should focus on making extension services more effective in the study area so that they can influence the adoption of CA. Proper implementation of CA would also influence positive perception of CA. The study recommends that since education level is significant, those who seek to promote CA must target educated respondents since they can quickly adapt and share the benefits with the illiterate or low-educated farmers who may take time to adapt.

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KEYWORDS

Adoption, Beans, CA, Farmers, Maize, No Til

THE EFFECT OF SOIL ORGANIC MATTER FRACTIONS IN CONSERVATION AGRICULTURE

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INTRODUCTION

Adding and building organic materials and fractions in the soil is a core focus of the conservation agriculture approach. Soil organic matter fractions vary significantly in particle/molecule size, solubility in water and other solvents, microbial decomposition rate, etc. This paper provides a structured discussion of the various fractions with selected case studies involving penetrometer data and chemical and plant analysis data from in-field trials.

SOIL ORGANIC MATERIALS

Organic materials in soils are operationally defined according to their extractability from soil (Stevenson, 1982; Senesi and Loffredo, 1999). The particle sizes and microbial/ faunal digestibility are indicated graphically in Figure 1. Due to microbial digestion and metabolism, the finer fractions (and non-humic substances such as sugars and amino acids) are depleted first, decreasing beneficial microbe activity and, therefore, associated plant health.

Organic residues (detritus) and composts can be added to soil or generated in situ through cover crops and incorporation of residues, forming distinct particulate organic carbon. However, it is the stabilising role of humates (extractable humic fraction insoluble in dilute acid) and fulvic acid that contribute significantly to soil chemical buffer reactions and soil physical properties through association with the mineral fraction. As such, it promotes soil particle aggregation and improves resistance to slaking. These fractions can be supplemented from particulate organic matter but are only efficient in the presence of earthworms and associated soil biota.

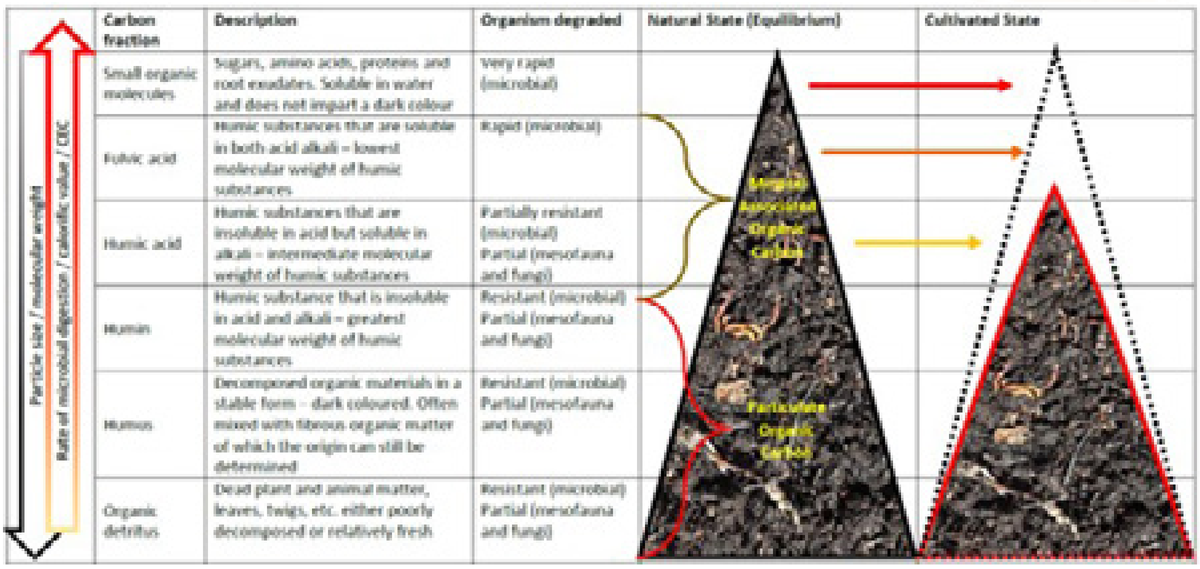

Figure 1. Soil organic carbon fractions, microbial/biological resistance and degradation upon cultivation

MATERIALS AND METHODS

The effect of humate amendment, in conjunction with soluble organic materials (fermented molasses – AminoK®) and Real Trichoderma (T. asperellum TRC900), was assessed in four settings – referred to as "Soil Program" (SP). The materials were applied to citrus and apple orchard soils in the sites through micro irrigation. Penetration resistance (PR) of treated and control soils was determined for a citrus orchard in the Kirkwood (Eastern Cape) area and an apple orchard in the Bethlehem (Eastern Free State) area with a Geotron digital manual-function penetrometer. Multiple measurements (minimum 20 per treatment but up to 40) were taken at centimetre depth intervals to a 5000 kPa maximum or 80 cm depth. The PR measurements were conducted at similar moisture levels in all cases.

Chemical soil parameters and plant nutrient uptake were assessed over a zero-treatment year (control) and a following treatment year in Patensie (Eastern Cape—average of 21 samples) and the Baltimore (Limpopo—average of 28 samples) area. At the Baltimore site, a wider range of products were applied, including mulches, humates, fulvic acid, fermented molasses and fish hydrolysates, and Real Trichoderma.

RESULTS AND DISCUSSION

<u>Penetration Resistance – Kirkwood and Bethlehem</u>

The PR was markedly lower in the SP treatments in Kirkwood, especially in the top 10 cm, where the control treatments exhibited values above 3000 and 4000 kPa, respectively, next to the trees and between the trees. Deeper than 10 cm, the SP yielded a more homogenous profile than the control treatments. The effect of mulch is evident in the apple orchard soils (Bethlehem), with a significantly more friable profile.

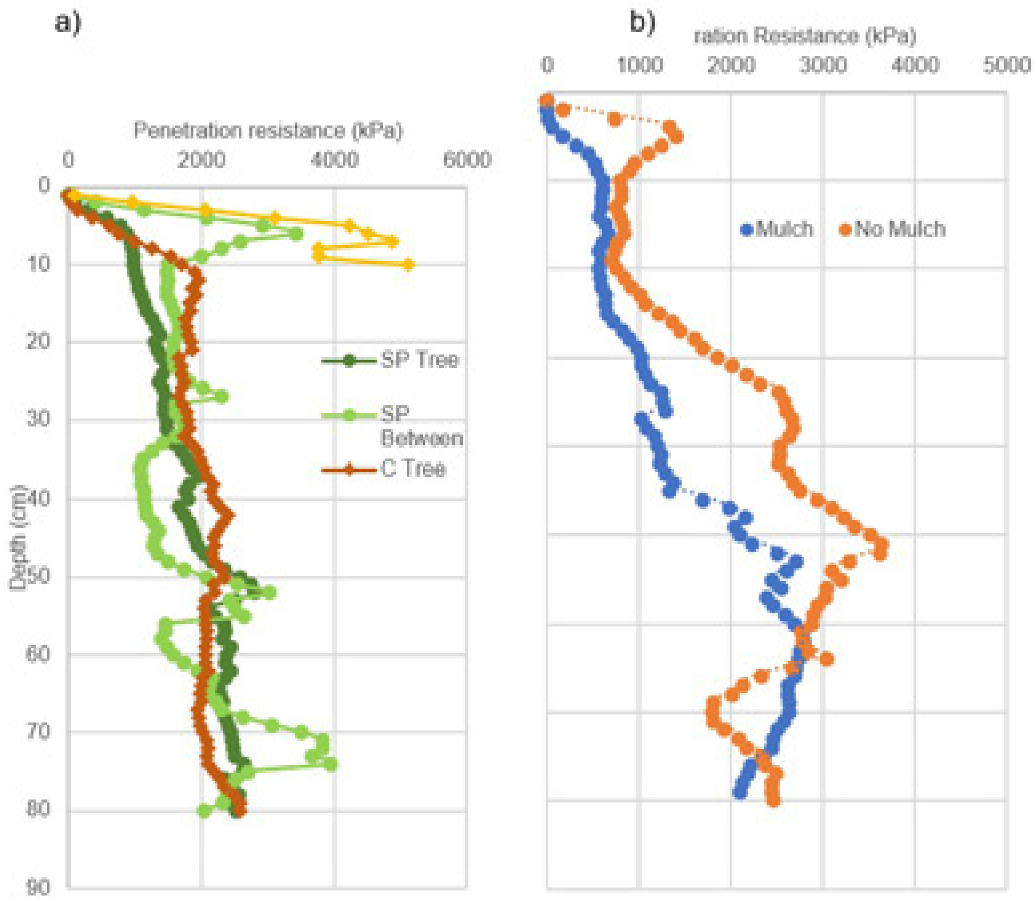

Figure 2. Penetration resistance for a) Soil Program and Control in a citrus orchard (Kirkwood) and b) an apple orchard (Bethlehem) Soil Program treatment with and without mulch

The common thread in organic amendment applications with biological agents such as Real Trichoderma is a decrease in the penetration resistance of the treated soils compared to conventional practices. These effects manifest, amongst others, as increased root development, decreased penetration resistance, increased water infiltration, and improved plant vigour.

<u>Soil Chemical and Plant Nutrient Parameters – Patensie and Baltimore</u>

Selected chemical results indicating an increased buffering capacity to counteract bicarbonate salts elevated soil pH, and improved Ca and K uptake by plants are provided for Patensie (Eastern Cape) and Western Limpopo areas in Figure 3. Both places are subject to poor water quality from rivers and boreholes. In the Patensie area, the water exhibits high Na and bicarbonates during drier periods. In the Limpopo area, borehole water exhibits very high bicarbonate levels (> 400 ppm).

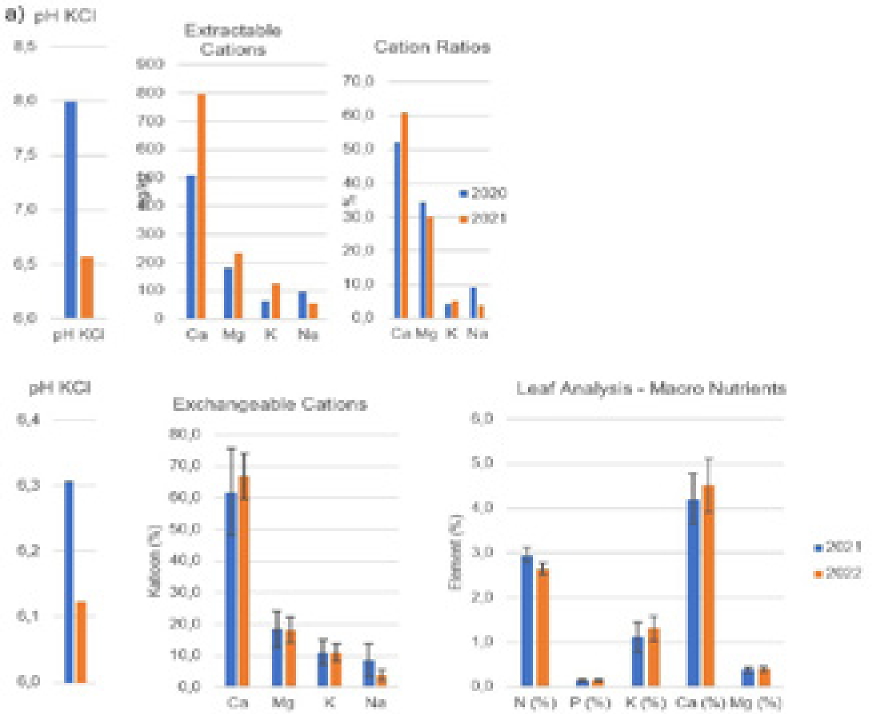

Figure 3. Selected soil chemical and plant nutrient levels for SP treatment on citrus a) near Baltimore in 2021 (average of 28 samples) and b) near Patensie in 2022 (average of 21 samples)

The pH (KCl) difference between the seasons is significant as it indicates a neutralisation of excessive bicarbonate. Elevated bicarbonate levels (alkalinity) manifest in high pH and low Ca, K, Fe and Zn availability. The two macronutrients, Ca and K, and micronutrients, Fe and Zn, form increasingly insoluble complexes with carbonate (divalent cations) and bicarbonate (mono-valent cations). Calcium undergoes an intermediate reaction with aqueous bicarbonate to precipitate finally as a carbonate species. The pH (water) and pH (KCl) where these reactions dominate are 7.4 and 6.2, respectively.Humates, fulvic acid and amino acid organo-complexes pose large numbers of functional groups (Figure 4) that donate protons (H+) that neutralise bicarbonates in the following reaction (Box 1):

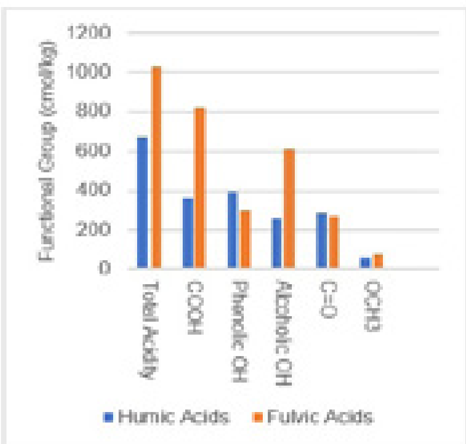

Figure 4. Organic functional groups

Bicarbonate neutralisation reaction:

$R\text{-}COOH \leftrightarrow R\text{-}COO^- + H^+$ (1)

(Organic matter functional group)

$KHCO_3 \leftrightarrow K^+ + HCO_3^-$ (2)

(Potassium bicarbonate dissociation equilibrium reaction)

$R\text{-}COO^- + H^+ + HCO_3^- + K^+ \rightarrow R\text{-}COOK + H_2O + CO_2$ (3)

(Exchangeable K adsorbed on organic molecule)

Box 1 Bicarbonate neutralisation reaction

CONCLUSIONS

Organic matter amendments vary substantially but buffer soil chemical reactions over a wide pH range to near-neutral values. The main contribution is through the surface charge characteristics of functional groups and their staggered dissociation constants. Knowledge of the role of specific (or combinations of) organic fractions aids farmers in maximising root and plant health and optimising fertilizer additions. Adding and building finer and more active organic carbon fractions play a significant role in various plant health, plant nutrition and soil health processes. The long-term benefits of organic matter "building" in soils exceed the short-term goals of increased yearly yields to future-proofing farming enterprises.

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KEYWORDS

humates, fulvic acid, soil organic matter, penetration resistance, soil chemistry

OPPORTUNITIES, CHALLENGES, AND FUTURE OUTLOOK OF CONSERVATION AGRICULTURE IN THE MIDDLE EAST AND NORTH AFRICA

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INTRODUCTION

Conventional tillage under cereal monocropping, with limited recycling of crop residues and pressure from increasing human and livestock populations, has led to soil, water, and environmental degradation in the Middle East and North Africa region (MENA). Conservation Agriculture (CA), considered a "climate-smart" system, strives to conserve and regenerate soils and protect the environment while reducing the cost of tillage. This paper reviews available literature on CA and synthesises its past trends, current opportunities, challenges, and potential benefits to the MENA.

MATERI**AL AND METHODS**

Historically, research on CA in MENA has concentrated on Morocco, Tunisia, Iran, and Syria, while Jordan, Lebanon, Iraq, and Egypt have recently embarked on CA research.

RESULTS AND DISCUSSION

About 25–40% of the region's 53 million hectares of arable land is estimated to be suitable for CA. In recent years, various studies have reported several benefits, including higher and more stable yields and profits, reduced risks of crop failure, input requirements, soil erosion, and improved soil moisture and quality under CA systems.

However, despite its proven benefits, adoption of CA in MENA is still very low for various reasons, including the lack of affordable and well-adapted no-till seeders for small farmers, the complexity of the CA system with the high knowledge demand, which posed a significant challenge for mostly uneducated farmers to comprehend, ill-conceived cereal intensification policies which inadvertently promote monocropping and a low diversification in the seed system, tradeoffs between residue retention and livestock feed, lack of adequate policy and institutional framework and incentives to enhance farmers' adoption, and the low involvement of the private sector in the dissemination of CA.

Effective strategies must be developed for the wider dissemination of CA in MENA by considering the region's unique features. Such methods include: 1) local development and support for affordable and versatile no-till seeders and effective rural advisory and extension service delivery systems; and 2) CA-based agronomic practices must be tailored to the local biophysical and socio-economic environment.

CONCLUSIONS

Despite the daunting past trends in its adoption and current challenges, we anticipate a bright future for CA in MENA due to several factors, including its moisture retention benefits in the face of advancing climate change, rising energy prices and wage rates, the emergence of younger and more educated farmers, increasing awareness on resource degradation, and changes in dietary preferences subsequently growing demand and prices of legumes and forages.

KEYWORDS

adoption, tradeoffs

CONSTRAINTS IN ADOPTION OF CONSERVATION AGRICULTURE AMONG THE FARMING COMMUNITIES IN DIFFERENT AGRO CLIMATIC ZONES OF TAMILNADU STATE, INDIA

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INTRODUCTION

Conservation Agriculture (CA) has been widely regarded as a viable alternative to intensive cultivation for enhanced productivity, environmental safety, and ecological sustainability. Despite good and long-lasting research showing positive results for CA, its adoption rate is minimal in several parts of India.

MATERIALS AND METHODS

The present study explored the knowledge, awareness, and adoption of CA among the farming community across Tamilnadu State, India, and identified the constraints, if any, in adoption to develop suitable policies for upscaling and outscaling CA. This social research study has attempted to empirically know the socio-economic characteristics of the farmers and their relationship with the knowledge and adoption of CA.

The study was conducted between 2010 and 2014 and in 2019 in seven agro-climatic zones covering the entire Tamilnadu State, each of them characterized by unique climate, rainfall, and cropping systems. One block in each zone with intensive cultivation of annual crops, the study villages and the respondents were selected by simple random sampling.

A total of three hundred and fifty respondents were randomly selected @ fifty respondents per agro-climatic zone. Fifteen independent variables and two dependent variables were studied, viz., knowledge and adoption of CA by the respondents and their relationship. Data was collected using a structured and pre-tested interview schedule and statistically analysed using the SPSS package.

RESULTS AND DISCUSSION

As regards the awareness and knowledge level, most of them do not have knowledge of minimum tillage (72.6%) and permanent soil cover (75.1%), but a majority are knowledgeable about crop rotation (71.1%). In addition, the respondents felt that adequate R&D on CA has to be undertaken in Tamilnadu, and the Government should support the popularization of CA. Regarding the adoption of CA, most respondents do not adopt minimum tillage (88.5%) and permanent soil cover (93.1%), whereas they adopt crop rotation (72.4%). Regarding constraints, knowledge constraint was ranked first, followed by bio-physical, technological, policy constraints, and socio-economic and institutional constraints, ranking second, third, fourth, fifth, and sixth, respectively. Inadequate knowledge of CA, uncertain monsoon and lack of availability of labour, non-availability of desired CA technologies and machinery, and lack of priority, promotion and incentives for adoption were considered as major constraints.

CONCLUSION

Establishing frontline demonstrations, organizing training programs, and promoting community-owned CA programs through institutional and governmental support would enhance the adoption of CA, which has the potential for long-term profitability and sustainability of agriculture production systems.

KEYWORDS

Minimum tillage, permanent soil cover, crop rotation, knowledge, adoption, Conservation Agriculture

SOUTHERN AFRICA'S ROADMAP TO SUSTAINABLE AGRICULTURAL MECHANIZATION (SAM): NAVIGATING CHALLENGES IN CLIMATE-SMART AGRICULTURE

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INTRODUCTION

Climate change, a long-term and severe threat, jeopardizes food security and nutrition in Southern Africa. Its impact is pervasive, affecting all aspects of food security, including availability, access, utilization, and stability (WFP, 2021). The evidence is stark, with rising temperatures, shifting precipitation patterns, and a surge in extreme weather events.

Global warming has significantly increased global surface temperatures, surpassing 1.1°C above pre-industrial levels between 2011 and 2020 (IPCC, 2023). In Malawi, seasonal droughts, intense rainfall, and floods are the most common hazards attributed to climate change. A 2018 report by CIAT and the World Bank revealed that the 2015 floods caused losses of USD335 million.

Navigating the complexities of agricultural challenges in Southern Africa requires collaborative and collective action. Embracing Climate Smart Agriculture (CSA) principles, particularly conservation agriculture (CA), can foster resilient, equitable, and sustainable agricultural systems. However, support for conservation agriculture (CA) remains limited, and countries in the region are at different stages of integrating CA into their national development policies and programs (FAO, 2010).

In this context, key questions remain: (i) What strategies can effectively address mechanization challenges for successful implementation of CSA in Southern Africa? (ii) How can collaboration among governments, development partners, the private sector, and local communities be strengthened to promote CSA practices and mechanization technologies? (iii) How can countries integrate CSA into mechanization policy frameworks and initiatives?

Against this backdrop, addressing the intersecting challenges of food security, climate change, and mechanization requires a strategic roadmap. This comprehensive roadmap outlines strategic interventions, policy reforms, and investment priorities to build resilient and sustainable agricultural systems. By charting a course towards CSA, the roadmap offers a framework for enhancing agricultural productivity, conserving and harnessing natural resources, and improving livelihoods across Southern Africa. To this end, a project was recently implemented by the FAO Subregional Office for Southern Africa (SFS) and the Plant Protection and Production Division (NSP) in collaboration with the Southern Africa Development Community (SADC) titled "Developing a Roadmap to Leverage Sustainable Agricultural Mechanization for CSA (SAM4CSA) in Southern Africa". This paper outlines a comprehensive regional roadmap for sustainable agricultural mechanization in Southern Africa. It serves as a strategic guide for stakeholders, including governments, development agencies, private sector entities, research institutions, and civil society organizations, to address the challenges and harness opportunities for sustainable agricultural mechanization.

MATERIALS AND METHODS

A holistic methodology was developed, addressing engineering, socio-economic, institutional, and environmental dimensions of agricultural mechanization, including climate-smart agriculture. The process comprised several phases for comprehensive analysis and strategic planning. The situational analysis was based on qualitative methods to gather primary and secondary data. Secondary data came from a literature review of various reports, while primary data was collected through interviews with senior officials from relevant departments. This analysis focused on four areas:

- Agricultural production systems
- Agricultural mechanization and climate-smart agriculture
- Agricultural equipment, machinery and tools across agricultural sectors and value chains
- Institutional environment, including legal and regulatory frameworks

The strategic planning phase translated these findings into a regional roadmap involving strategy development and action planning. This roadmap was validated through a regional consultation workshop from May 14th to 16th, 2024.

RESULTS AND DISCUSSION

Southern African countries display diverse strategies to address context-specific challenges in agricultural mechanization and CSA. Although they have a common goal of enhancing productivity and sustainability, as well as climate change adaptation and mitigation, the policy approaches differ. Most countries, except Tanzania and Zambia, lack standalone mechanization policies, incorporating these objectives into broader agricultural frameworks instead. For instance, Mauritius focuses on sustainable production and labour reduction, while Namibia emphasizes conservation agriculture and technology adoption. Governmental institutions are crucial in implementing mechanization initiatives, but effectiveness varies. Malawi's Ministry of Agriculture operates tractor hire schemes. However, limited finance and infrastructure hinder progress in countries, including Eswatini, where low yields and a shortage of CA implements impede the adoption of CA technologies. Despite these challenges, various initiatives aim to boost mechanization and productivity, such as Mozambique's Agricultural Value Chain Development Cooperation and Support Project and South Africa's focus on low-carbon agricultural growth.

We identified significant challenges smallholder farmers face in implementing sustainable mechanization, such as inadequate policy support, insufficient financial services, and weak supply chains resulting in low mechanization levels, especially in climate-smart agriculture. A systematic agricultural transformation roadmap is proposed to address these challenges, structured around four pillars. Pillar 1 focuses on enhancing access and affordability of mechanization tools by conducting stakeholder mapping, awareness campaigns, and financial support mechanisms to lay a foundation for broader agricultural transformation. Pillar 2 emphasizes stakeholder collaboration and partnership to foster a coordinated approach among diverse stakeholders, facilitating knowledge-sharing and maximizing the impact of mechanization initiatives for sustainable intensification of agriculture at scale.

Moving to Pillar 3, the roadmap underscores the importance of capacity development and research investment to drive innovation and promote sustainable agriculture practices. Research and innovation in mechanization technologies, coupled with education and skill development programs, aim to equip stakeholders with the knowledge and expertise needed for effective mechanization while minimizing negative environmental impacts. Lastly, Pillar 4 focuses on promoting the development of the mechanization supply chain, aiming to enhance the availability and reliability of equipment through local manufacturing, importation, and implementing hire service schemes, contributing to productivity, food security, and economic growth within the agricultural sector.

The formulation of the present roadmap is based on the ten elements of the "Framework for sustainable mechanization in Sub-Saharan Africa" (F-SAMA), which constitutes a reference for the development of agricultural mechanization in Sub-Saharan Africa (FAO and AUC, 2018). The four pillars align with the ten strategic elements of F-SAMA. The roadmap emphasizes the importance of key accelerators in successfully implementing agricultural mechanization initiatives, highlighting collaborative problem-solving among diverse stakeholders. These accelerators encompass access to critically important and complementary production inputs, enhanced agricultural product marketing, infrastructure expansion, leveraging digital technologies, and addressing land tenure constraints. Achieving synergy between accelerators and other policies demands a holistic approach emphasizing coordination, collaboration, and continuous monitoring throughout the roadmap implementation.

The proposed roadmap also emphasizes multi-institutional involvement, proposing the establishment of the Regional Committee on Agricultural Mechanization (ReCAM) at the regional level and National Committees on Agricultural Mechanization (NaCAMs) at the national level to oversee implementation and develop tailored roadmaps for enhanced mechanization within individual countries. The implementation timeline spans 2025 to 2035, focusing on resource deployment, pilot projects, partnerships, and capacity development initiatives to ensure coordinated efforts and sustainable development across the Southern African region.

CONCLUSIONS

Strategic planning is a powerful tool that can help allocate resources more efficiently, even when faced with complex challenges. Developing mechanization should be seen as a long-term investment in rural economic growth, essential for promoting sustainable and climate-smart agricultural mechanization development. The proposed roadmap offers a comprehensive strategy to address smallholder farmers' multifaceted challenges in adopting sustainable mechanization. The roadmap aims to create a synergistic effect by integrating the four pillars, fostering a holistic approach to agricultural transformation. Each pillar addresses a critical aspect of the mechanization ecosystem, from financial and ICE (information, communication and education) barriers to stakeholder coordination, capacity development, and supply chain development.

The focus on stakeholder collaboration highlights the importance of public-private partnerships in delivering SAM. Investment in research, education, vocational training and extension are essential for the long-term sustainability of SAM initiatives. Additionally, the emphasis on local manufacturing and supply chain development aligns with broader economic goals, aiming to reduce import dependency and stimulate local economies. Overall, the roadmap provides a well-rounded framework for addressing the key challenges in SAM, promoting a coordinated and sustainable approach to improving smallholder farmers' productivity and resilience in the face of climate change and other challenges. Implementing the roadmap for agricultural mechanization in Southern Africa will require significant investment over the coming years, aligning with the roadmap's ambitious goals. To ensure success, it is crucial to identify and secure funding from diverse sources, including public and private sector investments, international partnerships, and innovative financing models.

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KEYWORDS

Climate Change, Conservation Agriculture, Mechanization, Climate Smart Agriculture, Roadmap

FASTER THE ADOPTION OF THE CONSERVATION AGRICULTURE TO 1 MILLION HA IN MOROCCAN DRYLANDS BY 2030: CHALLENGES AND OPPORTUNITIES

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INTRODUCTION

Water stress and land degradation are severe threats to Moroccan agriculture, especially cereal systems, given the drought events of the last decades and the future recurrence of these events according to climate scenarios until 2050. Conservation agriculture (CA), including Direct Seeding (DS), is an alternative for sustainably improving agricultural land productivity in rainfed areas, especially for field crops.

Under the new Generation Green (GG) strategy (2020-30), the government of Morocco launched a national plan to promote CA in 1 million Ha to enhance the sustainability of the country's cereal-based system. This ambitious plan is supported scientifically by several initiatives (CGIAR/EiA/ CWANA F2R/ ClimBer, PRIMA CAMA, PRIMA R4M, WB, etc.) and research institutions (INRA, CGIAR/ICARDA).

The objective of this paper is to present updated data, policies, and evidence on progress toward the adoption of CA within the cereal-based systems in Morocco in 2020, with a goal of reaching 1 M ha by 2030, as well as to highlight the main outputs after four years of launching this ambitious program.

MATERIAL AND METHODS

The research applied a digital remote sensing CA platform, coupled with legacy field data and a survey with farmers' associations, technical advisors, and decision-makers, to collect key informants for selected agricultural provinces and regions and extension services concerned by CA and understand the barriers to CA adoption by small farmers.

RESULTS AND DISCUSSIONS

Stable crop yield was the primary benefit of adopting CA vs conventional tillage in Morocco, with its variable climate and frequent drought stress increased during the last 4 years (2020-2024). The result showed that CA enables farmers to reverse crop yield decline. Energy and input cost savings were the main drivers of enhancing the country's adoption of CA. The CA areas increased four times more compared to 2020, reaching 200.000 Ha by 2024 and 1 M Ha by 2030.

CONCLUSION

Monitoring the spread of CA using the survey with existing CA farmers' communities and applying digital platforms helped strengthen the adoption of the CA initiative and understand the limitations to overcoming the CA barriers in dryland areas.

UNANSWERED QUESTIONS AND UNQUESTIONED ANSWERS: THE CHALLENGES OF CROP RESIDUE RETENTION AND WEED CONTROL IN CONSERVATION AGRICULTURE SYSTEMS OF SOUTHERN AFRICA

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INTRODUCTION

Climate change and soil fertility decline in Southern Africa have increased the need for more sustainable cropping systems. Conservation Agriculture (CA), based on minimum soil disturbance, crop residue retention, and crop diversification principles, is considered a viable option. Previous research in the region in the last two decades has provided proof that cropping systems based on the principles of CA can reduce the exposure of crops to drought and heat stress. Some of the main drivers for increased resilience are increased water infiltration and available soil moisture in response to reduced soil disturbance and surface protection with mulch, which also minimises evapotranspiration and moderates soil temperature.

CA, although mainstreamed in research and extension systems in most Southern African countries, has often not been fully adopted due to the unanswered question of how to maintain sufficient ground cover in smallholder farmers' fields and the unquestioned answer that herbicides are the sole solution for weed control in CA systems once inversion tillage is abandoned. We believe that these unanswered questions and unquestioned answers are the primary reasons why farmers implement incomplete CA systems, dis-adopt or do not adopt them at all. Current farming systems in Southern Africa, characterized by intensive crop-livestock interactions and weed pressure, often pose challenges beyond the farmer and their ability to manage natural resources, requiring local, community-independent, and sometimes national solutions.

MATERIALS AND METHODS

The scientific evidence and experiences of over twenty years of on-farm research on CA adoption in southern Africa were assessed to understand the challenges and define sustainable solutions. In addition, the results of a recent representative farm survey conducted from March to June 2021 by the International Maize & Wheat Improvement Centre (CIMMYT) and the International Institute of Tropical Agriculture (IITA) were used to elaborate on the two aspects. The methodology, sampling procedure, and part of the data from this study have already been published by Tufa et al. (2023) and Thierfelder et al. (2024). Finally, we synthesized other published literature to support any propositions in this paper. Our focus was to examine the two research questions centred around why farmers cannot maintain sufficient ground cover under the present grazing traditions in mixed crop-livestock systems and why herbicide use is still a significant driver of CA adoption elsewhere. Our study defined alternatives to the unquestioned answer and gave possible solutions to the unanswered questions to guide further research and extension in the future.

RESULTS AND DISCUSSION

Crop residue retention

In our first unanswered question, we found that the current practice of seasonal free grazing is widespread and makes it practically impossible for CA farmers to maintain sufficient ground cover due to a seven-month dry period from May to November. Other factors that affect the lack of crop residue retention in rural areas are the competing use of this precious resource for building, fencing, and firewood, besides being incorporated into the soil or burned by mice hunters. In addition, limited biomass growth in low-productivity, semi-arid areas of southern Zambia and Zimbabwe limits the overall amount of crop residues that can be retained as mulch. Yet, crop residue retention is essential for functional CA systems in Southern Africa (Mhlanga et al. 2021).

To overcome the challenges of crop-livestock competition for crop residues, alternative strategies could be implemented: a) providing alternative fodder sources for livestock so they do not have to feed on crop residues but consume high-quality feed during the dry season; b) use of non-palatable species for groundcover that cattle will not graze; c) redefining grazing systems through improved rangeland management; d) enforcement of local bylaws that limit grazing in cropland areas; and e) replacing large cattle herds with mechanization solutions such as 2-wheel or 4-wheel tractors for land preparation and transport which would reduce grazing pressure. Results from shifts in grazing patterns in Ethiopia (Baudron et al. 2015) and

Zimbabwe (Savory and Butterfield 2016) have clearly shown how beneficial this can be for the soil and the environment. However, these solutions often go beyond the individual farmer and require the whole community, local leadership, and national governments to be involved. Increasing the availability of high-quality fodder seems to be a sensible solution that is within the reach of farmers and should be enhanced to improve both the livestock value chains and CA.

Weed control

Our second assessment was of the unquestioned answer that weed control in CA systems is only possible with herbicides. Indeed, weed control in CA systems is considered most effective with herbicides, and the primary reasons why the adoption of this crop management system increased exponentially in the 1990s and early 2000s worldwide had to do with the end of the patent on glyphosate. However, agriculture chemicals pose substantial costs for smallholders, which are already cash-constrained, and create health risks for smallholders, especially if they are not paired with in-depth training on safe use, application rates, and information on different types of products. They may also pollute the environment if not judiciously used.

In the long run, weed control with herbicides such as glyphosate cannot be the only solution for CA systems in the Global South, especially as an increasing number of weeds are becoming resistant to herbicides. It, therefore, requires other solutions around mechanical, biological, and cultural weed control practices that smallholders can apply.

These solutions are a) the use of mechanical tools for weed control such as mechanical weeders, cultivators, slashers and alike; b) cultural practices involving intercropping and rotations with competitive crop species to suppress weeds; c) strategic use of competition and suppression to control weeds; d) the use of biological agents such as arbuscular mycorrhizal fungi (AMF) to suppress weeds; e) allelopathy between crops to support control of weeds; and f) reducing weed seed production to deplete the weed seed bank.

Increasingly, agroecological and environmental movements worldwide have highlighted weeds' beneficial roles in farming. When weeds are maintained, they may contribute to the biological control of pests and diseases and widen the nutritional diets of rural farming communities. However, this requires careful research to manage competition between weed species and the crop of interest by smallholders.

CONCLUSION

We conclude that different management strategies are available to address insufficient ground cover on the soil, which is within reach of smallholder farmers. In addition, community grazing arrangements and improved rangeland management can enable farmers to maintain sufficient ground cover for livestock above ground and below ground. Various mechanical, biological, and cultural practice solutions are available to manage weeds in farming systems. However, to achieve lasting change in the landscape and fully adopt CA systems, these solutions require more than technological innovations but a concerted effort on multiple fronts. This may also include private incentives, changes in norms, institutional innovations, and favourable governmental policies.

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KEYWORDS

Crop/livestock interaction, diversification, fodder production, grazing systems, weed control

SOIL HEALTH AND SOYBEAN YIELD RESPONSES TO STRATEGIC TILLAGE AND COVER-CROPS IN LONG-TERM NO-TILLAGE

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INTRODUCTION

The expansion of no-tillage in Brazil is similar to the growth in the area of soybeans being cultivated; it can be estimated almost 40 million hectares are cultivated using this system. Conservation agriculture provides many advantages, including reduced erosion, lower costs, and enhanced soil organic carbon (SOC). At the same time, it has challenges, such as a high level of soil compaction, a vertical stratification of SOC/nutrients, and increased acidification at depth. Periodic disturbance, known as occasional or strategic tillage, has been promoted as a solution to solve all the challenges of long-term no-tillage. But what is the impact on soil health and SOC accumulated in the long-term of no-till? This study aimed to understand the effect of occasional tillage after 26 years of continuous no-tillage on soybean yield and soil characteristics.

MATERIAL AND METHODS

This research comprises a long-term trial initiated in 1996 at the Sugarcane Research Center (IAC) in Ribeirao Preto, Brazil. The site coordinates 21° 12'10.49" S and 47° 52'32.98" W, with an elevation of 614 m and a mean annual rainfall of 1454 mm. The trial began in 1996 on soil classified as a clayey Oxisol according to the Soil Taxonomy System. It followed a randomized block experimental design with four replications. It investigated four crop rotation treatments over the last 20 years, involving continuous no-tillage with corn as the main crop rotated with sunhemp, soybean, and sorghum/sunflower. In spring 2022 (Fig. 1), two strategic tillage events were introduced into part of the no-tillage treatment, with the plots further subdivided into two additional tillage treatments using deep ripping (>0.45 m depth) and moldboard plow (>0.35 and <0.45 m depth).

In November 2022, five cultivars of soybeans were planted in each sub-treatment. Following the soybean harvest (March 2023), the corn, sunhemp, soybean, and sorghum plots were replaced with oat+pearl millet, Lupinus, fallow, and a cover crop mix. In November 2023, the strategic tillage was performed again with one pass of a disc, after which the same soybean cultivars were planted under the different cover crops. The trial was evaluated for agronomic characteristics, root systems, nematodes, soil fertility, soil organic carbon, and soil physical and microbiological attributes.

Figure 1. Experimental area after strategic tillage in 2022 (left) and after planting soybeans in 20233. Ribeirao Preto, SP, Brazil.

RESULTS AND DISCUSSION

Regarding the growing season 22/23, results have shown no significant effect on the yield of strategic tillage for three cultivars. On the other hand, most soybean genotypes were affected by crop rotation history. The same trend was verified for growing season 23/24 (Fig. 2). Still, due to the worst environmental conditions (high temperature and drought) from September to December, the impact on the grain yield was higher, especially for genotype BRS 7380. The soil temperature was 15,5 0C higher in the treatment without residue on the surface.

Consequently, the plant population was reduced by up to 30%. For the cultivars M 6410, NS 6700, and M 5947, grain yields following pearl millet + oats and white lupine were 19% higher compared to cultivation following fallow and a cover crop mixture. For the cultivar BRS 7380, cultivation after pearl millet + oats resulted in gains of 600 kg ha-1 compared to the other options. Considering the effect of strategic tillage, it is observed in Figure 2 that the cultivars M 6410 and M 5947 did not show statistical differences between soil management practices. At the same time, NS 6700 yielded 660 kg ha-1 less in the subsoil + plough treatment. For cultivar BRS 7380, seeding on residue, regardless of previous tillage history, resulted in gains between 600 and 840 kg ha-1.

For the average of the cultivars, cultivation after pearl millet + oats, lupine, cover crop mixture, and fallow produced 4140, 3600, 3189, and 3180 kg ha-1, respectively. Concerning the effects of management practices, on average across cultivars, gains of 330 kg ha-1 are observed in planting on residues compared to incorporation. These results confirm the partial conclusion obtained in the 2022/23 harvest, demonstrating a greater effect of cropping history than adopted strategic tillage practices. However, it should be noted that the plots already had 26 years of no-till system in place, and no matter how drastic the disturbance from tillage practices may have been, they were not sufficient to differentiate them.

The scientific findings regarding strategic tillage are controversial regarding their effects on soybean productivity (Fidalski et al., 2015; Peixoto et al., 2019). Furthermore, for some soil attributes, these alterations do not persist for more than 2 years (Dang et al., 20215; Blanco-Canqui et al., 2020). Tillage has provided changes in the soil fertility only at the uppermost layer.

No difference was observed among the soil management strategies and crop rotation treatments for the activity of acid phosphatase, microbial biomass carbon, and arbuscular mycorrhizal fungi. However, for the growing season 22/23, the strategic tillage has reduced by 13%, 19% and 19% the activity of □-glucosidase, arylsulfatase and soil organic matter content, respectively, compared with no-tillage. For growing season 23/24 (Fig. 3 and 4), the strategic tillage has reduced the soil organic matter by 7% at the uppermost soil layer and all the enzyme activities, mainly for fallow (less 31%). Regarding the soil quality biological index (IQS, Embrapa), no statistical difference was observed among the cover crop options; for strategic tillage associated with fallow, this index falls below the range considered high (between 0.61 to 0.80).

According to Mendes et al. (2022), some soil enzymes are more sensitive to the impacts provided by management practices and function as harbinger of the consequences of inadequate practices. On the other hand, acid phosphatase exhibits unstable activity and is not included in the BioAS proposed by EMBRAPA for this reason.

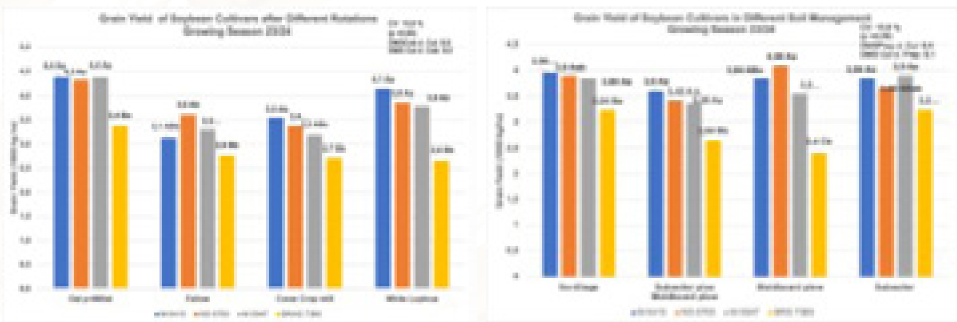

Figure 2. Grain yield in different crop rotations and soil management. Means come from 4 replications. Lowercase letter compares means treatment in the same soybean cultivar, and capital letters compare the cultivars in the same treatment. Ribeirao Preto, SP, Brazil.

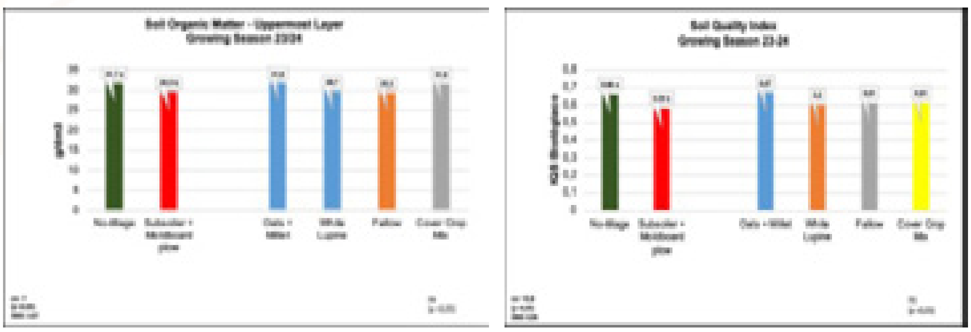

Figure 3. Soil organic matter and biological quality index in different crop rotations and soil management. Ribeirao Preto, SP, Brazil. Growing season 2023/24.

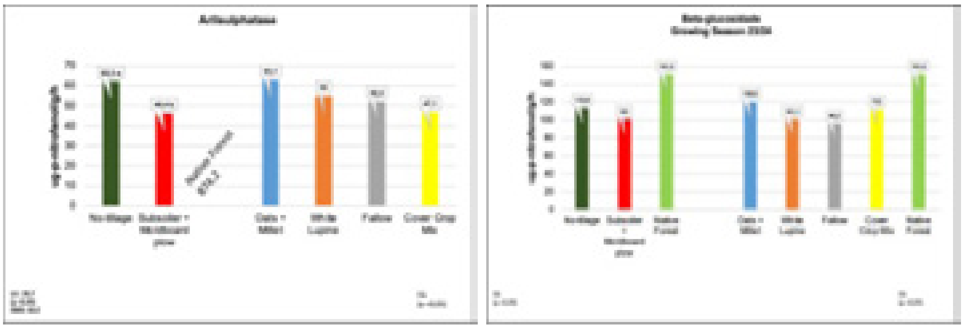

Figure 4. The activity of soil enzymes in different crop rotations and soil management. Ribeirao Preto, SP, Brazil. Growing season 2023/24.

CONCLUSIONS

In conclusion, adopting strategic tillage after 26 years of no-tillage has decreased the leading indicators of soil health (activity of β-glucosidase, arylsulfatase and soil organic matter content) without great advantages in soybean yield. The effect of strategic tillage was lower than crop rotation but was enough to reduce the soil quality biological index.

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KEYWORDS

Grains, Glycine max L., green manure, soil enzymes, soil strength

THE OPTIMIZATION OF CONSERVATION AGRICULTURE PRACTICES REQUIRES ATTENTION TO LOCATION-SPECIFIC PERFORMANCE: EVIDENCE FROM LARGE SCALE GRIDDED SIMULATIONS ACROSS SOUTH ASIA

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INTRODUCTION

Agricultural productivity in South Asia (SA), especially in the Indo-Gangetic Plains (IGP), is crucial for meeting the food demands of a growing population. However, this region faces significant challenges, including the over-exploitation of natural resources, soil degradation, and climate change. Conservation agriculture (CA) has emerged as a promising alternative to conventional tillage-based farming practices, offering potential benefits in resource efficiency, environmental sustainability, and crop productivity.

CA practices typically involve reduced tillage, maintaining soil cover through residue retention, and crop diversification through rotation. Despite its potential, the adoption of CA in South Asia has been limited, and its impacts on crop yields are highly variable across different locations and management practices. This variability necessitates a location-specific approach to optimizing CA practices, which is the focus of this study.

This paper uses large-scale gridded simulations to investigate the spatial and temporal variability of CA performance across South Asia's rice-wheat (RW) cropping system. The RW system is the most prevalent cropping pattern in the IGP, covering approximately 13.5 million hectares across India, Bangladesh, Nepal, and Pakistan.

Conventional RW production is highly resource-intensive, leading to groundwater depletion, increased greenhouse gas emissions, and declining soil health. The study aims to explore the potential of CA to enhance the sustainability and productivity of the RW system through an integrative modelling approach.

MATERIALS AND METHODS

The research integrates data from a nine-year long-term CA experiment, farm surveys, and geospatial datasets to parameterize and calibrate the Environmental Policy Integrated Climate (EPIC) model. The EPIC model, known for simulating crop growth, soil processes, and management practices, was employed to assess the impacts of five different CA configurations compared to conventional management practices. The CA configurations varied in their levels of tillage reduction, residue retention, and crop establishment methods, offering a comprehensive evaluation of their effects on crop yields and sustainability.

The study first established a baseline simulation for the RW system across the IGP using gridded weather, soil, topography, and crop management data. This baseline was crucial for understanding the current yield patterns and identifying the areas where CA could have the most significant impact. The EPIC model was then calibrated using data from a long-term CA experiment conducted in Bihar, India, which provided detailed observations on crop yields, soil health, and management practices under different CA treatments. This calibration was essential for accurately simulating the biophysical processes and management interactions that characterize CA.

RESULTS AND DISCUSSION

The baseline simulation results revealed that current RW yields are generally low, with significant spatial variability across the region. This variability is influenced by soil type, climate, and management practices. The simulation indicated that while conventional tillage practices (CTR-CTW) are widespread, they are not optimized for the diverse agroecological conditions of the IGP. In contrast, the potential yield gains from CA are substantial but vary widely depending on the specific CA configuration and location.

The study's simulations demonstrated that CA could potentially increase RW system productivity by up to 38% in some areas of the IGP. However, this potential is not uniformly distributed across the region. For instance, CA practices involving zero-tillage for rice and wheat (ZTDSR-ZTW) showed significant yield gains in areas with favourable soil and climatic conditions, particularly in the eastern IGP. Conversely, in regions where soil conditions or management practices are less conducive to CA, such as parts of the western IGP, the yield benefits were more modest or even negative.

One of the critical findings of this study is the importance of optimizing CA practices to local conditions. The simulations revealed that CA often results in yield penalties under current management regimes, especially for rice. This is primarily due to suboptimal planting and harvesting dates, inappropriate residue management, and insufficient nutrient application. However, when management practices were optimized—such as adjusting crop phenology, improving fertilizer application, and selecting appropriate sowing dates—the yield penalties were mitigated, and significant yield gains were observed. This underscores the need for a flexible, adaptive approach to CA, where practices are tailored to each region's specific environmental and socio-economic conditions.

The study also highlighted the long-term benefits of CA, particularly regarding soil health and environmental sustainability. While short-term yield responses to CA are often mixed, retaining crop residues and reduced tillage can improve soil structure, increase organic matter content, and enhance nutrient cycling over time. These long-term benefits are not immediately apparent in yield outcomes but are crucial for the sustainability of the RW system. The study suggests policymakers and agricultural stakeholders should consider these long-term benefits when promoting CA practices rather than focusing solely on short-term yield gains.

In addition to yield optimization, the study explored the potential of CA to reduce agriculture's environmental footprint in South Asia. By maintaining soil cover and minimizing soil disturbance, CA practices can reduce greenhouse gas emissions, improve water use efficiency, and enhance biodiversity. These environmental benefits are significant in climate change, where the RW system is increasingly vulnerable to extreme weather events and shifting climatic patterns. The study's findings suggest that CA could be vital in building climate resilience in South Asia's agricultural systems.

However, the study also acknowledges several limitations. One significant challenge is representing CA's temporal effects in the EPIC model, particularly those related to soil physical and chemical properties. The study's simulations focused primarily on yield outcomes, but CA's benefits extend beyond yield, including reduced labour and fuel costs, lower greenhouse gas emissions, and improved air quality. Future research should aim to incorporate these broader impacts into the modelling framework to provide a more comprehensive assessment of CA's potential.

CONCLUSION

In conclusion, this study provides valuable insights into the optimzation of CA practices for the RW system in South Asia. The findings emphasize the need for a location-specific approach to CA, where management practices are tailored to the unique environmental conditions of each region.

By integrating long-term experimental data, farm surveys, and geospatial modelling, the study offers a robust framework for evaluating the potential of CA to enhance agricultural productivity and sustainability in one of the world's most important food-producing regions. The results have important implications for agricultural policy and development, suggesting that CA can contribute to a more sustainable and resilient agricultural future for South Asia with the right management.

UNDERSTANDING SUSTAINED ADOPTION OF CONSERVATION AGRICULTURE AMONG SMALLHOLDER FARMERS: INSIGHTS FROM A SENTINEL SITE IN MALAWI

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INTRODUCTION

Sub-Saharan Africa (SSA) has experienced the worst impacts of climate change on agriculture over the past decades. Sustainable intensification practices such as Conservation Agriculture (CA) are viable options. However, adoption is perceived as low. CA sentinel sites provide good case studies for deeper insights into CA diffusion and adoption dynamics. This paper takes a deep dive into the Nkhotakota district of Malawi.

MATERIALS AND METHODS

In October 2022, we interviewed 620 households from Mwansambo and Zidyana EPAs for the treatment group where CA has been promoted since 2005 and Mtosa EPA as the control. We considered the extent (continuous implementation of any CA practices on either the same or different plot by a household for at least two years) and intensity of adoption (the number of years a farmer continuously implements any CA practices). Full adoption is the continuous implementation of all three CA practices.

RESULTS AND DISCUSSION

Thirty-one percent (31%) of the sample adopted full CA in the study areas for at least two years (https://doi.org/10.1017/S1742170524000061). This number is 57% in the treatment area and only 7% of farmers in the control group. Partial adoption remains the most prevalent.

We also find adoption decay, where adoption reduced from highs of 57% and 7% for at least two years for treatment and control, respectively, to 12% in the treatment group and practically zero in the control when we condition full CA adoption to at least 7 years.

Our results are different from those of past studies because we sampled households for interviews from actual villages known to have had contact with host farmers rather than sampling random villages. Second, our study focused on sentinel sites within the Nkhotakota district, where CA has been consistently promoted for over 15 years. Because adoption is not 100% even in the sentinel sites, this suggests incentives are needed to induce and sustain adoption. e.g., PES and conditional subsidies are used in the Pfumvudza program in Zimbabwe.

CONCLUSION

Results in this study demonstrate the value of focusing on sentinel sites where CA has been promoted for a long time to study adoption dynamics. The adoption estimates from sentinel sites in this paper are much higher than is often reported and highlight the value added by targeted adoption studies. Long-term promotion, extension provision, and experiential learning through field demonstrations hosted by farmers are key determinants of sustained CA adoption.

PROFITABILITY OF SHEEP PRODUCTION IN MODIFIED CONSERVATION CROPPING SYSTEMS IN THE MIDDLE SWARTLAND

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INTRODUCTION

Adding annual legume pastures into crop rotation systems with wheat has allowed Middle Swartland producers to diversify farm enterprises by adding a livestock component to their farming operation. Incorporating a livestock component may provide many benefits, including increased diversification, financial and income stability, and profitability. Even though livestock fit perfectly into crop rotation systems, there is concern about the impacts of livestock on soil compaction and - cover, posing various threats to the successful implementation of CA. Integrating a livestock component into a mixed farming system without mitigating CA outcomes requires livestock approaches based on lower stocking rates or alternative feeding systems. This paper aims to assess the financial implications of different approaches that could be followed to achieve successful crop-livestock integration within CA principles.

MATERIALS AND METHODS

Different climatic conditions, soil types and the degree to which the principles of CA are successfully applied may all influence the extent to which CA benefits are realised. Trials that were conducted at the Langgewens Experimental farm (Western Cape Department of Agriculture) showed that crop rotation systems (Table 1), combined with no-till and maximum levels of soil cover, tend to improve gross margins per hectare (Figure 1).

Table 1: Breakdown of the crop rotation systems in the Langgewens trial.

The three principles of CA interact with one another, and there are direct links between each of them and livestock in an integrated mixed crop-livestock system within a CA farming context.

All the rotation systems showed a relatively higher average gross margin than wheat monoculture, and the significance of a livestock component becomes clear since the crop-pasture systems tend to have relatively higher average gross margins than the cash crop systems (Figure 1).

Table 1: Breakdown of the crop rotation systems in the Langgewens trial.

System	Year 1	Year 2	Year 3	Year 4
A	Wheat	Wheat	Wheat	Wheat
B	Wheat	Wheat	Wheat	Canola
C	Wheat	Canola	Wheat	Lupin
D	Wheat	Wheat	Lupin	Canola
E	Wheat	Medic	Wheat	Medic
F	Wheat	Medic/Clover	Wheat	Medic/Clover
G	Medic	Wheat	Medic	Canola
H	Wheat	Medic/Clover with Saltbush	Wheat	Medic/Clover with Saltbush

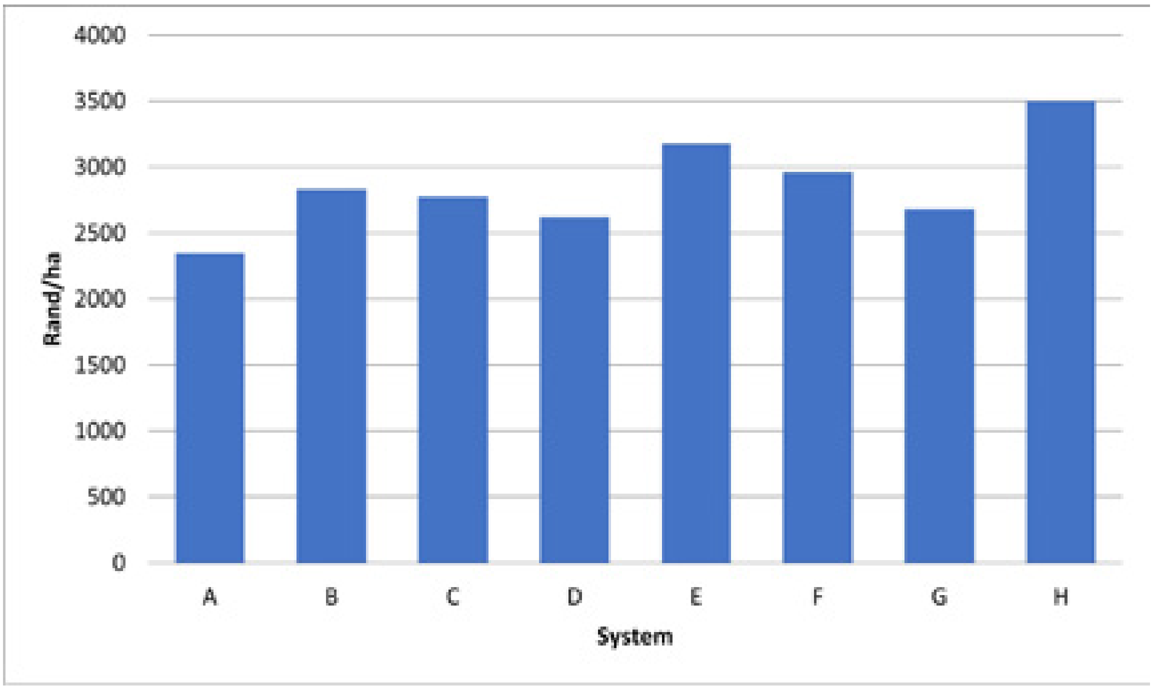

Figure 1. Average gross margin above all allocatable costs: 2002-2018. Source: Strauss, Hardy & Laubscher (2010).

The gross margin of each camp includes the income (Gross Production Value) and the directly and non-directly allocated variable cost. On the farm level, the choice between crop rotation systems may cause variations in investment requirements. Including pastures would decrease machinery requirements but increase investment requirements in livestock, livestock handling facilities, fencing and water supply.

The Langgewens Crop Rotation systems were simulated to accommodate the capital investment requirements in the whole farm, multi-period budget models. Each simulated system can then be compared in terms of return on capital investment and not only on a farming area parameter such as gross margin per hectare. This paper focuses on alternative sheep management strategies. The whole farm model also allows for a comparison of these strategies. The strategies were developed within an expert group discussion, including agronomists, soil scientists, pasture scientists, agricultural economists and practising farmers who farm in the Swartland area.

The expert group also validated the assumptions regarding establishing a typical farm, which forms the basis for the budget modelling. The whole farm budget model measures the yield on investment in terms of IRR % (Internal Rate of Return on Capital Investment). The focus of the livestock management systems falls on Systems E, F, G and H as they represent cash crop pasture systems.

The crop-livestock integration strategies

- Direct grazing: One breeding ewe per hectare pasture for Systems E, F and G was assumed as typical. The CA principle of maintaining sufficient levels of soil cover was considered the main limiting factor in the stocking rate. This also ensures that the danger of soil compaction during the wet period is negated. A stocking rate of 1.5 breeding ewes per hectare pastures for System H allows for adequate rest periods and the option to remove sheep from the field to the saltbush during wet periods.
- Intensive speculation approach: This strategy was developed to keep sheep off the soil. It involves a feedlot setup; the potential number of sheep that could be kept on the farm is still based on the number of hectares of pastures in a year. The medics or medic-clover mixes are mowed and baled when ready. The medic or medic-clover hay yield (in terms of tonnes of hay per hectare) determines the amount of speculation lambs put through the feedlot in a particular year.
- Sell medics: Half of the farm's financial performance depends on livestock in a farming system where 50% of the arable land is under medic production. CA producers in the Swartland area proposed the "sell-medics" approach during the expert discussion. The expert group agreed that by selling medics, one could reap the benefits of crop-pasture rotation systems without the concern of the livestock component's compaction effect.

RESULTS AND DISCUSSION

A simulation was included based on the livestock management approach for Systems E, F, G and H. The finer management implications, carry capacities, investment requirements and risks were developed and validated with the expert group. A strategy was accepted when consensus was reached. Capital investment requirements include the differences in infrastructure requirements of the different livestock approaches, which are mainly due to the higher need for fencing and feedlot- or other livestock facilities. The approach where medics are baled and sold to neighbouring producers has the lowest long-term capital requirement. The 'sell-medics' approach has no livestock housing or feeding requirements, the intensive speculation approach has the highest long-term capital requirement. The grazing approach requires a ram shed and sheepfold, whereas the intensive approach requires an additional lamb shed, a feedlot, and two camps. These camps are to be fully equipped with feed- and water troughs.

Livestock is considered part of the intermediate capital investment. Only the breeding ewes and rams are regarded as intermediate capital items for the grazing approach. Lambs and replacement ewes that are bred and sold over the duration of a normal farming cycle do not form part of intermediate capital. For the intensive speculation approach, the value of the lambs purchased in one cycle forms the livestock component's part of the intermediate capital investment.

The intermediate capital investment required for each strategy differs mainly due to differences in the livestock approaches and not the crop rotation systems. This is because crop rotation systems are all relatively similar. The mechanisation requirements of each strategy are influenced by the livestock approach, rather than the crop rotation system. The intermediate capital investments required for the intensive approach and when medics are sold are R 20 209 222 and R 11 876 379, respectively.

In terms of the whole-farm gross margin, the intensive approach returns the highest expected IRR in the rotation systems and seasonal variability scenarios. The "sell medics" approach has the second highest whole-farm gross margin across all the rotation systems and scenarios, with the grazing approach having the lowest whole-farm gross margin in every system and scenario. The effect of the higher stocking rate due to the saltbush pastures in System H can clearly be seen in the relatively narrower gap between the gross margins of the grazing approach and the "sell medics" approach in System H, compared to the other systems.

It is important to note that the yield and input data of the Langgewens trial influence the performance of the systems. Saltbush pastures only apply to System H when a grazing approach is followed. Consequently, in practice, Systems F and H would achieve the same financial performance under the intensive speculation approach or when medics are sold. In the model, however, the intensive speculation and "sell medics" approaches applied to System F are affected negatively by the deviations in crop yield and input data caused by the grazing approach followed by System F in the trial.

System H and medics sold as a cash crop have the highest expected IRR of all the strategies (8,6%). For each rotation system, the lowest expected IRR is constantly achieved when following the grazing approach (mostly around 5%). This is due to the low carry capacity prescribed by the group of experts to avoid negating the CA benefits and aims through compaction by livestock. The effect of having livestock on the medic pastures for a shorter period can be seen in the relatively smaller difference between the IRRs of H-G and the other strategies based on System H when compared to the differences in IRR of the grazing and other approaches in Systems E, F and G. System G has the lowest IRR of all the systems, irrespective of the livestock approach due to relative underperformance of Canola.

CONCLUSION

Overall, System H, combined with a sell-medics approach, performs the best on the whole-farm level. Between a grazing and intensive speculation approach, the intensive approach performs the best, regardless of the system.

KEYWORDS

Conservation farming, Crop Rotation Systems, Livestock management, Profitability

COMPARISON OF CONSERVATION, REGENERATIVE AND AGRO-ECOLOGICAL AGRICULTURE IN SOUTH AFRICA

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INTRODUCTION

Agricultural and food systems face many challenges, including climate change, increasing population, and land degradation. Semi-arid areas with high temperatures, low rainfall, and increasing variability are severely affected. To maintain good production, farming systems must change from conventional systems (with fully ploughed bare surfaces) to healthy agroecosystems that can address climate risks while maintaining food supply.

Conservation Agriculture (CA) promotes minimum soil disturbance, maintenance of permanent soil cover, and diversification of plant species. Regenerative agriculture (RA) focuses on regenerating soil vitality by including livestock, increasing biodiversity, improving water conditions, enhancing ecosystem services, supporting bio-sequestration, and thus increasing resilience to climate change. Agroecology (AE) is a scientific and social-economic community-based approach and movement addressing relationships between agriculture and the environment. As a social movement, it seeks to reconcile agriculture and local communities with natural processes for the common benefit of nature and livelihoods. AE is usually considered an over-arching concept overlapping certain aspects of both RA and CA. The main difference is that AE has strong social components, including co-creation of knowledge and responsible governance, and includes aspects of cultural and food traditions.

DISCUSSION

Shifting from conventional farming systems to any of these requires a period of transition with the introduction of alternative farming technologies and practices. These transitions are monitored as they progress from little (if any) integration in incremental stages—first increasing efficiency, then substituting alternative practices, and then redesigning the agroecological systems. Following this, the transformative levels within the food systems re-establish connections between farmers/growers and consumers/eaters and rebuild a sustainable, equitable food system locally and worldwide.

In South Africa, CA has been adopted by many grain farmers in both the Free State and Western Cape provinces, as these farmers now routinely use no-till techniques and maintain a permanent soil cover. RA principles are being used across many South African mixed farms where livestock (cattle, sheep, pigs, etc.) graze the cropping lands to return manure to the soil, which results in productivity benefits. The AE movement is dominated by small-scale farmers in groups who have good community connections and practice integrated farming systems from cereals and vegetables to traditional crops combined with a wide range of livestock.

CONCLUSION

The Department of Agriculture, Land Reform, and Rural Development has commissioned a project to develop an agroecology framework from the grassroots up, including an analysis of current pertinent legislation.

THE EFFECT OF TRICHODERMA ASPERELLUM ON FODDER YIELD IN THE SOUTHERN CAPE

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INTRODUCTION

Southern Cape's soil is inherently shallow, sandy, moderately acidic, and hardsetting. This is because the soils are old, have formed mainly from sandstone parent material, and are continuously leached in this Mediterranean climate. Fertility in these soils has thus been located primarily in the organic fraction. However, this organic matter has largely been oxidised due to decades of excessive tillage. This resulted in a concomitant decline in the soil microbial, especially the fungal population (Sándor et al., 2020). These losses have predisposed these soils to hardsetting because the naturally occurring iron is also typically reduced and leached during the wet and colder winter. Hardsetting is a natural phenomenon where soils are set to a hard, structureless mass upon drying, increasing the soil strength so that it cannot be cultivated until rewetting has occurred (Daniells, 2012). Since tillage has greatly reduced the soil bacterial and especially the fungal populations of these soils, it was hypothesised that artificial application of certain fungal strains might drastically improve fodder productivity. This study, therefore, aimed to measure the impact of Trichoderma asperellum TRC900 on fodder yield in the Southern Cape region of South Africa to present practical examples of conservation agriculture adoption in Africa.

MATERIALS AND METHODS

Eight sites in the Southern Cape region of South Africa, stretching from the Suurveld in the East to Suurbraak in the West, were selected for this study. A treatment and control field or block were then demarcated adjacent to each site. The control plots received the normal farm practice. In contrast, the treated fields received 200 mL or 100 g Trichoderma asperellum TRC900 with 5 kg Humate kernels per hectare during seeding and the standard farm practice. The seeded fodder crops typically consisted of barley or annual ryegrass, serradella, and canola. Measurements were done approximately three months after seeding, just before the first grazing event. They were done in triplicate in each of the treated and control fields by cutting 0.5 m2 of the fodder about 2 cm above the soil and then weighing the biomass. The treated field received monthly applications of 200 mL Trichoderma asperellum TRC900, 2.0 L Seabrix, and 2.0 L AminoK per hectare for the Tsitsikamma trial. In contrast, the fertiliser application was reduced to approximately half of the standard farm practice. In this case, fodder yield was measured with a rising plate meter. Fodder yield data for the Tsitsikamma trial thus represents the average for the ten months of June 2023 until March 2024. A two-way ANOVA was done using a randomised block design in RStudio (Posit team, 2024).

RESULTS AND DISCUSSION

The fodder yields obtained three months after seeding varied from 7 500 to 28 533 kg/ha (Table 1), largely reflecting the great difference in growing conditions from extensive rain-fed to fully irrigated. The fodder biomass obtained with the Trichoderma asperellum treatment was, on average, statistically significant ($p < 0.05$) 5 783 kg/ha or 51.4% more than the standard farming practice. There was considerable variability in the observed increases, varying from only 13.4% at Suurbraak 1 to 118.4% at Hoekwil. It was postulated that these differences reflected differences in the initial soil health and the environmental growing conditions. There was, however, no statistical difference between the field blocks (Table 2), except for Suurbraak 2. This implies that the treatment differences were much more significant than the differences between the selected fields - even for this widely differing region.Increases in above-ground biomass were associated with visibly more, larger, and longer leaves with thicker stems, as well as with increased rooting volume and depth. However, these parameters were not measured.

Table 1: Mean wet biomass fodder yields, based on triplicate measurements for eight fields in the Southern Cape region

Region	Field	Fodder Yield (kg/ha)		
		Control	Treatment	Difference
Suurveld	1	9 587	18 753	9 167
Suurveld	2	8 733	11 967	3 233
Suurveld	3	9 927	14 827	4 900
Hoekwil	1	10 553	11 967	1 413
Hoekwil	2	7 500	16 380	8 880
Suurbraak	1	13 000	15 700	2 700
Suurbraak	2	16 267	28 533	12 267
Suurbraak	3	14 467	18 167	3 700
Average		11 254	17 037	5 783

Table 2 Adjusted p-values for mean wet biomass fodder yields, based on triplicate measurements for eight different fields in the Southern Cape region

	Suurveld 1	Suurveld 2	Suurveld 3	Hoekwil 1	Hoekwil 2	Suurbraak 1	Suurbraak 2
Suurveld 2	0.72262						
Suurveld 3	0.99371	0.98701					
Hoekwil 1	0.91095	0.99992	0.99969				
Hoekwil 2	0.97761	0.99700	1.00000	0.99999			
Suurbraak 1	1.00000	0.67510	0.98888	0.88243	0.96576		
Suurbraak 2	0.02139	0.00018	0.00249	0.00059	0.00143	0.02615	
Suurbraak 3	0.98193	0.19984	0.69117	0.38906	0.57126	0.98910	0.18142

For the Tsitsikamma trial, no real difference was observed in the fodder yields at a saving of 324 kg N, 41 kg P, and 40 kg K, over the ten months of the trial (Table 3). The cost saving for the fertiliser (R8 238/ha) was offset by the soil amendment cost (R6 369/ha), resulting in a nett saving of R2 369/ha. Future treatments should, therefore, focus on optimising the soil amendment costs.

The Tsitsikamma trial initially aimed to apply no nitrogen fertiliser to the treated block. However, a nitrogen deficiency was observed in the treated block during the colder, wet winter months. This necessitated the re-introduction of nitrogen fertilisation during the winter months. It was postulated that biological mineralisation could not maintain the nitrogen supply during the colder months.

Irrespective of the cost saving, less (about half) fertiliser was used (implying less greenhouse gasses), the soils contained more earthworms (on average 6 vs 1 per spade-cube), and the compacted layers were less pronounced and occurred at shallower depths (data not shown).

Table 3 Fodder yields (wet biomass), fertiliser used, and the cost thereof for the Tsitsikamma trial

	Yield (Mg/ha)	**Fertiliser Used (kg/ha)**			**Cost (ZAR/ha)**		
		N	P	K	Fertiliser	reallPM	Total
Control	43.0	522	41	98	12 085	-	12 085
Treatment	42.0	198	0	58	3 347	6 369	9 716
Difference	1.0	324	41	40	8 738	-6 369	2 369

Research has shown that Trichoderma asperellum grows effectively in various ecosystems and stimulates root growth as a rhizospheric, epiphytic, and/or endophytic microorganism. Plant growth is further promoted by increasing the plant's tolerance to biotic and abiotic stresses, and by acting as a direct and indirect biological control agent. Trichoderma asperellum thus promotes root growth through a direct impact on pathogens by eliciting an immune response in the plant roots and by increasing the plant root's ability to take up water and nutrients (Poveda & Eugui, 2022; De Beer et al., 2023).

Increased and deeper penetrating roots, together with the increased Trichoderma asperellum fungal mass, imply inter alia greater below-ground biomass, greater biological activity, increased aggregate stability, increased porosity, increased water infiltration, increased water adsorption at a lower tension, increased air exchange, and increased cation exchange capacity. As such, Trichoderma asperellum thus offers the possibility to transform the marginal hardsetting soils of the Southern Cape region into productive, healthy soils that require less fertiliser inputs.

CONCLUSIONS

Inoculating fodder seeds with Trichoderma asperellum increased the above-ground fodder yield by 5 783 kg/ha or 51.4%. The associated increased below-ground root biomass and microorganism activity bodes exceptionally well for soil health, especially for the following season. Therefore, these results addressed two of the primary principles of conservation agriculture: "minimal mechanical soil disturbance" and "increased soil organic matter". This is because the increased soil organic matter content and faunal activity would counter the hardsetting nature of these soils and would thus negate the need for excessive mechanical soil cultivation in the following seasons.

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KEYWORDS

carbon, earthworms, organic matter, root growth, soil health

A DIVERSE SOUTH AFRICAN CONSERVATION FARMING JOURNEY IN A NUTSHELL

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INTRODUCTION

AI am a proud ambassador of Regenerative Agriculture from South Africa. As I stand before you, I am reminded of the words from the Book of Hebrews: "Faith is the substance of things not yet seen." These words resonate deeply with our mission and vision as farmers who strive to create a sustainable future through regenerative practices.

Today, I want to share my journey with you and the immense potential that lies within the choices we make every season, every day, and every moment. What does it take to make a positive impact? A single choice. Every season, every day, every opportunity, in each moment – to seize the moment and positively impact another's life, family, business, environment, and even in your soil and life.

I was born in 1989 in Estcourt in the Midlands of KwaZulu-Natal and grew up in the beautiful, majestic Drakensberg—Okhahlamba, which means "the barrier of spears" in isiZulu. Growing up surrounded by incredible no-till farmers like William Gibbings and no-till pioneer Mr Anthony Muirhead, we would often stop to count earthworms and marvel at our Father's creation.

I was educated at Winterton Primary School and then Weston Agricultural College, where I matriculated as head boy in 2007. My father, Ian Stewart, instilled in me wisdom that led me to become a tradesman in the electrical and plumbing trades before continuing my passion for agriculture. In 2014, I made a fantastic decision that significantly impacted my personal life—I married Lana, my queen, who won my heart and continues to win hers every day. Today,

Together, we are blessed with three sons, ages 7, 5, and 3. In 2016, teaming up with my best friend Bruce Gibbings, we were thrilled to win the Pioneer competition for the highest dryland maize/corn yield. After six years in the high-potential yielding area of the Drakensberg, I joined Zunckel Farms to manage their Free State operations in Warden. This was a springboard for my future, exposing me to advanced equipment and technology while broadening my horizons.

Practising no-till and regenerative agriculture, my neighbours often questioned the use of cover crops and cattle in ultra-high-density grazing formations, planting no-till corn, soya, winter wheat and even dry beans. Over time, I built strong relationships with these farmers by answering their questions and demonstrating the benefits of these practices. They began to understand soil health, the importance of earthworms, and the value of maintaining organic material in and on the soil.

I had the great fortune of meeting individuals like Danie Slabbert of Reitz Riemland Study Group, who taught me about ultra-high-density grazing, and DF Vyfer, whose dynamic breed of the Adapter is now a significant part of our farm's cattle choice.

After much prayer, I resigned from Zunckel Farms and joined the i-Link Team of Dr. Hendrik Smith, Fritz Otto, Andrew Ardington, and others at the forefront of regenerative agriculture. With my wife Lana, we began Eternal Values, a company where we sell cover crop seed and silage inoculant while giving advice and mentorship to farmers.

This has been an enormous responsibility because mentorship and networking do not happen alone. Substantial social responsibility and trust must be met before any sale.

To make things happen- we need Intelligence, perseverance and integrity.

Then comes the pleasure of seeing farmers succeed…

We cannot convert countries at a time, but we can and ought to convert one farmer at a time. Each has its own revelation and heart conviction about the impact of their choices on future generations and what is left to them.

So many universal concepts need to be made into an individual application- for maximum impact.

Saying no to something that does not fit into your dream is the first step to positively impacting your journey. The next step is finding an alternative to say yes to.

In our search for a farm of our own, the family and I were led to Dewetsdorp in the Southern Free State, where we began a new venture on a debt-free 2000Ha Farm. We farm with Done Merino sheep and have a portable hen hotel; we are also proud of the Adapter beef cattle, Boran Bulls, Thuli, and Boxelder cattle.

We plant various mixed cover crops to harvest either by sheep, cattle or caseIH and perhaps John Steenhuisen … ag, I mean a John Deere combine. We use these multispecies to improve soil health for the first two years before we plant a cash crop, as this will unlock nutrients with the tailored cover crop mixes, setting up the cash crop's success without chemicals and synthetics.

All this while educating our sons in ecological and logical farming methods. Being dynamic is about constant learning and adaptation. My father's adventures in the Drakensberg mountains, capturing the majestic snowfalls, peaks, and valleys, taught me to appreciate the beauty of nature and the importance of soil recovery from conventional practices.

To me, the footprint in the soil says a lot – direction, weight, soil moisture, and the intent of our steps.

What are your footprints? Do you have a direction? Is there life-giving moisture in the soil? Is it covered and blessed or naked and hungry? Can a rainstorm satisfy the soil's needs, or will it erode? Are your frequent passes over the soil calculated conservatively or hasty without care? Does your soil resonate with life and joy, or is it sad and despondent? Agriculture is a journey of seeing, learning, touching, smelling, hearing, and tasting the goodness of our labour. Many farmers face the challenge of transitioning to regenerative practices, but incredible groups and pioneers are ready to share their knowledge and experiences.

CONCLUSION

If you want to make a positive impact in agriculture, consider this…

Let us support the passionate farmers who are proud to farm the right way, focusing not only on economic gains but also on the health of the soil. This will evidently lead to better lives in the soil, water, and air. We should engage with the people on the land, understand their practices, challenges, and motives, and invest in their journey towards a healthy environment.

The best indicator of a positive impact is the willingness of the next generation to fearlessly and passionately continue the legacy set before them.

CONSERVATION AGRICULTURE IN SMALLHOLDER FARMING SYSTEMS IN THE NATAL MIDLANDS: A CASE STUDY OF MARTINA XULU

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INTRODUCTION

Martina Xulu is a 69-year-old smallholder farmer residing in Swidi village, a rural farming community in Ozwathini, in the Midlands of KwaZulu-Natal. She is one of 150 farmers that the Mahlathini Development Foundation (MDF) has supported in implementing conservation agriculture in mixed farming systems since 2018. Farming provides for most of the household income, alongside social grants.

Ozwathini is situated along the moist Midlands mist belt in the subtropical oceanic climate zone, marked by cooler and drier winters and mild summers. The mean annual rainfall is above 800 mm, of which 90% falls between October and March. The soils are generally deep, well-drained, and reddish brown.

Martina Xulu's total farming area is 0,3 ha, with a wide range of crops and livestock. Regarding crop production, the system includes maize, beans, cover crops, amadumbe, sweet potatoes, potatoes, fruit trees, vegetables and herbs. Vegetables are planted in trench beds, tower gardens, and shallow beds containing high amounts of organic matter. Livestock include pigs, goats, cattle, layers, broilers, multipurpose chickens and rabbits. The farmer cuts and carries cover crops for her livestock, sometimes allowing them to graze and produce manure, improving soil fertility. The principles entrenched in this farming system are reduction in soil disturbance, increase in soil cover and diversification.

Due to the advent of climate change and many years of conventional tillage, declining yields and soil degradation have been significant challenges, adversely affecting income. Conservation agriculture was introduced as an approach to reducing soil erosion, promoting diversification, and improving yields.

MATERIALS AND METHODS

Participatory Innovation Development (PID) to Farmer-level experimentation was used to incorporate conservation agriculture principles into this farming system. The aim was to engage and collaborate with Mrs Xulu in exploring possibilities for adapting to climate change and other external influences. Experiments were designed and implemented with the farmer beginning in the first year. In the first season, which was in 2019, the area was planted under maize intercropped with beans and cowpeas on a 400 m2 plot, and the rest of the field remained under conventional tillage. The following year, summer and winter cover crops were incorporated into the 400 m2 trial. In the third season, the entire farming system was converted to minimum tillage, meaning it had a CA trial and a CA control.

The trial was expanded to 800 m2, where maize, beans, and cover crops were planted in eight-row strips. In the 4th season, a 1000 m2 collaboratively managed trial (CMT) was grown, including maize, beans and summer cover crops on ten 10x10 m plots. In the 5th season, a remedial trial of summer cover crops, namely sunflower, sun hemp, sorghum, cowpeas and turnips, were planted. Close monitoring in conjunction with limited quantitative measurements was used to backstop and benchmark the results obtained, hence the modifications in experimental design over the years.

RESULTS AND DISCUSSION

The results of the experimentation process were largely positive and brought many lessons for both the farmer and research facilitators. Since maize is a staple crop and a source of income, it was a deciding factor in whether the farmer would adopt conservation agriculture as a practice or not. Yields were measured in kilograms and calculated in tons per hectare to estimate the yield that would have been obtained if the farmer planted on one hectare. In the first season (2019), yields were only obtained for legumes, which were 0.9 t/ha and 0.3 t/ha for beans and cowpeas. Maize yields were abysmal due to soil degradation from excessive tillage and the sudden transition from conventional to minimum tillage. In the second season (2020), for maize the farmer obtained a yield of 2.3 t/ha from the CA trial and 2.9 t/ha from the conventional plot, a significant improvement from the first season.

She sold green mealies, earning an income of R1200.00 from her trial and R1500.00 from her conventional plot. Bean yields came to 0.9 t/ha, with an income of R525.00. In the third season (2021), her entire field was planted under CA, and she obtained a yield of 2.3 t/ha for maize and 2.68 t/ha for beans and an income of R 1050.00 from green mealie sales. Beans were used for household consumption. The fourth season (2022) saw a decline in yield, where maize yields were 1.2 t/ha on the CA trial, 1.3 t/ha on the CA control and zero t/ha for beans. The decline in yield resulted from hailstorms, which caused crop damage.

Alternating periods of excessive heat and high-intensity rainfall also contributed to yield losses due to fungal diseases and pest outbreaks. In the previous season (2023), a 1000 m2 remedial plot was planted, including a summer cover crop mix with added cowpeas and turnips. Sixteen bags of lime were incorporated into the soil before planting, and the two-row tractor-drawn planter was used. Due to the obscurity of her field, the tractor could not reach certain areas, so they were planted using the harraca planter. The farmer allowed goats to graze the cover crops and cut and carried 12 times for her calves and pigs. This season (2024), she planted winter cover crops. However, germination was low.

System diversification, reduced soil erosion, and savings on inputs and tractor hire are among the benefits witnessed under CA. In terms of diversification, since 2019, with the support of MDF, the farmer has incorporated a greater variety of crops into her system, as she has also experimented with winter cover crops, including black oats, fodder peas, and fodder radish. The incorporation of cover crops contributed to improved soil fertility and soil health while also benefiting livestock.

Other crops incorporated into her farming include vegetables such as frilly lettuce, kale, Chinese cabbage, herbs, carrots and peas, which have been pivotal in supplementing household food supply. Livestock has diversified from just pigs and goats to incorporate a variety of poultry, rabbits, and cattle. Poultry is a source of meat and eggs, bringing an income of around R 700/month. Rabbits are mainly for manure and wee, which is applied to her garden. A total of 5 pigs were sold at a local abattoir for R 6000, and income has also been made from pork of sale in the village. Amadumbe brings an average income of R 900, sweet potatoes R 960 and potatoes R 2250.00 per season.

Her average annual income is R 18 610, R 1550.00/month. She recently sold one cow for R 12 000 and 3 goats for R 5000, giving her an extra income of R 17 000. Her annual expenditure amounts to R 17 000 and consists mainly of variable costs. Income is derived from selling locally and occasionally to bakkie traders. Mrs Xulu, like most smallholder farmers, has had no success accessing the mainstream market. The inconsistency in production and low production volumes has made securing long-term relationships with retailers challenging.

An essential component of conservation agriculture is promoting synergy in the system, evident in the various components of Mrs Xulu's production, as nothing goes to waste. Surplus field crops and vegetables such as pumpkins and cabbages are fed to pigs. The manure from the pig pens is spread on the field below, reducing the need for synthetic fertilisers. Cover crops, maize, and bean stover have played a role in reducing feed costs by providing a supplementary feed source.

A change in perspective resulted in incorporating a greater variety of crops and livestock, improving household food security.

CONCLUSION

Although there have been positive results from this experimentation process, it was not without challenges. The ability of the farmer to be flexible enough to absorb the risk of adopting new practices, which may succeed rather than sticking to an old way that was perpetually failing, is the main reason for the expansion over the years. Mrs Xulu has mastered the art of resilience by fully incorporating conservation agriculture principles.

Despite challenges with unpredictable and often destructive weather patterns, fluctuating yields, health issues and a myriad of other challenges, consistency has played a significant role in the success of her farming. In the future, her goal is to increase the incorporation of cover crops for her livestock and change to yellow maize instead of SC701. Regarding livestock, she wants to focus more on poultry and goats.

It has become evident that farmers can no longer maintain a myopic view of the impact of climate change on their livelihoods. A paradigm shift is needed if climate resilience is to be achieved. Most smallholder farmers tend to prioritise yields and income over environmental sustainability. Partly, this is the reason for relying on and misusing synthetic inputs.

Mrs Xulu is one of the few farmers who have realised that the overuse of synthetic chemicals will ultimately kill what you are trying to sustain. With that being said, the point is not to pit conservation agriculture against conventional tillage but to explore ways to increase yields in conservation systems.
In conclusion, conservation agriculture has great potential to improve smallholder farming resilience through enhanced sustainability and income savings.

KEYWORDS

climate change, conservation agriculture, food security, mixed farming, sustainability

LENTE FARM REGENERATIVE DAIRY FARM DEVELOPMENT PROCESS

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INTRODUCTION

This farm consists of 500ha of land. It is situated in the Western Ruens Shale Renosterveld. The soils are duplex soils derived from shale, Table Mountain sandstone and gravel from sandstone. Soil depth is 400mm on average. The dairy utilises 160ha of dryland and 80ha of irrigated land for pasture production. The rest of the farm is a mountainous area and is not utilised. The herd is made of jersey cows, of which not more than 350 are in milk. The rainfall is mainly in the period from April to November. In the last four years, that has varied from 398mm to 853mm per annum.

Dryland production became unprofitable because of low monoculture cereal hay production, problem weeds, and high production input costs. Climate change made the situation worse, and change was needed. Regenerative agriculture was the only option that made economic sense.

DESCRIPTION OF PRACTICES

Previously, the drylands were under subterranean clovers and localised ryegrass. Continuous grazing was practised. This was changed 20 years ago to oats hay production. Initially, production was high due to using carbon from the soil and the excellent performance of chemical fertilisers and herbicides. Resistances of certain grass weeds, like Bromus diandrus, to chemicals, became a problem and made hay production uneconomical. The low quality of the hay forced a new production vision.

This started the research into regenerative agriculture, and videos of Gabe Brown and others led to a new understanding of the problem. The importance of life in the soil became my main focus. The amount of life in the soil was never appreciated in the farming operation. Understanding the roles of microbes and other life in soil made it easier to work with nature. The five rules of regenerative agriculture set out by Gabe Brown made the puzzle understandable.

In the last three years, the production practices were changed on the dryland side. The pasture mix is based on a mix of permanent and annual cultivars. The permanent cultivars are chosen to give rise to living roots and soil cover year-round. Legumes, grasses, brassicas and herbs for grazing are planted. The farm is in a Mediterranean climate, and excellent weather cultivars are more adapted to the area. This system aims to produce fodder that is in balance with nature. The milk production is secondary to the performance of the pastureland. The number of cows is based on the performance of the pasture; thus, the cow is only seen as the combined harvester of the pastures. Concentrates are supplied. The concentrate's purpose is to balance and complement the pasture.

High-pressure grazing is used on pastures. Pasture recovery is 25 days in summer and up to 45 days in winter. This system is followed mainly on the irrigated pastures. Dryland pastures are utilised in winter and follow the same grazing system. Electric fencing is used to put out daily rations for the cows. Grazing aims to utilize 50% of pasture as feed to leave 25% and accept 25% as trampled. Fodder flow planning is critical for the profitability of the dairy. Maise silage plays an essential role in fodder flow. It is produced in rotation with pasture on the irrigated land.

After harvesting the maize silage, the land is planted to pastures. It is critical to grow a short-growing maize cultivar as early as possible to ensure that the pasture after the maize is ready for grazing at the beginning of June. The maize silage is for the feed bank and getting rid of kikuyu grass that invades the irrigated pastures.

The utilization of pastures is based on only the recovery time of the pastures. In practice, measuring pastures using a disk meter does not work. It will not necessarily correspond with the recovery time. In summer, there are 60ha of pastures, and recovery is 30 days. The drylands are then typically dormant. Two ha per day is optimal to allocate to the animals; the utilization is then monitored as follows. Are the cows lying down? Are the blocks under or over-utilized? Are the weights of the cows on par in the milking parlour, and are their milk production suitable?

The farm will stick to the allocated hectares. The following tools are then used to ensure that the optimum recovery time of the pasture is met without compensating for cow performance:

1. Add maize silage to the ration
2. Slaughter under-performing cows
3. Use dry cows to finish off leftover pasture
4. Change concentrate rates
5. Buy in Lucerne

In the winter, recovery time is 45 days, but dryland pastures are abundant. Dryland pastures will be allocated to the milk cows and the irrigated pastures. The amount of dryland allocated will be varied to reach optimal recovery time. In the spring, pasture grows faster than it can be utilized. Some dryland camps will then be taken out of the grazing cycle and utilized later as standing hay.

Multi-species makes a lot of sense! The multi-species approach has led to a decline in diseases; fungi are not a problem anymore, and no sprays are applied. Although no herbicides are sprayed, the Bromus problem is declining. Although there is an abundance of insects, snails and slugs, no control measures are taken, and production is not visibly declining. These pastures will flush with any rain or dew. The nutritional value is higher than hay and cereal grazing, as seen in the cows' milk production. The different root depths enable the pasture to utilize water at various depths.

Chicory especially amazes me because it survives our dry summers. Its deep root system also forms deep pores to exchange gasses and water. These plants can also handle waterlogging better than seedlings. Predator insects can survive as there are enough plant species to host them and to keep the insect species in balance. Then, there is also the obvious advantage that the clovers give to the soil.

The living roots of plantain, lucerne, and chicory provide food for the fungi and bacteria in the soil in summer. I see the plants as solar panels for the soil, putting the sun's energy into the soil to feed the soil without cost. In the past, that advantage was lost. Now, there is also no risk of soil erosion. Last year, I made hay from the pasture. That practice will not be continued as soil cover and seed production will be lost. Standing hay would have been a much better option. This basic LISA (Low-input sustainable agriculture) system demands less input but much more grazing management, and the farmer needs to be open to different views.

The pasture system is cheaper than hay production as the mechanisation cost, fertiliser, and chemical control are lower. I make a little bit of compost every year. I get a longer and better response of pasture to compose than synthetic fertiliser. I plan to put in more effort to experiment and understand the production and application of compose.

Interplanting the dry lands with a pasture mix strengthens them every second year. At this stage, it is somewhat of a shotgun approach to see what works. Based on what I learned, the seed mix will be adapted every year. The vision is to learn how to sustain the optimum fodder production while implementing Gabe Broun's five rules of regenerative agriculture.

CONCLUSION

I believe in the five rules of Regenerating agriculture. My vision is that the soil will be more productive as the microbial life will be able to thrive. Changes can now be seen even after only three years of the new practices on the dry land pastures. Most of the regenerative rules on the irrigated land were followed for more than 20 years. In the last three years, I only made little changes to the irrigated land, like using fewer synthetic fertilizers. The irrigated land's performance is still good even though some fields have received zero composition or synthetic fertiliser for the past two years. I still break many rules every fourth year when I plant a maze. To control Kikuyu, I use Glyphosate and a rotavator; synthetic fertilizer is also applied. I am busy investigating better practices, for example, interplanting pasture into the maize crop when the maize reaches 400mm height.

This system has brought joy and fun to the farm and relieved stress. The mindset changes from controlling all aspects of farming to believing that nature knows best, which makes a lot more sense to me. To be successful in this system, nature must be given a change. A farmer must be a lifelong student to successfully change from a controller to a regenerative producer.

OUR WAY TO NO-TILL FARMING

KLAUS KEPPLER

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INTRODUCTION

With two of my children and their families, we work on our farm, "Hofgut Dettenberg", in southern Germany, about 80km north of the Alps and Lake Constance. In addition to farming, we keep about 4800 laying hens and sell the eggs, homemade pasta, and butchered chicken on farmers' markets and selected grocery stores.

The third part of our business is bagging dried grass pellets as a service to owners and sellers of these pellets. The agricultural part includes about 144 ha of arable land and about 8 ha of grassland, including the grassland pasture for the laying hens. Approximately 60ha of cropland is located within a water protection area. We work within a temperate climate, which means an average rainfall of 924 l and an average temperature of 9,01°C on humus-rich sandy loam.

OUR CONSERVATION AGRICULTURE SYSTEM AND PRACTICE

Because working our quite loamy soils needed much time and workforce in a time when workforce got rare on our farm and the other hand, grain prices were low, we decided back in 1992 to change our agricultural system to conservation tillage, meaning to skip usage of the plough on our fields. At the same time, political support measures were based on a farming system to maximise profits, resulting in very simple or even no crop rotations. At that time, support measures focused on cereals with row spacing greater than 17,5cm, green cover, minimum tillage, and release of Cycocel for wheat.

In the following years, soil tilling depth was gradually reduced by about 2cm per year from 27cm in the beginning to 10cm in 2000. In the first years, we cultivated our fields three times with the chisel plough and planted our crops in combination with a rotary harrow. Beginning in 2001, we replaced the chisel plough and continued soil tillage with two passes of compact disk harrow and reduced the working depth to 5cm. At the same time, we bought the first direct seeder and started our no-till trials with a yield difference of about 1t/ha. With the emergence of the first biogas plants in 2003, crop rotations changed again. Oilseed rape was replaced by silage maize and grass-clover lays.

After that change, the first harvest came up with decreasing yields due to the extreme drought in summer on one hand and heavy rain with up to 50l/h within minutes on the other hand. This also changed our objective from only economic reasons for conservation tillage towards soil-based reasons, namely water holding capacity, humus enrichment and soil health, to prospectively avoid such yield losses in the future. At the same time, the requirements for farming in water protection areas became even more stringent, particularly regarding autumn nitrate levels. This necessitated the integration of intensive cover crops into our crop rotations.

In the following years, soil tillage intensity was further reduced to one passage until 2011, when yields were no different between tilled and no-tilled fields. Consequently, we have been no-tillers since 2012. The complete abandonment of tillage has necessitated a further adjustment of crop rotation, culminating in a consistent change of summer and winter crops and foliage and cereals in a rotation of maize, wheat, sunflower, oilseed rape, and barley with various cover crops. Oilseed rape has just been reintroduced to cope with the ban on glyphosate in water protection areas from 2022.

To handle extreme droughts, which we have had several times in summer now, we built a rainwater retention basin in 2011. This basin allows us to retain water when there is too much and use it for irrigation when there is too little. Its capacity is sufficient to irrigate the surrounding area once with approximately 30 litres per m² of rainfall.

IMPACT, SUCCESS, AND PROGRESS

Looking back on 30 years of conservation agriculture, we have managed to build up highly active soils rich in soil life, which can degrade up to 10 straws per hectare. The gradual reduction in tillage depth and intensity, together with the addition of grass-clover rotations and the introduction of cover crops in the early 2000s, has revitalized our soils by providing permanent root penetration and feeding our soil life with organic leftovers such as roots, straw or frozen and dead cover crops.

In 1992, we had an average of 2.2-2.5% organic matter in the first 25cm depth. It took us about 24 years, to increase this average to 2.8% organic matter in 2016. Recent analyses of our soil samples show that the last 8 years of no-till have made our soils very "humus-rich", with an average of 3.5-4% organic matter in the first 25cm depth. This outstandingly high enrichment of 0.7-1.2% organic matter on average within only 8 years can be attributed to refraining straw removal since 2008 in combination with a complete waiver of tillage since 2012 when degradation of organic matter was reduced to a minimum.

This, together with about 200 up to 320 earthworms per square meter and their whole bodies, helps to prevent surface run-off and erosion during heavy rainfall while increasing the water-holding capacity of our soils and helping our crops to cope with dry spells. In addition, the high and rapid turnover of crop residues, thanks to healthy soil life, reduces phytosanitary problems and, therefore, the need for fungicide application in our fields.

Reducing the need for crop protection products is just one way our farming system's efficiency is being sustainably transformed. Initially, the stepwise reduction of field passages reduced the variable costs of machinery, fuel, and labour since 1992, increasing profit contribution per working hour. Furthermore, experiments variegating the frequency of fertilization on our farm showed in 2008 that a single supplementary application of mineral fertilizer to organic fertilization with, e.g. fermentation residues of biogas plants is enough to reach the same yields as various applications do.

We are, therefore, reducing the number of fertilizer applications. Back to plant protection, we were able to optimize efficiency again in 2016, when we started to apply pesticides only at night to reduce their loss through wind and thermal air movement. At night, the temperature, wind speed and humidity are almost perfect for the pesticides to reach the plant, reducing the amount used by up to 40-50%. So today, we have a profit contribution of around €250 per working hour, compared to around €85-100 in conventional farming systems.

Finally, if we look at absolute yields over the last 30 years, we can see that the average yield has remained static since 2005, while the variation between years has increased. The start of no-tillage experiments in 2001 made observing yield differences between no-tillage and conservation tillage possible. The difference peaked in the early years at an average of 1 t/ha, slowly decreasing to 0.8 t/ha in 2005. Five years later, the difference was only about 0.3 t/ha; in 2012, it was 0 t/ha.

CONCLUSION

Since absolute yields seem not to be increasable anymore, especially due to our strict fertilizer legislation in Germany, our focus is on further optimization and, therefore, reduction of pesticide use. Our vision is to develop an agricultural no-till system based on mixed cultivation of living mulch and crops alternating in rows.

This eliminates the need for non-selective herbicides such as glyphosate. Even though there is a chance that glyphosate will be allowed to be used in Germany, we are working on solutions to be ready in case it is eventually banned. Such a system could also make fertilization more efficient again because, with the help of CULTAN, the fertilizer could be placed more selectively and aimed at the corps roots, whereas the cover corps roots, at the same time, don't get any fertilizer.

Summing up, 30 years of conservation agriculture and 10 years of no-till taught us a lot about soil health, function, and life. However, we want you to take home the following: "Those who stop getting better have stopped being good." -Philip Rosenthal (originally German, translated)-

CHINESE DAIRY FARMING IN THE MONGOLIAN DESERT

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INTRODUCTION

China Shengmu Organic Milk (Ltd) is the world's largest organic dairy farming company; 100,000 organically managed dairy cows graze on 34 farms in pure desert sand near Byannur in Inner Mongolia. In 15 years, the area has been transformed by soil and water conservation, while millions of trees (many poplars) have been planted.

DESCRIPTION OF BACKGROUND AND THE CONSERVATION AGRICULTURE SYSTEM

Shengmu ranches dairy cattle which are milked three times daily, with much of the feed (irrigated ryegrass, oats, sunflower and cover crops) cut and carted to the dairy cows, which spend half the day under shade, as temperatures during the heat of the day are dangerous for cattle.

Cows are allowed sand-baths (which they enjoy) and some hours of carefully managed strip grazing. Milk is processed locally, and a milk powder factory was recently completed. Soil has changed from less than 1% organic matter to over 3% organic matter, and part of the secret to this transformation is the Yellow River, which flows under the desert.

Centre-pivot irrigation has assisted the remarkable transformation of desert sand into sandy loam, on which healthy and prolific crops grow. Fifteen years ago, pioneers spent five difficult years setting up infrastructure (five-minute video available), and now cows and farmers enjoy a transformed and highly productive environment.

Dairy manure provides fertiliser, and all food is grown on-site. Minimum tillage and crop rotation are practiced, but mulching is not practical in the desert environment; however, planting millions of trees has somewhat transformed the climate.

IMPACT, SUCCESSES AND PROGRESS

Figures support the productivity, showing that there is still room for improvement in calving interval, number of calves in a cow's lifetime, and access to pasture for dairy cows. However, the farms are remarkably successful, given the harsh environment, and the Chinese government is now committed to supporting organic conservation dairy farming in several regions of China. We were hosted for the Asian Organic Innovation Summit by members of Xichong Organic District, one of several such districts in China.

CONCLUSIONS

Organic Conservation Dairy Farming is viable, even under desert conditions, if the local ecology is understood. Conservation agriculture's ability to transform soil and support animals shows the potential for such practices to become mainstream around the world, even in the face of climate change.

SURFACE TEMPERATURE VARIATION AS A PROXY FOR SOIL HEALTH ASSESSMENT IN CERRADO BIOME AGROECOSYSTEMS

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INTRODUCTION

Soil health is crucial to maintaining sustainable agricultural practices that ensure long-term productivity and food security. Chemical, physical, and biological analyses, such as soil respiration or enzymatic activity, can assess soil health. Despite the availability of different methods, large-scale assessments are often not possible due to the high human and financial resources needed.

By exploring the interplay between soil enzymatic activity and land surface temperature, this study seeks insights into optimizing agricultural strategies that balance productivity, sustainability, and overall soil health in evolving agricultural landscapes.

In tropical regions subjected to intense heat and heavy rains, systems with suitable productivity and resilience require plant species diversification and permeable soils with minimum disturbance, permanent soil cover, and intense biological activity. Different conservation practices have been adopted in Brazil, aiming to improve biodiversity and soil cover quality, such as the No-Till (NT) system, Integrated Crop Livestock Systems (ICLS), intercropping, crop diversification, crop rotation, and use of cover crops.

No-till (NT) practices have gained widespread adoption due to reduced erosion and increased moisture retention. However, long-term experiments in Brazil have revealed that even with NT management, maintaining constant soil cover and implementing cropping systems with high crop residue input is crucial to balance Soil Organic Matter (SOM) decay in tropical climate conditions

(Mendes et al., 2018). Yet, there is scant information on strategies to achieve diversified and permanent soil cover in NT systems, particularly in regions with a dry season, and how management influences land surface temperature and enzyme activity. This research aims to fill this gap, providing practical insights for optimizing NT systems in such conditions.

Land surface temperature can be applied in rural landscapes to assess soil cover quality, letting the identification of heat islands (characterized by bare or tilled soils or with low cover). Remote sensing images, such as Landsat 8's thermal band, capture the energy emitted by objects of interest, enabling monitoring of changes in the surface occupied by agroecosystems. Analysis of those images allows farmers to evaluate crop rotation plans and other strategies to increase biomass production and improve soil coverage.

Soil enzymes can be a potential soil health indicator due to their relationship to soil biology activity, ease of measurement, and rapid response to changes in soil management. Soil Bioanalysis Technology (Soil-Bio), based on including s-glucosidase and Arylsulfatase in routine soil analysis, aims to incorporate microbial analyses in large-scale on-farm soil health assessments in Brazil. The enzymes can be measured directly in air-dried soil samples collected at the postharvest stage. The method utilises low-cost reagents in a network of certified laboratories.

The rationale of this work is based on identifying a) how cropping systems affect surface temperature, followed by b) assessing the potential impact of cropping systems on soil enzyme activity, and finally, c) examining the correlation between surface temperature and enzyme activity.

MATERIALS AND METHODS

The soil health assessment was conducted at a farm scale. The study focused on soybean and corn crops integrated with livestock production. Various parameters, including enzymes, land surface temperatures, crop yields, and chemical analysis, were evaluated across nine plots covering approximately 1,900 hectares. These plots had different crops and management strategies over eight years (2017-2024), characterized by a five-to-six-month dry season, mean annual temperature of 22.3 °C, and precipitation of around 1,200mm. The farm's predominant soil type is Ferralsol, with 60% clay content.

The study delved into different strategies to maintain soil cover during the dry season in No-Till annual crops at a farm level: Integrated Crop Livestock Systems (ICLS), which involved intercropping maize (Zea mays) as a summer crop with Brachiaria brizantha, grazed during the dry season, and soybean followed by cover crops. These cover crops included maize as a second crop associated with Brachiaria ruziziensis, or a mix of diversified cover crops such as B. ruziziensis, Pennisetum glaucum (pearl millet), Fagopyrum esculetum(buckwheat), Cajanus cajan (pigeonpea), Crotalaria juncea (sunnhemp), among others.

Adopting NT management with short-cycle soybean varieties (cycle < 105 days) enables a second crop, or a mix of cover crops, to be sown following the harvest of early maturing soybeans. Short-cycle soybeans have a lower yield potential than medium/long-cycle soybeans. On the other hand, when using late-maturing soybeans (medium or long cycles) and sowing a second crop or cover crops at the end of the rainy season, crop losses can occur due to erratic rainfall.

The management of crop systems was categorized as follows: ICLS; Soybeans (Short Cycle) followed by Cover Crop Mix sowing; Soybeans (Medium/Long cycle) followed by Cover Crop Mix sowing; Soybeans (Medium/Long-cycle) followed by overseeding of cover crops (Brachiaria and/or Millet); Soybeans (Medium/Long-cycle) without cover crops in the dry season Soil enzymes (s-glucosidase and Arylsulfatase, 0-10cm depth) were evaluated at the end of each crop cycle (May) in 2020-2024. The surface temperature difference (Δ surface temperature) reflects the variation of the plots about the mean surface temperature of the remaining native vegetation (two fragments) on the farm.

Considering the structure of the collected data, we applied mixed effects modelling and a restricted maximum likelihood (REML) estimation method to analyze the relationships between the variables crop management practices and Δ surface temperature and between the variables crop management practices and soil enzymes s-glucosidase and Arylsulfatase. The blocks (plots) were

considered random factor variables in the model. Normality and homogeneity of variances were verified on standardized residuals. Tukey tests were used to identify specific differences between crop management practices.

RESULTS AND DISCUSSION

The linear mixed-effects model revealed a significant effect of crop management practices on Δ surface temperature ($P < 0.001$). Crop Livestock Integration Systems (ICLS) and short-cycle soybeans were associated with the lowest changes in surface temperature, while Cover Crop Overseeding was associated with the highest surface temperature. The differences in land surface temperature between cropping systems management show that the earlier the window for seeding cover crops, the better the soil cover quality in no-till systems. Management systems with earlier introduction of cover crops, such as ICLS and short cycle soybeans, showed a lower Δ surface temperature.

Crop management practices affected Arylsulfatase ($p = 0.0295$) activity. ICLS had the highest activity of this enzyme, while Cover Crop Overseeding had the lowest activity. The effect of crop management on arylsulfatase activity indicates that soil cover quality affects microbial metabolic processes and, consequently, enzyme activity. The Δ surface temperature exhibited a significant negative association with s-glucosidase levels ($p < 0.001$), while there was no significant relation of Δ surface temperature with Arylsulfatase ($p = 0.0515$). Enzyme activity over the years indicates that Arylsulfatase is more stable or tolerant to higher temperatures stress than s-glucosidase. The correlation analysis revealed a significant effect of SOM on s-glucosidase ($P = 0.0036$) and a correlation between SOM and Δ surface temperature ($P<0.001$). Microbially-driven SOM decomposition is regulated by the quantity and quality of SOM, which is affected by temperature (Hou et al., 2016).

CONCLUSIONS

The ICLS showed a more marked effect than other management practices on land surface temperature (resulting in the lowest values) and arylsulfatase enzyme activity (with higher levels). There is great potential for agricultural production from rehabilitating degraded pastures with the implementation of a crop-livestock integration system and significant potential to boost soil quality in agricultural production systems with livestock integration.

Changes (Δ) in the surface temperature of cropping systems can be used as a practical tool to complement biological soil analysis. Moreover, this metric can predict s-glucosidase activity, an indicator of soil quality. This practical approach could contribute to developing a set of robust and scalable indicators that are accessible to technicians and farmers and aim to measure soil quality and, consequently, the health of soil and crops.

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AREAS WHERE CONSERVATION AGRICULTURE CAN ADVANCE

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INTRODUCTION

Eight authors with impeccable ZT/CA experience accepted the challenge to participate under this title.

MATERIALS AND METHODS

The authors edited six key topics selected to incorporate into the CA concept to provide farmers and technicians with the additional sustainable and profitable practices in ZT/CA that they are demanding. Putting all of these onto the CA platform is the most logical route to making CA more holistic regarding farmer aspirations and contributions to reducing global warming and food prices while increasing the world food supply for a growing population.

RESULTS AND DISCUSSION

1. A new soil analysis protocol specific to CA

By John N. Landers and Pedro L. De Freitas

A common practice in soil sampling is to remove the overburden and leave bare soil to be sampled. This approach was established long before the advent of CA and needed to be adjusted to include the analysis of nutrient and carbon reserves in humus and in crop residues left on the surface (Blancaneaux and De Freitas, 1996; Derpsh et al., 2014). All other sampling instructions should be followed to avoid fermentation, except for using a cotton or sackcloth bag for the crop residues. This protocol should highlight the superiority of CA as a sustainable management system, especially regarding the nutrient reserves in humus and crop residues. Later, the aerobic breakdown of the residues by microbial action converts them to humus. The latter gives up its nutrients in organic and chemical (especially K) forms.

Plant roots easily absorb organic molecules. This organic dimension is overlooked in traditional chemical analysis. The new protocol, together with the bio-assay described in section 3, gives farmers and technicians a more holistic understanding of plant nutrition and soil health, enhancing the approximation of CA with pioneer farmers in OA and RA, already practising ZT/CA.

2. Reduced pesticide soil half-lives under the high biological activity of CA

By John N. Landers

The presence of an active microbial community in the soil can influence pesticide persistence in various ways. Soil microorganisms can degrade or transform pesticides into less toxic forms. In addition, the biological activity of the soil can affect the sorption and leaching of pesticides, influencing their mobility in the soil.

In this context, a study by Portilho et al. (2015) demonstrated, under controlled laboratory conditions (microcosms at 28°C, with humidity at 75% of field capacity, over 51 days), that soils exhibiting higher biological activity, indicated by increased enzymatic activity, experienced a substantial reduction of 48 t0 85%in the half-life values (TD50) of the insecticides bifenthrin, permethrin and thiotoxam. Soil samples were collected at a depth of 0 cm to 10 cm from a long-term field experiment at Embrapa Agropecuária Oeste in Dourados MS. This compared integrated crop x livestock (ICL) systems under zero tillage (ICLZT, in Landers, 2019) with the same system under conventional tillage (ICLCT).

Soils with higher biological activity were under ICLZT, while ICLCT treatments showed lower biological activity levels. The half-life values (TD50) for bifenthrin, permetrin and thiotoxam were notably shorter (68.2, 85.3 and 48.1%, respectively), compared to those observed in ICLCT treatments (Table 1). This highlights a significant advantage of maintaining soils with higher biological activity, such as those under ICLZT or simply ZT – the ability to reduce the environmental persistence of pollutants over time. This aspect is often overlooked but holds substantial importance in environmental management and needs to be included in international databases.

Table 1. Reductions in soil half-lives of pesticides (TD50, in days) under integrated crop x livestock systems with and without zero tillage.

Table 1. Reductions in soil half-lives of pesticides (TD50, in days) under integrated crop x livestock systems with and without zero tillage.

Pesticide	CT	ZT	%
Bifetrin	44	14	68.2
Permetrin	47	7	85.3
Thotoxam	89	46	48.1

Source: Portilho et al. (2015).

3. The Potential of soil bio-assays for nutrient management in CA
By the team of Ieda C.Mendes

Improved soil health is crucial for enhancing nutrient use efficiency in agricultural systems. In Brazil, the long-term adoption of Conservation Agriculture has revealed limitations in the traditional soil fertility approach, emphasizing the need to consider soil biological functioning in routine analyses (Anghinoni and Vezzani, 2021). Variability in crop yields, even in soils with similar chemical compositions, and successful crop production under suboptimal soil fertility conditions underscore the importance of incorporating soil bioindicators into assessments (Mendes et al., 2017, 2020; Anghinoni and Vezzani, 2021; Nicolodi et al., 2008).

Healthy soils, despite similar fertilizer inputs, produce higher crop yields than those undergoing biological degradation. This is because, over time, in conservationist systems, residual biomass accumulates, a potential energy source for biological activity that decomposes these residues, releasing nutrients and forming complex organic compounds (Anghinoni and Vezzani, 2021).

In this context, biological indicators better reflect the storage and cycling of nutrients released from the residual biomass in CA systems. In Brazil, Soil Bioanalysis Technology (SoilBio), a new protocol of routine soil analysis involving the evaluation of two soil enzymes (arylsulfatase and beta-glucosidase), provides new insights into a soil´s capacity for nutrient cycling (Mendes et al., 2024).

By this approach, large-scale soil health assessments are based on chemical and biological indicators in a framework consisting of three soil functions: (F1) nutrient cycling (defined by the activities of GLU and ARYL), (F2) nutrient storage (given by soil organic carbon, SOC and cation exchange capacity, CEC) and (F3) nutrient supply (based on Ca2+, Mg2+, K+, P, pH, H+Al; Al3+, sum of bases and base saturation). The SoilBio protocol of routine soil analysis, completed with the evaluation of the two soil enzymes plus the calculation of soil quality indicators (SQIs), contributes to characterization of biology and biochemistry (Mendes et al. 2024).

4. Promising sustainable and profitable innovations for CA to expand.
By John N. Landers, Ademir Calegari, Rafael Fuentes-Llanillo and Rui Casão-Junior

Commercial farmers, research and industry have driven innovations in CA. There is much positive spinoff for the small farm sector. CA must now include all new sustainable technologies and respond to farmers' demands. Technologies that should be considered:

- New spraying technologies could reduce pesticide use by up to 90%; (The Economist, 2024);
- Biological controls for pests and diseases, substituting chemicals (Parra, 2023).
- ZT/CA for horticulture crops (EPAGRI, 2019; Lima e Madeira, 2013).
- Drones for crop scouting and spot spraying of early foci. (Nobre et al., 2023).
- New inoculants for Gramineae and soil microbes (Hungria et al. 2021).
- Permanent legume or grass swards under ZT crops (Landers, 2024).
- New planter and drill designs for heavy residues (Casão-Junior, 2020).
- Much more diversified rotations, including several cover crops (Sá et al., 2015).
- Mid- and long-term financial analyses of diversified rotations and cover crops (USDA-SARE et al. 2020):
- Controlled traffic farming to restrict compaction to permanent tramlines, leaving crop areas uncompacted (Tullberg et al., 2007)

These must be incorporated into national policy and programs, engaging with the private sector.

5. How to integrate CA with Regenerative Agriculture and Organic No-till Agriculture, on a worldwide definition of Agricultural Sustainability.
By Tom Goddard and Don Reicosky

The rivalry between different would-be sustainable nomenclatures serves no valuable purpose for farmers. After an initial assessment, we consider ways and means to bring them together, as flagged by Landers et al. (2021).
Conservation Ag (CA) – just three easily measured, precise, globally adaptable principles. They foster soil health (Derpsch, 2024). CA has multiple benefits to agricultural sustainability (FAO, 2023).

Regenerative Ag (RA) – uses the three principles of CA plus two or more, but CA is not always explicit. Additional principles can be difficult and expensive to measure. It is a very relaxed, accommodating definition. Adoption of any number of characteristics appears to satisfy the definition. RA claims benefits to soils, landscapes and the environment, possibly including rural economic and social benefits (Cruz, 2023).

Organic No-Till Agriculture (ONTA) – limited to natural inputs (FAO, 1999). Man-made inputs are alien. Needs on-farm green manure, biomass and/or imported manures and biomass. FAO (2024) lists permitted inputs. Bio-assays allow easy measurement of biological soil enzyme activity. ONTA needs price premia or direct sales to consumers to offset higher production costs. Certifications are rigorous in eliminating all non-natural inputs. However," natural" sulphur and copper minerals as fungicides are permitted (Thakur, 2024).

Many more terms are emerging that are variants of the above.

All systems that claim sustainability must acknowledge CA principles as a sine qua non. What should we do now?

- CA must explicitly embrace new sustainable technologies to expand its coverage.
- Many more farmers should measure CA values on-farm.
- Found and funded a no-tillage-based Sustainable Agriculture Platform umbrella for CA, RA and ONTA, accommodating variants in a two-tier concept: (I) no man-made chemicals, (ii) bio-controls and reduced chemicals.
- Introduce effective measures to meet regulatory or market needs.
- Researchers need to be explicit about methodologies to allow valid comparisons.
- Increase CA policy and institutional support (Kassam et al., 2014).

6. The importance of rotations and cover crops to improve CA sustainability.

By John N. Landers and Ademir Calegari

Worldwide positive effects have been achieved and reported elsewhere about suitable implementation of cover crop species and crop rotation in diverse CA cropping and farming systems. USDA-NASS (2020) showed 71% of farmers reported better weed control and 68% said soil moisture management improved; yields after cover crops increased 5% in soybeans, 2% in corn and 2.6% in spring wheat. The Agricultural Research Institute of Paraná (IAPAR) showed a 65.2% increase in maize yield following Vicia sativa L. and positive effects in eight other cover crops (Calegari et al., 2008; 2012). Sá et al., in northern Mato Grosso, Brazil, showed positive results from diversified rotations. USDA-SARE (2023) demonstrated a first-year loss of US$-31.36 acre-1 for cover crops but a profit of US$17.90 acre-1 after 5 years.

Many farmers treat cover crops as a cost with unquantified returns; more analyses like these need to be done worldwide and promulgated. In France, Guinet et al. (2023) found reduced pesticide use with CA, but Munier-Jolain (2024) pointed out that glyphosate use on cover crops could reverse this. However, Zhang et al. (2024) found crop diversity reduces total pesticide use less than species at the system level. Supporting this, (Munier-Jolain, 2024) showed that pesticide use treatment frequency index (TFI) ranged from 13.5 for potatoes to 0.4 for buckwheat. In Africa, stubble gazing is the biggest constraint to ZT/CA rotations.

CONCLUSIONS

The authors have detailed many ways for CA to widen its scope and respond to farmer demands for new CA practices that are both profitable and sustainable. The old mantra of three principles has been successfully applied. Farmers want to incorporate new practices into the CA concept. The tide of progress will not be stemmed.

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COMPARISON OF THE EFFICIENCY OF ENERGY CONSUMPTION OF CONSERVATION AGRICULTURE AND CONVENTIONAL METHODS IN WHEAT, RAPESEED AND IRRIGATED COTTON CROPS IN GOLESTAN PROVINCE, IRAN

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INTRODUCTION

The agricultural sector has a significant share in energy consumption. The main factor contributing to increased energy consumption is population growth, resulting in more food demands. Energy is one of the crucial properties of the human lifetime and is generally classified as a non-renewable resource. Since vast amounts of energy are consumed in the agriculture sector, an energy audit is an essential strategy in countries, especially developing and an arid country like Iran. Conservation Agriculture (CA) as an implement for sustainable development can lead to saving agricultural resources.

MATERIALS AND METHODS

This study calculates the energy consumption and production of three major agricultural products, wheat, rapeseed, and irrigated cotton, through completely random sampling and interviews with farmers. The energy consumption coefficient, energy efficiency, energy intensity, productivity, and net energy added are determined using these methods. This research aims to examine and compare the indicators of energy consumption efficiency and efficiency in two groups of wheat farms using conventional tillage (CT) (subsoiling, ploughing, discing, and seed drilling) and no tillage (NT) (without subsoiling, ploughing, discing, and direct seed planting) in the eastern regions of Golestan Province, Iran, specifically in the cities of Gonbad, Minudasht, and Galikesh.

Therefore, the objectives of the study are 1-The uncertainty of energy efficiency in three main crops, including wheat, rapeseed and cotton irrigated production in Golestan province on the one hand and the occurrence of the energy crisis at the global level and the necessity of targeted energy consumption on the other hand. 2- Evaluating and future research of energy parameters, including net energy, energy efficiency, specific energy and energy efficiency, and state appropriate strategies for improving energy parameters in wheat, canola and irrigated cotton production.

For this research, we used the following process: Quantity measurement (energy efficiency rate). Surveys and library studies refer to valid domestic and scientific literature (articles and books) in the field of practical methods of increasing energy efficiency in agricultural products. The subjects of this research are farmers who grow wheat, rapeseed and irrigated cotton in Golestan Province.

111 to 121 farmers were selected, and these sampling were done entirely randomly. Interviews, tables, average energy consumption comparison tests and information banks related to the research topic. Two groups of farmers using CT methods (sub-soiling operations, moldboard plough, disc and planting with seeder) and No-Till (without ploughing and direct seeding) were carried out in the eastern regions of Golestan province.

First, the required statistical data were prepared and collected by surveying two samples of farms with CT and NT methods to measure the energy indicators, including energy consumption efficiency, net energy, and energy efficiency in the surveyed farms. Each sample consisted of 15 farms selected in equal proportion. We used the following formula to calculate energy indices, as shown in Table 1.

Table 1: Energy indices that are being used in this research.

Materials and Methods

Common and commercial varieties of agricultural products were used in this study. Energy indices were calculated using equations 1 to 4

$$EUE = \frac{EOU\ (MJ\ ha^{-1})}{EIN(MJ\ ha^{-1})}$$

Equation (1) EUE: Energy Use Efficiency, EOU and EIN: output and input energy MJ ha^{-1})

$$EE = \frac{EIN\ (MJ\ ha^{-1})}{Y(Kg\ ha^{-1})}$$

Equation (2): specific energy , Y: economic yield (kg ha^{-1})

$$NEG = EOU(MJ\ ha^{-1}) - EIN\ (MJ\ ha^{-1})$$

Equation (3): NEG: Net Energy Gain

$$EP = \frac{Y\ (Kg\ ha^{-1})}{EIN(MJ\ ha^{-1})}$$

Equation (4): Energy Productivity

RESULTS AND DISCUSSION

The results obtained regarding the average energy consumption per hectare are shown in Tables 2 to 6 below:

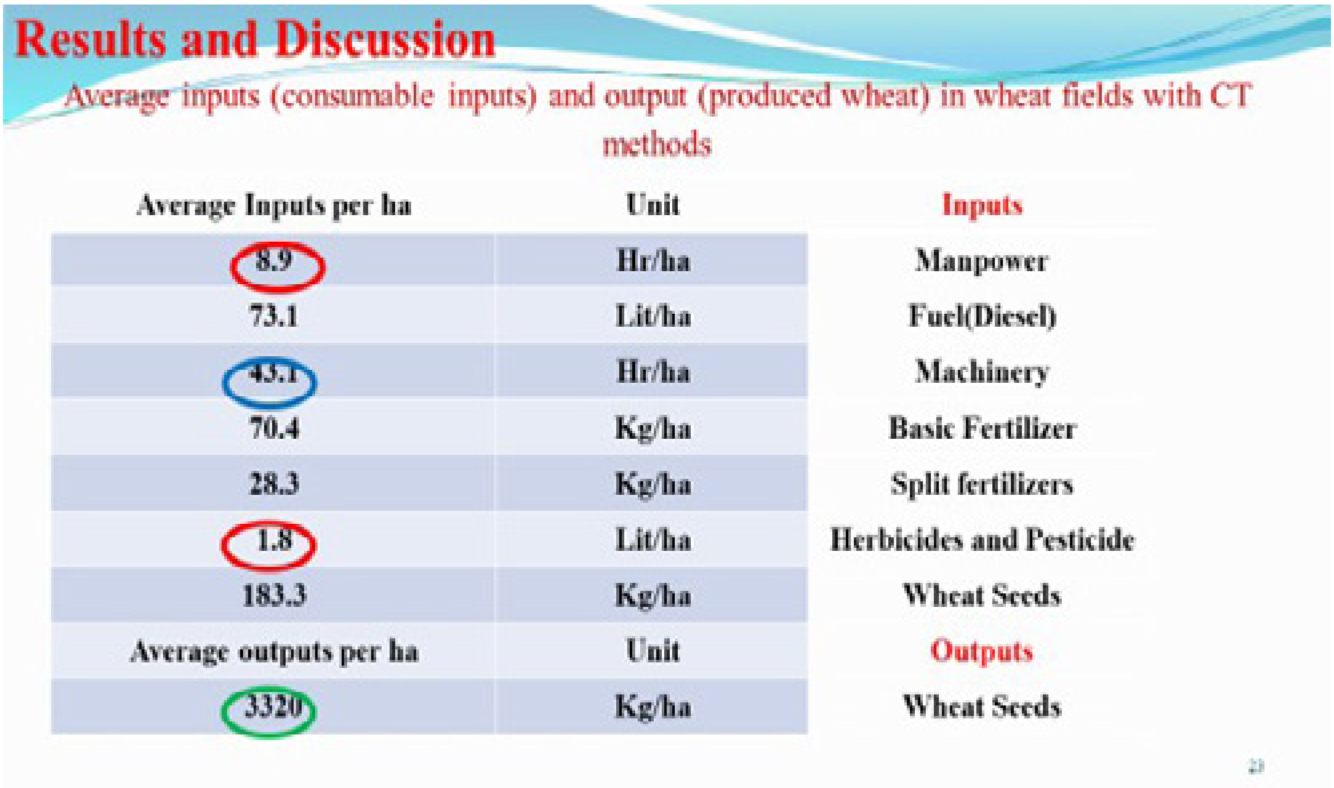
Table 2: Average inputs (consumable inputs) and output (produced wheat) in wheat fields with NT methods

Results and Discussion

Average inputs (consumable inputs) and output (produced wheat) in wheat fields with NT Methods

Average Inputs per ha	Unit	Inputs
4.3	Hr ha^{-1}	Manpower
29.8	Lit ha^{-1}	Fuel
18.6	Hr ha^{-1}	Machinery
32.2	Kg ha^{-1}	Basic Fertilizer
14.3	Kg ha^{-1}	Split fertilizers
1.00	Lit ha^{-1}	Herbicides and Pesticide
155	Kg ha^{-1}	Wheat Seeds
Average outputs per ha	**Unit**	**Outputs**
3426.7	Kg ha^{-1}	Wheat Seeds

Table 3: Average inputs (consumable inputs) and output (produced wheat) in wheat fields with CT methods

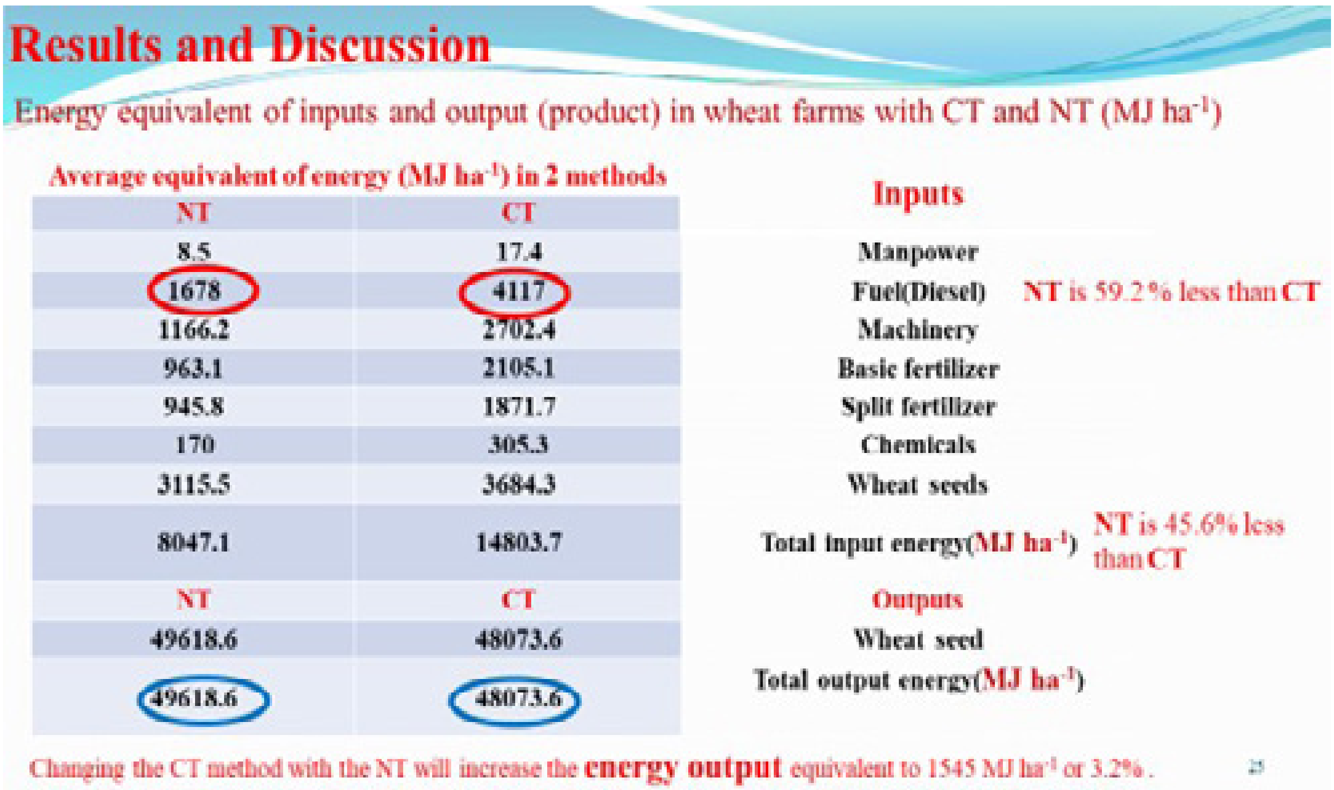


Results and Discussion

Average inputs (consumable inputs) and output (produced wheat) in wheat fields with CT methods

Average Inputs per ha	Unit	Inputs
8.9	Hr/ha	Manpower
73.1	Lit/ha	Fuel(Diesel)
43.1	Hr/ha	Machinery
70.4	Kg/ha	Basic Fertilizer
28.3	Kg/ha	Split fertilizers
1.8	Lit/ha	Herbicides and Pesticide
183.3	Kg/ha	Wheat Seeds
Average outputs per ha	Unit	Outputs
3320	Kg/ha	Wheat Seeds

Table 4: Energy equivalent of inputs and output (product) in wheat farms with CT and NT (MJ ha-1)



Results and Discussion

Energy equivalent of inputs and output (product) in wheat farms with CT and NT (MJ ha^{-1})

Average equivalent of energy (MJ ha^{-1}) in 2 methods		Inputs	
NT	CT		
8.5	17.4	Manpower	
1678	4117	Fuel(Diesel)	NT is 59.2 % less than CT
1166.2	2702.4	Machinery	
963.1	2105.1	Basic fertilizer	
945.8	1871.7	Split fertilizer	
170	305.3	Chemicals	
3115.5	3684.3	Wheat seeds	
8047.1	14803.7	Total input energy(MJ ha^{-1})	NT is 45.6% less than CT
NT	CT	Outputs	
49618.6	48073.6	Wheat seed	
49618.6	48073.6	Total output energy(MJ ha^{-1})	

Changing the CT method with the NT will increase the **energy output** equivalent to 1545 MJ ha^{-1} or 3.2% .

Table 5: EUE, specific energy, net energy and energy productivity in wheat fields with CT and NT methods.

Results and Discussion

EUE, specific energy, net energy and energy productivity in wheat fields with CT and NT methods.

	Change	Wheat NT	Wheat CT	Items
89.8 %	2.92	6.17	3.25	(EUE)
	-2.11	2.35	4.46	(EE)
	8301.6	41571.5	33269.9	(NEG)
	0.20	0.43	0.22	(EP)

In CT wheat farms, each MJ of energy consumption (input) has led to 3.25 MJ output ha^{-1}. But in NT farms, each MJ (input) ha^{-1} is combined with 6.17 MJ ha^{-1} .

The average NEG and EP in NT are 41571.5 MJ ha^{-1} and 0.43, respectively, which are in better and favorable conditions compared to the NEG and EP of CT.

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Table 6: The average energy consumption efficiency and the total energy consumed in two groups of wheat fields under investigation.

Results and Discussion

The average efficiency of energy consumption and the total energy consumed in two groups of wheat fields under investigation

Change %	Wheat NT	Wheat CT	Index
89.88	6.17	3.25	EUE
-45.64	8047.1	14803.7	Total Energy (MJ ha^{-1})

The change of the cultivation method from the CT with NT has been associated with a 45.64% reduction in energy consumption.

Also, with this change, the efficiency of energy consumption will increase by 89.88%.

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CONCLUSION

Based on the total results and findings of this research, it seems that the application of NT methods is justified and recommended in terms of the superiority of energy consumption efficiency indicators for wheat farming systems in the climatic conditions of the eastern regions of Golestan Province.

According to the results, it reduces approximately 59.2% of fossil fuel consumption. The change in wheat farming method from the CT method to NT has been accompanied by a 45.64% reduction in energy consumption. Also, with this change, energy consumption efficiency will increase by 89.88%.

The results showed that human labor allocated the lowest amount of energy input or consumption for both groups of wheat farms studied. However, wheat farms' highest share of input or consumption energy belonged to fossil fuel inputs, and in NT wheat farms, it belonged to wheat seed inputs.

Therefore, efforts to reduce the consumption of these types of inputs in wheat farming will significantly reduce energy consumption. CA is a new approach that has been paid attention to in managing agricultural systems today because it can play a significant role in the efficiency and productivity of energy resources. To reduce the share of indirect energy, crop residues should be kept on the soil surface instead of burning.

Therefore, according to the results and findings of this research from the analysis of energy indicators, it seems that the use of NT methods can be justified and recommended in terms of the superiority of the energy consumption efficiency index for the wheat farming system in the climatic conditions of Golestan province.

KEYWORDS

Agricultural Mechanization, Conventional Tillage, Fossil Fuel, Global Warming, No-till Farming, Productivity.

CONSERVATION AGRICULTURE SYSTEM STABILITY UNDER VARYING RAINFALL

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INTRODUCTION

Our research on Conservation Agriculture (CA) has been the cornerstone of the Langgewens Research Farm's long-term crop rotation trials since 1996, spanning a robust 20-year period. The initial six years of the trial involved minimum tillage and loosening of the soil before sowing with an adapted seed drill could commence. A suitable no-till tine seeder was obtained in 2001, and from 2002 onwards, complete CA principles were implemented. T

hough concentrated between April and October in the Swartland, the annual rainfall could be more consistent. This paper evaluated the performance of different cropping systems under varying winter rainfall regimes over this extensive 20-year period from 2002 to 2021. Wheat yield and gross margins of the various systems were compared to test the stability of the eight varying CA 4-year rotation systems (1 monoculture control, three cash crop and four cash crop/pasture rotation systems).

MATERIALS AND METHODS

The eight systems tested included monoculture wheat as the control system (WWWW- System A). The three cash crop rotations included a three-year wheat and one-year canola rotation (WWWC – System B), an alternating system of cereal and broadleaves (WCWL – System C), and a double-up system of two years of cereals followed by two years of broadleaves (WWCL – System D). The latter two systems included lupine as the legume in the rotation.

The pasture phases in the crop/pasture systems were based on an annual legume pasture called Medic (Medicago spp). The pasture phases of systems F and H included clover (Trifolium spp) along with the medic and alternated with wheat. System H also included Old Man saltbush (Atriplex nummularia) as part of the grazing. System E is the base crop/pasture system (MWMW), while system G alternates the medic pasture with wheat and canola (MWMC).

The crop/pasture systems included sheep grazing the pasture in winter and the residues in summer. In system H, the sheep grazed the saltbush at the start of the season to enable the medic/clover in that system to establish before the grazing animals returned adequately.

The trial setup is such that all crops of each system tested were represented in the field every year. Annual yields and all direct input costs were recorded. All the data was then fed into a financial program to determine the gross margins of each crop and system.

It was decided to divide the annual production season rainfall into three scenarios: low, average, and high. The bottom 25% formed the poor rainfall category, and the top 25% formed the high category. The division was done following consultation with farmers regarding the spread of low, high, and close-to-average rainfall over 20 years. The average rainfall of the low category was 215 mm per, 324mm for the standard and 445 mm for the high rainfall category.

Average wheat yield and gross margin per system were determined and then analysed to determine which system performed best in the three rainfall categories and if specific systems are more stable than others independent of rainfall. Data was analysed using SAS software (Version 9.4; SAS Institute Inc, Cary, USA). Fisher's least significant difference (LSD) was calculated at the 5% level to compare treatment means.

RESULTS AND DISCUSSION

The average wheat yield in the three categories was 2041 kg ha-1 in the low group, 3672 kg ha-1 for the standard group, and 3869 kg ha-1 for the high group. The average gross margins per hectare for the three were R2375, R5211, and R3636. The highest rainfall years occurred before 2011, while the three lowest rainfall years occurred after 2014.

Our findings indicate that systems incorporating pastures demonstrated greater stability across all rainfall categories. This held for both wheat yield and gross margins. There was a discrepancy between the yield and gross margins between the average and high rainfall categories. One would expect that the slightly higher output in yield in the high rainfall category would also improve the gross margins, but that was not the case.

All the wettest years occurred in the first half of the 20 years when input costs were still higher than later in the timeline, which could be the reason for the discrepancy. The commodity prices also improved over the 20 years. Cash crop systems were only competitive in wheat yield in the high rainfall category. Poor canola and legume yield in some years negatively impacted the gross margins of the cash crop-only systems.

Our findings reveal a promising trend. The gross margins of the crop/pasture systems, which incorporated pastures and an animal factor, were generally more stable than those of the cash crop systems. This stability, a testament to the resilience of these systems, was primarily attributed to the additional income from the animal factor, which acted as a buffer against fluctuating crop yields. The lower input costs across these systems further reduced the financial risk, offering a beacon of hope for the future of rain-fed farming in the Swartland production area.

CONCLUSIONS

Our study's key conclusion is clear: rain-fed system yield and gross margins will always face pressure due to varying climatic conditions. However, introducing an animal factor and legume pastures as integral parts of the cropping system under conservation agriculture practices can significantly enhance the system's stability and resilience. This finding is particularly relevant in the Swartland production area, where the unpredictable climatic conditions of dryland farming in the Western Cape pose significant challenges.

KEYWORDS

conservation agriculture, cropping systems, gross margins, rainfall, yield

NUTRIENT MANAGEMENT FOR GRAIN AND OILSEED CROPS IN THE SUMMER RAINFALL REGION OF SOUTH AFRICA

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INTRODUCTION

Inorganic fertilizers use continuously increased global crop yields and allowed farmers to grow crops in nutrient-poor soils. Nitrogen (N), a critical component of chlorophyll and amino acids, is generally the most limiting nutrient for successful crop production. Additionally, phosphorus (P) and potassium (K) also play essential roles in plants' biochemical and metabolic processes. Applying inorganic NPK fertilizers containing one or more nutrients enables farmers to avoid nutrient deficiencies and secure profitable crop yields.

However, increasing fertiliser costs may reduce the profitability of fertilisation, and more efficient use of fertilisers in crop production systems is underscored. Excessive application of fertilisers is common and leads to adverse ecosystem impacts, including soil biodiversity losses, water bodies' eutrophication, and groundwater contamination. Fertilisers directly or indirectly plays a large part in the emission of harmful greenhouse gasses. Alternative agronomic management approaches such as conservation agriculture (CA) and agroecological practices have been proposed to reduce the reliance of crop production systems on inorganic fertiliser use. Crop and soil responses to CA are highly variable, meaning optimal nutrient management varies between cropping system types, soil types, and production regions.

Distinct climatic and soil conditions are found across the summer rainfall region of South Africa. The primary rainfed production systems mainly consist of monoculture maize or maize-sunflower/soybean rotations. Under pivot irrigation, maize generally forms part of an intensive double-crop system in rotation with wheat planted during winter. More recently, due to favourable soybean prices and lower input costs, maize is progressively replaced by soybean, a crop that utilises residual soil P and K. Semi-arid conditions with deep sandy soil types are found in the central to western regions (400 to 550 mm annual rainfall), with a more subtropical to humid climate (600 to 900 mm annually) in the eastern regions of South Africa, combined with more sandy textured and shallower soils. Resource-limited soils are mainly found across the central to western regions, with K as the only abundant soil nutrient. Under intensive irrigated conditions, available soil K may be limited. Consistent crop yields are hampered by irregular rainfall patterns and prolonged drought periods in the western to central regions. Despite the more advantageous rainfall conditions, crop yields are limited by low soil fertility, poor nutrient availability and high soil acidity in the eastern regions.

This systematic review serves as a basis for proposing future nutrient management strategies by first recognising the current knowledge gaps. The aim of this review is, therefore, to establish the current state of NPK fertiliser research for maize, sunflower, and soybean under rainfed and irrigated conditions in South Africa. The effect of fertiliser NPK on crop yield was critically evaluated. Opportunities to advance overall nutrient use efficiencies under various management strategies are proposed.

MATERIALS AND METHODS

Using a well-defined systematic approach, peer-reviewed literature that reported on the sole or combination effects of NPK fertiliser on maize, soybean, and sunflower yield in South Africa was collated. The papers were collated using keyword combinations such as 'maize yield', 'sunflower yield', 'soybean yield', 'nitrogen fertilizer', 'phosphorus', 'potassium', 'nutrient', and the Afrikaans counterpart. Google Scholar and the Institute for Scientific Information Web of Science Database were used for the literature search. The "Web of Science Core Collection" option was used. Published papers were assessed in full text and included based on a pre-defined set of criteria: (i) the effect of inorganic N, P, or K fertiliser on crop yield was evaluated as a treatment; (ii) experimentation included at least two rates of an inorganic fertiliser nutrient; and (iii) statistically sound field trials generated the data with at least three replicates.

Pot trials and greenhouse studies were excluded. Spatial and agronomic trial management information, such as soil textural class, NPK fertiliser sources, total NPK application rates and timing, soil tillage system, and crop yields, was extracted. The effects of sulphur and micro-elements on crop yield were excluded due to a lack of available information. Field trials conducted under rainfed and irrigated conditions were considered with no timeframe limitations. The last online search was conducted on 2 November 2023.

RESULTS AND DISCUSSION

Sixteen papers were published between 1987 and 2022, representing 20 individual field trials. Seven field trials were performed in the drier western region, four in the eastern region, and three in the far-east KwaZulu-Natal province. Five trials (soybean and maize) were conducted outside the traditional summer crop production region and were located in the Eastern Cape, Limpopo, and Mpumalanga Lowveld regions. An average field trial duration of two years was observed for 90% of the trials, with only two field trials conducted over five years.

The majority (n=14) of the field trials were performed using maize as a crop, followed by sunflower (n=4) and soybean (n=2). Maize is the most extensively grown crop in South Africa, which is why it has dominated the research agenda over the past few decades. Approximately 70% of all fertiliser field trials performed across maize, sunflower, and soybean crops were conducted under rainfed conditions, indicating an apparent lack of nutrient management field trials under irrigated conditions. Irrigated maize production systems are yield-driven, leading to excessive inorganic fertiliser use to avoid yield penalties or nutrient mining. However, the profitability of such an approach is still questionable.

In this study, rainfed maize yield increased ($P<0.05$) as N-rates increased between 0 to 100 kg N ha-1 and ranged between 2 500 and 12 200 kg ha-1. When more than 100 kg N ha-1 were applied, maize yield was generally highly variable, ranging between 6 500 and 13 000 kg ha-1. This highlights the importance of managing N use efficiency according to site-specific soil, climate, and farming system conditions. Considerable efforts were made between 1980 and 2000 to investigate inorganic N fertiliser effects on maize yield and soil chemical parameters in South Africa. However, since 2011, maize fertiliser research has largely become reactive without proper goal setting.

This led to stagnant nutrient management strategies in the maize-dominated cropping systems, intensifying soil chemical challenges such as subsoil acidification. Despite the introduction of no-tillage across the eastern regions several decades ago, scientific and readily available data on yield responses to fertiliser management strategies, with or without including additional crop-soil practices such as cover crops and using various NPK sources, remain absent. Modern genetic breeding strategies have improved traits such as abiotic and biotic stress resistance and tolerance. Still, the lack of enhanced soil-crop management practices may have limited the effectiveness of these newly introduced genetic traits.

Peer-reviewed journals reporting the NPK fertiliser effects on soybean and sunflower yields have been largely scarce over the past few decades. Only two fertiliser trials were performed for soybeans where the impact of P application rates was investigated in the northeastern production regions under irrigated and rainfed conditions, with variable yield responses due to seasonal climatic effects. For sunflowers, three papers reported on NPK fertiliser effects on yield under rainfed (n=2) and irrigated (n=1) conditions.

Under rainfed conditions, the response of sunflower yield to increasing N-fertiliser rates was highly affected by seasonal rainfall amounts and timing. During seasons with adequate rainfall, greater sunflower yields ($P<0.05$) were found when N-fertiliser application rates increased from 0 to 60 kg ha-1. Sunflower yield responses to variable P and K fertiliser rates were generally insignificant when high soil P and K levels were present. These are highly site-specific observations and should be further investigated over the long term.

The conversion of cropping systems under rigorous soil tillage to reduced tillage systems such as minimum- and no-tillage has been a recent development across the summer rainfall region of South Africa, explaining why 77% of all fertiliser field trials were performed under intensive soil tillage practices across all three crops, with only 17 and 6% under no-tillage and CA, respectively.

These newly introduced agronomic management approaches present novel challenges and benefits linked to nutrient cycling, availability and distribution in the soil profile, improved soil microbial activity, soil carbon sequestration, and soil acidification. Future fertiliser research should investigate crop yield and soil chemical and biological dynamics under complete CA systems. Despite global acknowledgement over past decades, agroecological concepts have yet to be integrated into local nutrient management strategies.

CONCLUSION

The systematic review underscores the lack of scientific data detailing the impact of NPK fertilisers on grain and oilseed yields in South Africa. There is an urgent need to establish new and adaptable nutrient management strategies for the grain and oilseed crop production systems in the summer rainfall region of South Africa. Future scientific NPK fertiliser research should consider agroecological concepts closely aligned with the CA framework, such as soil nutrient recycling, carbon sequestration, and diversity.

KEYWORDS

Climate-Smart farming, environmental impact, fertiliser, nutrient cycling, soil carbon

THE ROLE OF CONSERVATION AGRICULTURE IN ENHANCING BIODIVERSITY IN AGRO-ECOSYSTEMS

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INTRODUCTION

Global agriculture needs to address several challenges to ensure its future. Not only does it need to provide food for a growing population while ensuring food security, but it also needs to ensure the economic viability of farmers while protecting agricultural ecosystems.

Over the last century, pressures on agricultural ecosystems have increased, threatening their continuity and the services they provide. According to the European Environment Agency (EEA, 2019), it is estimated that around 81% of agricultural habitats in the European Union are in poor condition, mainly due to agricultural intensification, landscape fragmentation and soil depletion.

Due to these pressures, approximately one-third of the world's soils are estimated to be degraded (FAO, 2015), and agricultural land accounts for approximately 18% of the global total of degraded land (Bai et al., 2013). This situation fails agricultural soils to perform their functions properly, and thus, a reduction in the biodiversity of agricultural ecosystems in quantity and diversity. Although the situation of agricultural ecosystems varies between regions, countries and soil and climatic conditions, the trends and challenges are common in the face of critical habitat loss and biodiversity loss (Bourlion and Ferrer, 2018).

However, international efforts are underway to halt and reverse these alarming rates of degradation globally and combat desertification (UNCCD, 2017). Various global policies, including the UN Sustainable Development Goals (SDGs), directly and indirectly, include land and soil and their linkages to biodiversity conservation. Improving soil health and functions is, therefore, necessary to improve habitats.

According to the Assessment Report on Land Degradation and Restoration published by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2018), Conserving land and soil resources is more profitable than restoring them. Therefore, to conserve and regenerate these resources, sustainable soil management is necessary to maintain biodiversity in agricultural ecosystems and to preserve habitats and species. Farming based on Conservation Agriculture (CA) principles: minimal mechanical soil disturbance, permanent cover and species diversification can increase food supply and provide a valuable tool for climate regulation and safeguarding ecosystem services (FAO, 2015).

MATERIAL AND METHODS

To evaluate the impact of the adoption of practices based on the principles of CA on the biodiversity of agricultural ecosystems (edaphic fauna, epigean fauna and pollinators), a bibliographic analysis was carried out following the PRISMA2020 methodology (Page et al., 2020) to refine the most relevant articles according to the topic to be addressed. To analyse the effect, more than 200 articles and publications were found to be appropriate for the study on the impact of adopting CA practices and the conservation and enhancement of biodiversity in agroecosystems.

RESULTS AND DISCUSSION

- Impact on the edaphic fauna

Edaphic fauna are the living organisms that inhabit the soil profile. They play a fundamental role in agricultural ecosystems, favouring nutrient cycling, maintaining soil health, and improving soil fertility. The soil fauna includes a wide range of organisms, from microorganisms such as bacteria, fungi, and protozoa to small animals, mainly mites, nematodes, springtails, and earthworms.

Soil management based on CA principles favours the activity of soil fauna and, thus, the proliferation of beneficial organisms. Several studies show how introducing CA practices maintains and increases the number of beneficial soil mites (Figure 1). By leaving the soil undisturbed and maintaining plant residues from the previous crop or cover crops in the case of perennial crops, the number of individuals can be increased by up to 85%, depending on soil and climatic conditions.

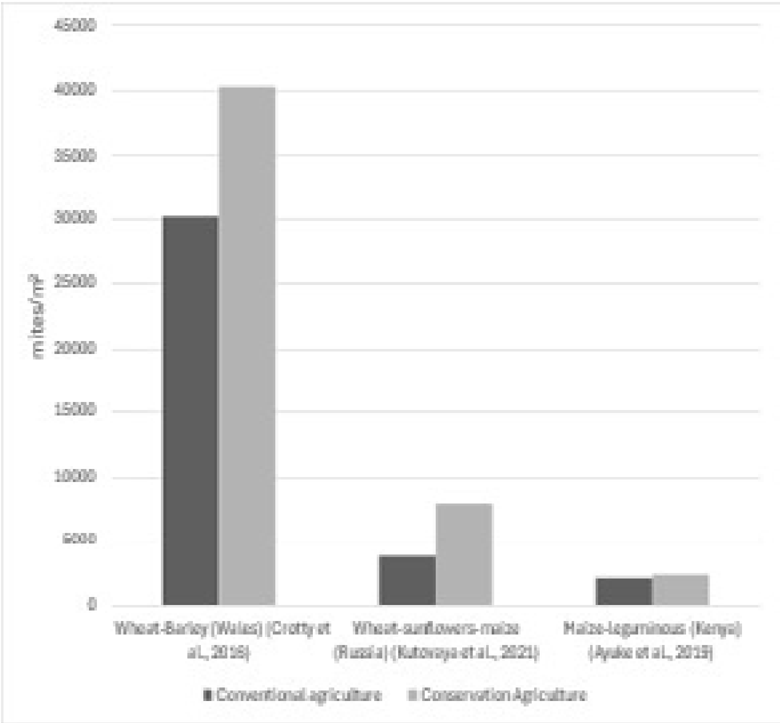
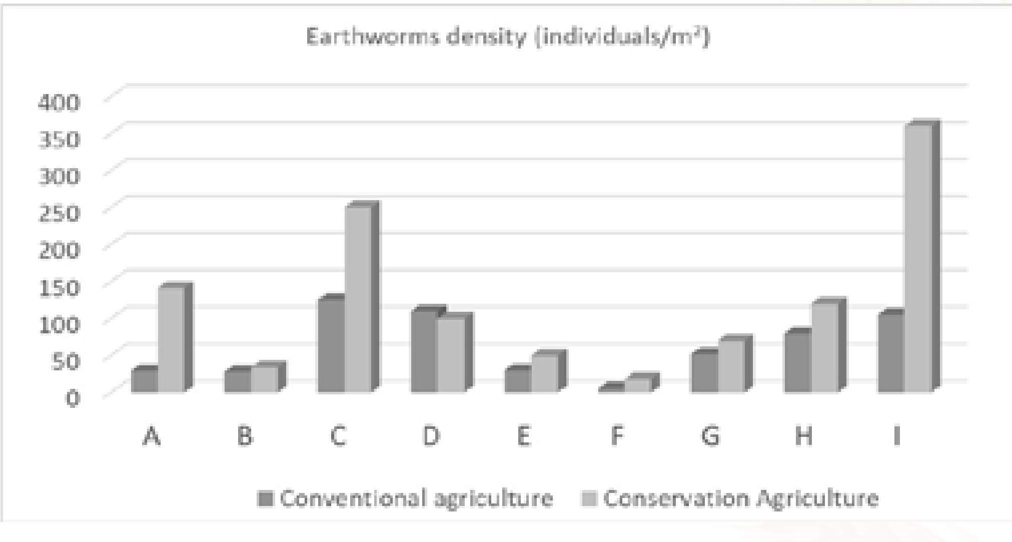


Figure 1. Comparison of the number of mites found in CA and conventional agriculture rotation in different locations. Source: Own elaboration Adapted from Crotty et al., 2016; Kutovaya et al., 2021; Ayuke et al., 2019.

There is also evidence that other organisms, such as bacteriophage nematodes, have increased by more than 70%. This increase in organisms contributes to the proliferation of soil biodiversity and sustainable pest and disease management.

One of the most widely accepted indicators for assessing the status of soil biodiversity is the number of earthworms present. In this case, it has been shown that CA management can increase the earthworm populations (Figure 2) by up to 300%, thereby improving soil properties and health.



	REFERENCE	ROTATION	LOCATION
A	Dulaurent et al., 2023	Wheat, barley, rapeseed and peas	France
B	Mcinga et al., 2020	Corn, wheat and soybeans	South Africa
C	Pelosi et al., 2014	Corn, wheat and rapeseed	France
D	Pelosi et al., 2014	Wheat, barley, rapeseed and peas	France
E	Pelosi et al., 2014	Alfalfa, corn, wheat and soybeans	France
F	Muoni et al., 2019	Cotton, Corn	Zambia
G	Torppa & Taylor, 2022	Wheat, barley	Sweeden
H	Torppa & Taylor, 2022	Wheat, barley, rapeseed and peas	Sweeden
I	Henneron et al., 2015	Wheat, peas	France

Figure 2. Impact of CA on earthworm abundance in different rotations of annual crops. Source: Own elaboration

- Impact on the epigean fauna

Soil biodiversity is not limited to the living organisms that inhabit the soil profile. A wide range of organisms have a main habitat on the soil surface.

According to the literature reviewed, different groups of organisms on the soil surface are richer in terms of abundance and diversity in CA than in conventional agriculture. There is, therefore, a benefit in the biodiversity of the agricultural environment, which ultimately impacts the crops themselves through the ecosystem services provided by this fauna, as they are key parts of the food chains and play a crucial role in controlling and regulating natural processes. Firstly, they break down crop residues, facilitating the recycling of dead matter and converting it into nutrients that can be used by the rest of the biota and the crop itself. Secondly, they are important predators, slowing down the appearance of pests and providing an important and free biocontrol service.

In this sense, CA contributes to an increase of up to 300% in the number of ants, 16% in the number of arthropods and more than 300% in the number of spiders.

This summary has paid particular attention to beetles, as they are usually predators, thus helping to control the populations of other soil animals that could be a pest to the crop. They also have a pollination function. In this sense, CA has a very positive effect on the abundance of ground beetles (Figure 3), with increases of up to 150%.

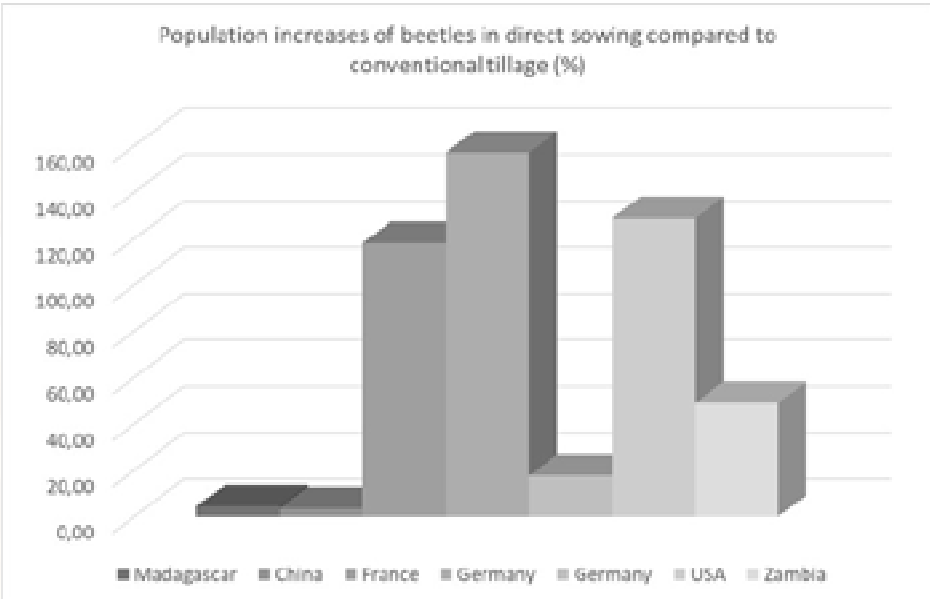


Figure 3. Increases in different comparative studies in the abundance of beetles in CA compared to conventional tillage. Source: Own elaboration Adapted from Massaccesi et al., 2020; Henneron et al. (2015); Puliga et al. (2021); Hakeem et al. (2021); Rakotomanga et al., 2016; Xin et al., 2018, Redlich et al., 2021; Muoni et al., 2019.

- Impact on pollinators insects

Another critical aspect of improving biodiversity is the conservation of pollinating insects. Approximately 87% of the world's major food crops depend on pollinators. One of the most important groups of pollinating insects is wild bees. 75% of wild bee species nest in the soil and spend a large part of their life cycle there. In this sense, adopting practices based on the three principles of CA provides critical benefits for the conservation and enhancement of pollinator species in agricultural landscapes due to the non-alteration of the soil.

Soil-nesting female bees and wasps dig tunnels leading to brood cells, in which they lay eggs on a food reserve. Therefore, agronomic practices that alter the continuity of topsoil layers and disrupt soil structure create unfavourable conditions for the nesting of these pollinating species (Holzschuh et al., 2007).

In particular, intensive tillage, the complete removal of vegetation cover, and the disappearance of spontaneous vegetation pose serious problems in the nesting of these pollinators (Scheper, 2015). Therefore, soil disturbance caused by conventional agriculture eliminates nest continuity, reducing larval emergence by up to 50% (Ullmann et al., 2016).

On the other hand, tillage reduces landscape continuity and the availability of floral resources, thereby reducing pollinator visits to agricultural ecosystems and resulting in significant economic losses. Several articles show that this reduction in floral resources and the increased distance for pollinators to obtain food due to landscape fragmentation significantly reduces pollinator visits by up to 50-60%.

Therefore, integrated management of agricultural landscapes for the conservation and enhancement of pollinator species should consider different strategies that contribute to landscape continuity to promote pollinator dynamics. In agricultural areas where plant resources that provide shelter for pollinators are threatened by intensification of tillage, the introduction of large areas without soil cover and monoculture and the introduction of practices based on CA are key to providing these essential resources without jeopardising crop profitability.

CONCLUSIONS

CA provides proven benefits for biodiversity and the sustainability of agroecosystems, offering a viable solution to the challenges of global agriculture. The literature shows that the introduction of a system based on CA principles improves the density and richness of soil organisms and insect pollinator populations in agricultural ecosystems due to CA:

- favours the activity of soil fauna,
- improves soil properties and soil health,
- contributes to pest control and residue decomposition,
- conserves and enhances pollinator habitats,
- Favours landscape continuity.

To achieve real sustainability in worldwide agriculture, the transition to land management based on the application of CA principles, providing farmers with the necessary tools, must be a priority for global agricultural policies.

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KEYWORDS

Ecosystem-services, no-tillage, groundcover, soil-fauna, pollinators

LABLAB PURPUREUS (L.) SWEET INTERCROPPING PROVIDES PRODUCTION, SUSTAINABILITY, AND ENVIRONMENTAL BENEFITS FOR FARMERS IN NORTHERN TANZANIA

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INTRODUCTION

Lablab purpureus (L.) Sweet, a crop native to Africa but nearly lost to African farmers during the colonial era (Maass et al., 2010), has enjoyed a resurgence in production over the past 20 years in northern Tanzania. Limited research screening lablab cultivars as national and international institutions have conducted a food or forage crop (Ewansiha, et al., 2007, Whitbread, et al., 2011, Gachuiri et al., 2021).

However, relatively few studies have examined lablab performance intercropped with maize (Zea mays L.), despite intercropping being the most common production system in throughout the continent (Forsythe, 2019). A significant challenge for lablab producers throughout the tropics is insect predation, especially at flowering and podding stages (Khan et al., 2020). Our objective was to evaluate Lablab's agronomic performance and ecosystem services under sole and intercropped conditions. We hypothesized that intercropping would result in greater productivity, improved soil cover, and less pest damage than sole cropping.

MATERIALS AND METHODS

We studied 40 unique lablab accessions, including 12 accessions from a core collection identified by Pengelly and Maass (2001), registered varieties from Kenya, and landraces collected from Tanzania, Kenya, Uganda and Ethiopia. Replicated trials were conducted from 2016 through 2019 on research stations in northern Tanzania's lowland, midland and highland agroecological zones for nine site-years.

Plots were managed using conservation agriculture principles with both sole-cropped lablab and lablab intercropped with maize. Both crops were seeded at 44,444 seeds/ha in both cropping systems, and intercropped lablab was planted 1-2 weeks after maize. Two registered cowpea varieties were included as reference species in all experiments.

Grain yields were measured from the centre of each plot, with maize harvest beginning after partial dry-down followed by further drying and threshing. Lablab and cowpea harvest started as soon as dried pods were present on the earliest-maturing plots and was repeated on a roughly monthly schedule with three to five harvest dates depending on the location and year.

To assess productivity and ecosystem services, biomass and nitrogen content were measured on a representative subset of 14 high-potential lablab accessions and one cowpea accession in two years, as reported by Nord et al. (2020).

Early-season soil cover of living lablab was measured in five site years using two 4 m transects in each plot, while late-season soil cover was estimated several months into the dry season at four site years using digital photographs taken from a 3 m height above each plot and a standardized rating scale.

Insect predation was measured using a bucket-tap method described by Miller et al. (2018) and Forsythe (2019). Land equivalent ratios (LER) were assessed from the five available site years of data recommended by Oyejola et al. (1982).

RESULTS AND DISCUSSION

Intercropping reduced lablab grain yield to an average of 63% of sole cropped lablab yield. Maize yields, in contrast, were not measurably affected by intercropping. The combined productivity of the two crops increased significantly under intercropping, as reflected by land equivalent ratios (LERs), which ranged from 1.41 to 1.93 across the site years. These values fall within the typical range of other maize-legume intercropping studies (Seran and Brintha, 2010). Lablab biomass was reduced to 57% of sole-cropped lablab yield. Biomass yields remained more stable than grain yields over the varied environments of all site years, and LERs ranged from 1.59 to 2.56 (Nord et al., 2020).

Late-season soil cover was not significantly affected by intercropping (P=0.1), but there was a significant interaction between the intercropping main effect and site years. In the lower rainfall of 2016, intercropping either reduced lablab late-season soil cover (TARI) or made no notable difference (TPRI). In 2017, with adequate rainfall, intercropping appeared to increase lablab late-season soil cover, suggesting that plants took advantage of residual moisture to recover from maize competition with later-season growth. Lablab foliage covered plots with an average of 21% live plant cover even after up to five months with no rainfall.

Intercropping with maize reduced sucking bug populations (Riptortus pedestris, Clavigralla tomentosicollis) to 44% of sole-cropped lablab at TARI in 2016 (P<0.001), and 47% at NMAIST in 2018 (P<0.001). Flower/pod boring larvae (Maruca vitrata, Helicoverpa armigera, Etiella zinckenella) were reduced to 70% of sole-cropped lablab at NMAIST in 2018 (P=0.013) but were unaffected at TARI in 2016. Aphid colonization (Aphis craccivora) was reduced to 39% of sole-cropped lablab at TARI in 2017 (P<0.001) but was not measurably affected at NMAIST in 2018. The accessions most susceptible to aphid attack in earlier trials were not included at the latter site, thus making any potential effect of intercropping more challenging to measure.

CONCLUSION

Lablab-maize intercropping has the potential to significantly increase the productivity and sustainability of maize-producing small-scale farmers in northern Tanzania. Total grain and biomass productivity were consistently and significantly higher under intercropping. Such productivity increases can contribute to greater food security and enhance soil health in cropping systems where biomass is returned to the soil at season's end. While intercropping suppressed the early biomass of lablab, intercropped plants were able to recover and protect soils with live foliage even after months of no rainfall.

By reducing insect competition, maize-lablab intercropping can also reduce the need for synthetic pesticides which threaten profitability and human and environmental health. This study also found evidence of cultivar differences in insect susceptibility, which, when combined with intercropping, lay the foundation for an effective and environmentally friendly integrated pest management system. Maize farmers in northern Tanzania and throughout sub-Saharan Africa practice legume intercropping for good reasons despite extension messages, which have sometimes denigrated the practice as backward. This study adds to a growing body of evidence showing that intercropping should be embraced for its production benefits and environmental services.

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KEYWORDS

Lablab purpureus, cover crops, drought resilience, intercropping, insect management

SOIL MOISTURE DYNAMICS IN MAIZE-LEGUME INTERCROPPING SYSTEMS IN SEMI-ARID REGION

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INTRODUCTION

More than 70% of the smallholder farmers in Zimbabwe rely on rainfed crop production for food security (Camberlin et al., 2009), as agriculture constitutes the primary source of livelihood and income (Mujeyi et al., 2021). However, cropping and grazing lands are dwindling due to population increase, prompting some smallholder farmers to adopt cereal-legume intercropping systems. The integration of food crops and forage legumes into cropping systems has the potential to enhance household food security (Mkuhlani et al., 2020, Nyamayevu et al., 2024 (Ates et al., 2018; Mkuhlani et al., 2020), increase feed quantity (Mutsamba et al., 2019, 2020) and improve feed quality. Intercropping cereals and forage legumes can boost yields of associated crops by suppressing weeds and reducing pest and disease infestations (Mhlanga et al., 2015).

Additionally, forage legumes also ameliorate soil fertility through nitrogen fixation and enhance water productivity with their deep-reaching taproots (Dabney et al., 2001; Dahmardeh et al., 2009; Chimonyo et al., 2016). Forage legumes also provide live mulch, which reduces raindrop impact, soil erosion and runoff (Rao et al., 2015; Schultze-Kraft et al., 2018 Franke et al., 2018). However, another school of thought suggests that intercropping may reduce yields of component crops due to competition for resources such as light, nutrients, and water (Correia et al., 2014). For example, intercropping systems might increase competition for soil moisture with the cereal in semi-arid regions where rainfall is erratic. Given these conflicting perspectives, this study aims to assess the soil water dynamics when forage legumes are intercropped with maize in semi-arid regions. The study hypothesizes that intercropping systems extract more soil moisture in semi-arid regions, leading to reduced productivity.

MATERIALS AND METHODS

Site description

The study was conducted in the semi-arid region of Mutoko District, Mashonaland East Province, Zimbabwe, during the 2021/22 and 2022/23 growing seasons. Trials were established at five experimental sites: Farm 1 (17.3233°S, 32.3822°E), Farm 2 (17.3281°S, 32.3808°E), Farm 3 (17.1944°S, 32.3142°E), Farm 4 (17.2136°S, 32.3519°E), and Farm 5 (17.1540°S, 32.2080°E). The study area falls within Natural Region IV (NR IV), which is typically recommended for extensive livestock production. NR IV receives annual rainfall from 450 to 650 mm, with temperatures varying between 14°C and 31°C (Mugandani and Wuta, 2012). The growing wet season is rain-fed, lasting from November to March.

The dominant soil types in Mutoko are fersiallitic coarse-textured sandy soils derived from granite, which generally have low fertility (Table 1). These soils are classified as 5G.2 according to the Zimbabwean Series and Ferralic Arenosol according to the FAO classification. Due to their low clay content, they are characterized by low available water capacities (Nyamapfene, 1991).

Experimental design

The experiment tested a drought-tolerant maize variety (SC419), mucuna, and cowpea. The treatments were maize/mucuna intercrop, maize/cowpea intercrop, sole maize, sole cowpea, and sole mucuna. These treatments were established on five farms; each considered a replicate. A Randomized Complete Block Design (RCBD) was employed, with the five treatments randomly allocated on each farm to account for variability among the farms. Maize and mucuna were planted at a population density of 37 037 plants/ha for sole and intercrops. Cowpea was planted at a density of 74 074 plants/ha in the sole cropping system and at 37 037 plants/ha in the intercrop system.

Data collection and analysis

Daily rainfall was recorded using rain gauges installed at each farmer's field. Polyvinyl chloride (PVC) access tubes were inserted into the soil down to a depth of 180 cm, depending on the soil profile of each plot. A Tripe probe measured soil moisture content at 10-cm intervals throughout the profile. The productivity of intercropping was

Table 1. Characteristics of the experimental sites before implementing trials

Site name	% Carbon	Colour	Texture	pH (CaCl2)	Initial N-ppm	P-ppm	K-meg/100g	Ca-meg/100g	Mg-meq/100g
Farm 1	0.91	PB	Mgs	5.2	40	48	0.19	1.35	0.55
Farm 2	1.47	PB	Mgs	4.9	19	27	0.11	1.35	0.43
Farm 3	1.22	PB	Mgs	5.0	26	17	0.08	1.31	0.58
Farm 4	0.88	PB	Mgs	4.9	39	13	0.15	1.04	0.61
Farm 5	1.09	PB	Mgs	4.3	16	17	0.08	0.79	0.28

**Where PB = Pale brown, Mgs = medium-grained sands*

evaluated using the Land Equivalent Ratio (LER), following the method outlined by Dariush et al. (2006). Rainwater Use Efficiency (RWUE) was used to assess how efficiently the rainfall is converted into crop yield. RWUE was calculated as the ratio of total grain yield (GY) or total biomass yield (BY) relative to the amount of rainfall (RF) received from planting to harvest (Madamombe, 2024). The formula for RWUE is: RWUE = (GY or BY/ RF) * 100. Data was statically analysed using R software. Statistical significance was determined at $P \leq 0.05$.

RESULTS AND DISCUSSION

During the 2021/22 and 2022/23 cropping seasons, the experimental sites received an average cumulative rainfall of 436 mm and 708 mm, respectively. Subsequently, the significant interaction between season and treatments significantly influenced soil moisture content and crop yields. In the 2021/22 season, the mucuna sole and maize sole treatments had the highest mean total profile moisture content of 74.4 mm and 73.3 mm, respectively. These values were significantly higher than the moisture content in maize/mucuna (59.6 mm), maize/cowpea (63.1 mm), and cowpea sole (64.7 mm) treatments. This suggests that there was competition for soil moisture in intercrops. The differing rooting depths of the crops within the same plots (Kwenda et al., unpublished) likely affected the water uptake and led to competition for moisture. These findings align with previous studies, such as Eskandari and Kazemi, 2011, which showed that intercrops tend to have lower soil moisture content than sole crops due to competition and higher moisture extraction by the two companion crops. Despite the higher plant densities and greater ground cover in intercrops and sole cowpeas treatments reducing soil evaporation, the dense foliage may have increased evapotranspiration, as noted by Correia et al. (2014), leading to reduced soil moisture status.

In contrast, during the 2022/23 season, the mucuna sole (91.7 mm) and maize sole (93.8 mm) treatments had the lowest mean total profile moisture content compared to cowpea sole (104 mm), maize/cowpea intercrop (97.7 mm), and maize/mucuna intercrop (106 mm). Even with higher plant populations, the intercrop and sole cowpea treatments retained more soil moisture than sole maize and mucuna. This result aligns with Mbaga and Friesen (2003), who found that maize-legume intercropping systems conserve soil moisture better in wetter seasons by providing shade, reducing wind speed, and improving infiltration.

These results demonstrate that, in sandy soils, intercrops cause more moisture stress during dry seasons (such as 2021/22), whereas the benefits of moisture retention through intercropping become more pronounced in wetter seasons. Visually, during the first dry season, maize in intercrops was more prone to wilting than legumes (Figure 1), which was reflected in lower maize grain and biomass yields in intercrops compared to sole maize. This was also supported by the LER for both intercropping systems, which was less than one based on grain yield, indicating that the intercropping systems were less efficient than monocropping.

Figure 1. Response of maize and legume to moisture stress during the 2021/22 season

However, the LER exceeded 1 based on the total biomass harvested, showing that intercropping was more efficient in terms of overall biomass production (Figure 2). During the 2022/23 season, the LER for both intercropping systems was greater than one based on grain yield and total biomass, suggesting that intercropping was more efficient than monocropping in a wetter season.

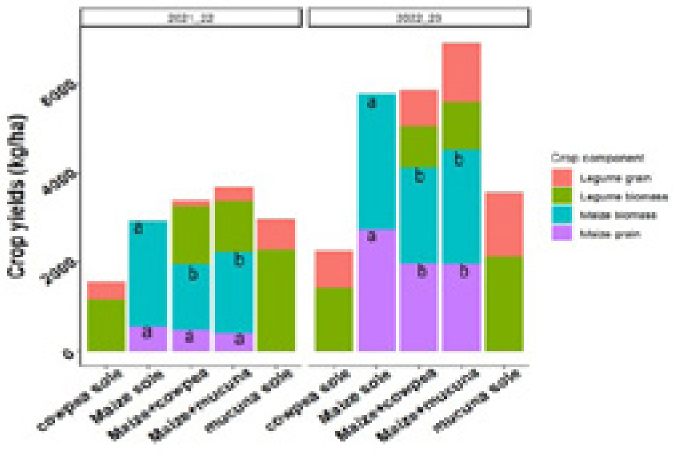

Figure 2. System productivity in Mutoko during the 2021-22 and 2022-23 agricultural season

In the first season, rainwater use efficiency (RWUE) based on total biomass output increased in the order of sole maize, maize/cowpea intercrop, and maize/mucuna intercrop (Figure 3). However, during the 2022/23 season, the maize/ mucuna intercrop had the lowest RWUE (8.8), which was significantly lower than sole maize (10.3) and maize/cowpea intercrop (10.4 kg/ha/mm). These results are consistent with the findings of Madamombe (2024), which showed that RWUE is lower in dry seasons compared to wet seasons.

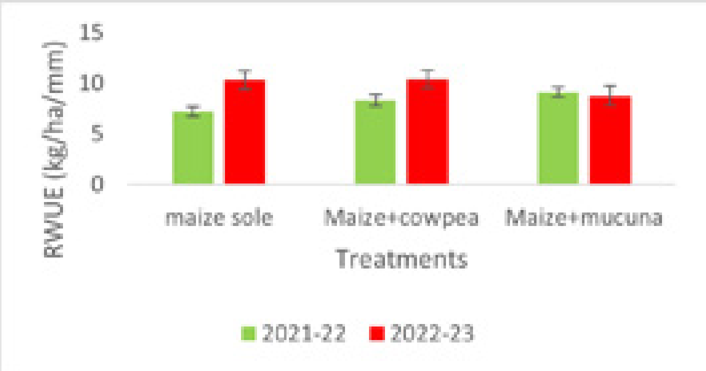

Figure 3. Rainwater use efficiency (RWUE) per hectare of maize in different cropping systems during the 2021-22 and 2022-23 seasons. Error bars denote standard error.

In mixed crop-livestock systems, the higher total biomass output from cereal-legume intercrops can increase the availability of nutritious livestock feed (Chakoma et al., 2016) and subsequently enhance milk production (Gwiriri et al., 2016).

CONCLUSION

The benefits of intercropping for soil moisture conservation depend on the wetness of the season, particularly in sandy soils. In wetter seasons, intercropping systems were more efficient in terms of both grain and biomass production, while in drier seasons, moisture stress was more evident. Additionally, higher biomass output from intercrops may improve livestock feed availability in mixed crop-livestock systems, contributing to enhanced farm productivity.

RECOMMENDATIONS

1. Farmers should consider adopting intercropping systems in wetter regions or seasons to enhance soil moisture retention and increase biomass output.
2. In drier areas, additional water conservation methods such as tied ridges, infiltration pits, and mulching should be integrated into cropping systems to mitigate moisture stress.

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ROLE OF FARMER COOPERATIVES IN REFINING AND SCALING OF SMART AGRICULTURE TECHNOLOGIES IN HARYANA, INDIA

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INTRODUCTION

Farmers of Haryana and Punjab have significantly contributed to India's Green Revolution and have primarily relied on the rice-wheat rotation for the past six decades. However, this system has led to various environmental and agricultural challenges, including groundwater depletion, soil health deterioration, energy crises, and frequent climatic hazards. Traditional farming practices such as intensive tillage, burning crop residue, imbalanced fertilizer use, and unscientific irrigation have exacerbated these issues, resulting in stagnant crop yields and reduced farm incomes.

A participatory research-extension system focusing on Conservation Agriculture (CA) and Climate Smart Agriculture (CSA) was started in 2010 under the CIMMYT's CSISA and CCAFS projects to address these challenges. Under the leadership of Dr ML Jat, CIMMYT, farmer cooperatives were established to create knowledge hubs and link the farmers with research and development institutions for timely technology advancements. These cooperatives aim to promote CA by collaborating with varied stakeholders to help farmers and to adapt technologies suited to their local bio-physical and socio-economic conditions.

DESCRIPTION OF CONSERVATION AGRICULTURE SYSTEM AND PRACTICES

Conservation Agriculture (CA) and Climate Smart Agriculture (CSA) are transformative approaches aimed at achieving sustainable intensification in the current crop production system (rice-wheat system). CA principles focus on minimal soil disturbance, permanent soil cover, and diversified crop rotations. These practices help in improving soil physical (bulk density, infiltration, organic matter, water retention), chemical (N, P, K and micro-nutrients) and biological (MBC, MBN) capabilities, thereby contributing to overall soil health. Key CA practices include zero or minimal tillage, direct seeding, crop residue management, and integrated pest and nutrient management.

1. Zero or Minimal Tillage: This practice involves minimal soil disturbance, which helps preserve soil structure, reduce erosion, and maintain soil moisture. Machinery like the Happy Seeder, which places the seeds without disturbing the soil, has been instrumental in reducing residue burning and improving soil health.
2. Crop Residue Management: Instead of burning crop residues, which contribute to air pollution and soil nutrient loss, residues are retained on the field. This helps moderate soil temperature and moisture and escapes the wheat from the 'Terminal heat' effect in India's western Indo-Gangetic plains (IGP). The organic matter embedded in crop residues enriches the soil microbial diversity/ activity.
3. Direct Seeding: Direct seeding eliminates the need for traditional ploughing, reducing labor and fuel costs while delimiting soil erosion. This method has shown significant benefits in increasing the crop window by early crop establishment and reducing water usage.
4. Integrated Pest and Nutrient Management: CA promotes balanced fertilizer use and biological pest control methods, reducing dependency on chemical inputs and fostering a more sustainable ecosystem.
5. Diversified Crop Rotations: Introducing a variety of crops in rotation improves soil biodiversity, breaks pest and disease cycles, and enhances nutrient cycling within the soil.

IMPACT OF FARMER COOPERATIVES

Farmer cooperatives in Haryana have emerged as key players in disseminating, evaluating and refining CA/CSA technologies. These cooperatives function as centres for participatory research and improve the adoption of technologies by following the concept of 'Seeing is believing' with respect to all production issues related to crop establishment, tillage, water, energy and nutrient management. Leveraging Information Communication Technologies (ICTs) with cooperatives facilitates timely access to critical information and resources, enabling farmers to make informed, fast decisions.

1. **Knowledge Exchange and Training:** Cooperatives provide platforms for farmers to share their experiences, learn from peers, and receive training on new technologies. This peer-to-peer learning model enhances the credibility and acceptance of new practices.
2. **Custom Hiring Centers:** By pooling resources, cooperatives offer machinery and equipment for hire, making advanced technologies accessible to small and marginal farmers who might not otherwise afford them. This reduces the cost of cultivation and increases operational efficiency.
3. **ICT Integration**: ICTs in cooperatives have revolutionized information dissemination. Farmers receive real-time updates on weather forecasts, market prices, and

best practices, which helps them adapt to changing conditions and make better decisions.

4. **Resource Sharing**: Cooperatives enable members to share seeds, fertilizers, and other inputs. This collective approach reduces costs and ensures the availability of high-quality resources.
5. **Environmental Benefits**: Adopting CA/CSA practices through cooperatives has led to significant environmental benefits. Reduced residue burning has improved air quality, while better soil management practices have enhanced soil health and biodiversity.

CA/CSA practices across Haryana. The model's success has inspired similar initiatives in other regions, demonstrating its potential for widespread adoption.

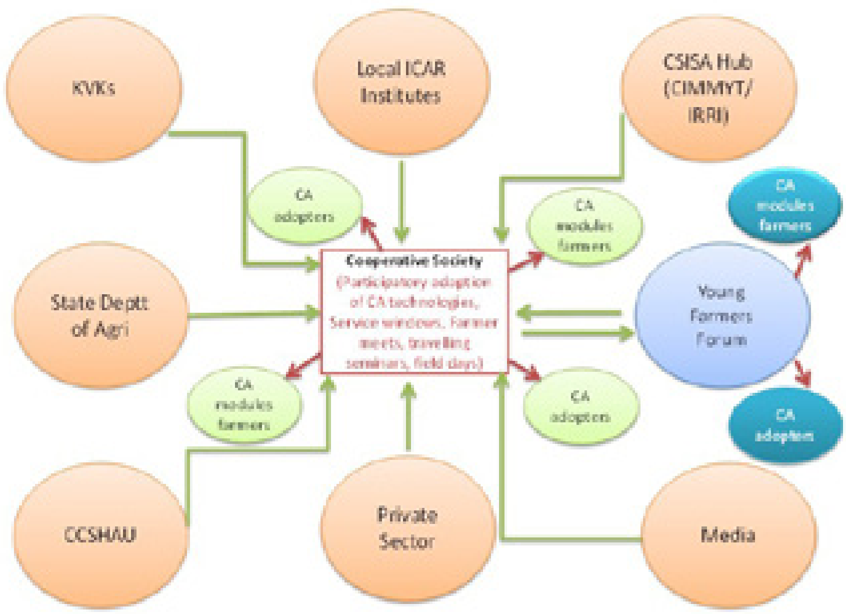

Figure 1. Innovative pathway of farmer-led cooperative society for CA-based technology adaptation and scaling-out

SUCCESS AND PROGRESS

The success of farmer cooperatives in Haryana can be attributed to their participatory approach and the integration of farmer knowledge into the research-extension continuum. Several success stories highlight the impact of these cooperatives on agricultural productivity, environmental sustainability, and farmer livelihoods.

1. Improved Soil Health and Productivity: Implementing CA practices has improved soil structure, higher organic matter content, and increased water retention. These improvements have led to higher crop yields and more resilient farming systems.
2. Economic Gains: Cooperatives have significantly increased farmers' profit margins by reducing input costs and improving productivity. The introduction of the Happy Seeder, for instance, has reduced the cost of rice residue management while boosting wheat yields and reducing weed (P. minor) problems.
3. Climate Resilience: CA/CSA practices have enhanced the resilience of farming systems to climatic variability. Improved crop establishment, residue management, soil health, and water management practices have mitigated the impacts of extreme weather events, such as moisture and heat stress.
4. Social Empowerment: Cooperatives have empowered farmers by involving them in decision-making processes and giving them a voice in the research and development of new technologies. This empowerment has fostered a sense of ownership and responsibility among farmers.
5. Scalability: The cooperative model has proven scalable, with numerous cooperatives successfully implementing

CONCLUSION

The society's innovative approach to technology dissemination has significantly enhanced the reach and adoption of Conservation Agriculture (CA) practices among farmers in Haryana and western IGP. Since its inception in early 2010, the society has facilitated the transfer of CA-based technologies from a small-scale demonstration on 2-3 acres to a wide-scale adoption over 250 acres by 2011-12. The use of Information Communication Technologies (ICTs) by layering weather forecasts and CIMMYT Agriplex cell phone-based message services has further expedited the dissemination of real-time, actionable information to hundreds of farmers which helped in mitigating risks such as water stagnation, water and nutrient application, terminal heat and yellow-rust attack in wheat. By fostering collaboration among varied stakeholders, promoting sustainable practices, and leveraging ICTs, these cooperatives have addressed the challenges posed by traditional farming systems. The participatory approach, which integrates farmer knowledge and innovation, has effectively disseminated CA/CSA technologies, improving soil health, higher productivity, economic gains, and enhanced climatic resilience. The success of these cooperatives serves as a model for sustainable agriculture, offering valuable lessons for other regions and contributing to the broader goals of environmental sustainability and food security.

KEYWORDS

Conservation Agriculture, Farmer Cooperatives, ICTs, Rice-Wheat (RW) System, Sustainable Agriculture, Participatory Research

CONSERVATION AGRICULTURE AND LIVESTOCK INTEGRATION

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INTRODUCTION

Phumelele Hlongwane and Nothile Zondi are small-scale farmers in the Emmaus area of Bergville, in the Drakensberg foothills. We farm small areas of roughly 1ha each under communal tenure in the Amangwane Tribal Authority and the Okahlamba Local Municipality. The climate is subtropical, with an average rainfall between 750 mm and 1350 mm per annum and an average temperature of around 23.40C. Climate variability has been extreme, with drought, heatwaves, hailstorms, and flooding becoming regular events.

DESCRIPTION OF CA SYSTEM AND PRACTICES

Generationally, our fields have been mono-cropped to maize, using conventional tillage, fertilisers, and hybrid seed. We started implementing Conservation Agriculture (CA) in 2014, including practices such as close-spacing, micro-dosing fertilizer, intercropping, crop rotation, and a range of cover crops and legumes for soil health and livestock integration.

Our fields are divided into plots or strips; we use this system to utilize all the land at our disposal effectively. For example, the first plot or strip will be planted with Maize only, the second maize and legumes, which can be either beans, Lablab or cowpeas and the third plot or strip will be cover crops because we planted during summer; we usually use a mixture of summer cover crops which in this case would be Sorghum, Sun hemp and Sunflower. After the third plot or strip, we repeat the cycle until we have utilized the fields.

However, we would reserve the last plot for Maize and Pumpkin. This planting design is not fixed; it is changed every 3 years through crop rotation, meaning the crops planted in those plots would shift to other plots. We have utilised our field without tilling the soil; we plant using a two-row planter, which we obtained through the Mahlathini Development Foundation; we also have a haraka seed planter, which makes things easier when planting.

As farmers with livestock, we also plant for our livestock. We also produce fodder, including crops like Lespedeza, tall fescue, short-season maize, and winter cover crops. We grow these crops in the same field at the same time. These plants also play a role in soil cover, especially winter cover crops during winter, as we understand the significance of keeping our soil always covered.

The goal is to build organic matter content on the soil while utilizing the land for food production and livestock feed. One of our biggest challenges is controlling the livestock of other farmers in the community; they roam around the village and end up interfering with our cropping fields and destroying crops and soil cover, leaving the soil bare and exposed to the sun, wind and heavy rains. To solve this issue, our fields have been adequately fenced to keep livestock away from the fields.

The impact of Climate Change has also been felt starting 3 seasons back. We have encountered hailstorms which destroyed 70% of our produce, and now we are seeing temperatures rising in November and December without any crop of rain. These are the challenges we face as smallholder farmers as far as climate change is concerned. CA is a solution to climate change itself. CA practices are designed to better adapt to most climate change events. However, some events, such as hailstorms and strong winds, cannot accommodated in these practices.

When harvesting, we do not harvest everything in the field. Maize stover are cut a few centimetres above the roots and lying down in the field while their roots are left in the soil. Summer cover crops are also cut roughly 60 cm above the ground, leaving the rest of them to regenerate and keep the soil covered. Cover crops and the residue after harvesting beans we use them to make livestock feed, while we use sunflower for poultry feed.

Maize, legumes and pumpkins are for household consumption. Then surplus, we sell them to our local market in town, but we also sell them within our homesteads (farm gate). We produce Mielie meal with our maize for household consumption and consume green mealies.

IMPACTS, SUCCESS, AND PROGRESS

We started seeing positive results after 3 years of practising CA through reduced run-off and erosion, improved soil quality and improved yields. Over the last 6 years, maize yields have stabilized at around 5,5t/ha for our CA plots compared to 2t/ha for the conventional controls. Runoff has been reduced by 31%, and soil organic carbon has remained stable at around 2,5%. Maize yields have slowly increased in the past 6 years, and the quality of the produce has been very satisfactory. Intercropping maize with beans, cowpeas, and pumpkins has improved both maize yields and quality.

Starting from 3 years ago, we observed that our soils were softer than when we were practising conventional tillage and mono-cropping. They can hold water for some time. The soil structure has been effectively improved over time. We also have been having fewer cases of pests and diseases detected in the fields. These practices have proven to decrease diseases in the soil and in plants; this is because of intercropping and crop rotation. Soil texture has also improved over time; we are now seeing more of darker soil in the field, which is undeniable proof of an increased building up of organic content in the field. Our soils are becoming more adaptable to heat stress and drought. However, these two factors are still a challenge to the soil.

Water productivity for CA maize grown as an intercrop with beans or cowpeas is higher than single-cropped CA maize. Water productivity for CA plots is significantly higher than for conventional tilled plots. Volumetric water benefit for intercropped and rotated CA plots and strips has shown to be six million litres per hectare more than conventional tillage, and mono-cropped CA plots have shown to be one million litres per hectare more.

CA has increased yields and soil health, decreased input costs and improved local incomes. Introducing legumes and cover crops has increased soil fertility, helped feed livestock as a substitute for overgrazed pastures in the winter season, and provided feed for poultry and goats. Because of these goods yields, there is plenty to sell, increasing income from the local markets where the produce quality comes into play. Because of micro-dosing fertilizer and avoiding the application of chemicals, the input expenses have also been decreasing over time.

CONCLUSION

We are still learning and striving to increase organic matter content so that we can no longer depend on fertilizers while conserving our land for future generations. We are also striving to be successful, independent farmers and to undertake a wider range of farming businesses. Agriculture is a game of determination, consistency, and, most importantly, patience.

KEYWORDS

CA practices, Livestock integration, organic content, yields

PARTICIPATORY ON-FARM RESEARCH TO ADAPT CONSERVATION AGRICULTURE IN THE SEMI-ARID NORTH-WEST PROVINCE, SOUTH AFRICA

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INTRODUCTION

This study presents 10 years (2013–2023) of experiences and results from research using a farmer participatory systems research approach to developing and adapting CA among commercial grain farmers in the Ottosdal area in the North-West Province of South Africa. The Maize Trust of South Africa funded the project with material contributions from participating farmers and is currently managed by ASSET Research in collaboration with the Ottosdal No-till Club.

DESCRIPTION OF CA INITIATIVE AND ACTIVITIES

In the Ottosdal project, on-farm trials were a key tool to involve and assist farmers in adapting CA in the region. The objectives and designs of these trials were jointly done by participating farmers and researchers. Around 100 trials were established in this period comprising the following themes:

1. Crop rotation systems under CA.
2. Tines versus coulter fitted on no-till planters.
3. Plant population densities (high versus low) under CA.
4. Maize cultivar evaluation under high plant population density CA cropping systems.
5. Conventional crop systems versus CA crop systems.
6. The testing and screening of cover crops.
7. Green fallow soil restoration trial.
8. Livestock integration trial.
9. Comparing conventional tillage, no-tillage and conservation agriculture

RESULTS, IMPACT, SUCCESS AND PROGRESS

The following key results were achieved in the implementation of around 100 on-farm trials for 10 years:

- Results from the six seasons of crop rotation indicate that maize following sunflower and maize in monoculture in no-till systems outperform maize following other crops such as forage sorghum and soybean. This is contrary to published results for tilled soil. The rainfall use efficiency for maize was also relatively high compared with that of tilled maize in the area, indicating that CA systems improve the efficient use of limited resources. Sorghum performed well when it followed maize, cowpea, soybean and sunflower crops. Soybean performed well when preceded by cowpeas, maize and forage sorghum. Sunflower yields were above the mean when preceded by forage sorghum, maize and sunflower in monoculture.
- Narrow 0,52 m spaced rows with increased plant population densities were compared to the local width of 0,76 to 0,91 m spaced rows and lower plant densities for maize. Except for three trials, the yield of maize was similar or higher in the Argentinian system compared to that of the local system in the remaining 16 trials. Overall, in all trials, the yield advantage of the narrow rows was 0,55 t ha-1. In the case of sunflowers, 0,52 m spaced rows had an average yield advantage of 0,16 t ha-1 over the 0,91 m spaced rows at similar plant densities. The yield of maize in local conventional systems was lower than that of NT systems tested.
- Yields were similar for tine vs disc no-till planter treatments, although a tine working depth of 240 mm instead of 150 mm resulted in a maize yield increase.
- A trial aimed to indicate the optimum plant population density for maize, soybean, sunflower and sorghum in conservation agriculture systems. Three maize response curves of the 0,9 m spaced rows indicate that the optimum plant population density is between 30 000 and 38 000 ha-1, while the third curve is inconclusive. Two of the 0,76 m row-spaced trials suggest an optimum plant density between 23 000 and 30 000 ha-1. Sunflower and sorghum yields showed no significant response to a range of ‘normal’ plant population densities, while the optimum for soybean appears to be above 300 000 plants ha-1.
- Seven trials were done on three farms in three seasons comparing conventional and CA (no-till) cropping systems. The performance of no-till maize grown in 0,52 m rows at 40 000 ha-1 and in 0,91 m rows at various densities was compared to the performance of maize grown in the tillage system which is applied on the farm and plant densities equal to or below 24 000 ha-1. Tillage systems varied from moldboard ploughing and strip-till to deep ripping. There is strong evidence that the yield

of the no-till maize improves due to no-till. In only one of the seven trials, the yield of the conventionally tilled maize was higher (by 0,8 t ha-1) than that of one of the no-till systems. In the other six cases, the yields of the no-till systems were equal to or higher (from 0,04 to 2,42 t ha-1) than the yields of the conventional system, most likely due to improved water infiltration capacities of the soil, as found in one trial.

- A trial investigated grain yield and soil health as affected by a sunflower-cover crop-maize rotation system and monoculture with maize and sunflower in two plant arrangements. This statistically laid-out trial started in 2018/2019 and was planted extremely late (January 2019) due to drought. Maize plant arrangement affected yield. Maize in 0.52 m rows at 40 000 plants ha-1 had a significantly higher yield (0,65 t ha-1) than maize in 0,91 m rows at 22 000 plants ha-1, confirming previous results. The results of the 2019/2020 season showed that the yield of maize is affected by a rotation X plant arrangement interaction. In monoculture, the yield of the 0,52 m spaced rows was only 3% higher than that of the 0,91 m spaced rows. The corresponding value for rotated maize was 19%. Across row widths, the yield of the rotated maize was 24% higher than that of the monoculture crop. In contrast, yield did not respond to plant arrangement nor rotation system in 2020/2021, probably due to excessive rainfall and hail damage.
- A statistically laid-out trial aims to determine whether the nitrogen application rate can be lower when rotated with a cover crop mixture utilised by cattle. Results of this first season suggest that the nitrogen fertilisation rate can be reduced by about 40 kg ha-1 from what is typically recommended for maize in the area.
- Another trial aimed to determine if and how a cover crop's legume-to-grass ratio or composition affects the yield of maize rotated with it. In 2019/2020, the yield of the still non-rotated maize fertilised with zero to 100 kg nitrogen ha-1 responded expectedly and reflects the trial's results well. In 2020/2021, no response either to the nitrogen fertilisation or to the composition of the cover crop was found, probably due to excessive rain during December 2020.
- Results of a trial comparing crop rotation systems from the six seasons of crop rotation suggest that some crops are affected by the preceding crop as indicated. No crop system seems to have a striking organic matter content, soil respiration or aggregate stability above another. This is most likely due to the slow change of these parameters, as the trial is in its sixth season. No apparent difference exists among the plant nutrients either. None of the measured soil parameters has any relationship with the grain yield. This trial was concluded in 2019/2020.
- A trial investigated grain yield and soil health as affected by a sunflower-cover crop-maize rotation system and monoculture with maize and sunflower in two plant arrangements. This trial aims to determine how the rotation systems and plant arrangements affect soil health and crop yields. The potassium content increased in the sunflower–cover crop–maize system relative to the maize–maize system, confirming other related research findings. A cropping system X plant arrangement interaction affected the microbial diversity index and the gram-negative bacterial biomass. To date, none of the soil parameters have shown any relationship with the yield of maize. Nematode-specific indices were calculated and used to infer the soil ecosystem health status of the treatments. Differences were found. This trial continues.
- A screening trial played a significant role in testing and learning the suitability and the different attributes of a range of cover crops in that area. The trial also served as an excellent demonstration and awareness tool at annual field visits and conferences.
- Using a CC mixture as a green fallow multi-species cover crop system showed that CA could quickly recover some critical soil ecosystem functions and restore degraded soils.

CONCLUSIONS

The farmer participatory systems research approach guided and supported the project team in implementing a range of on-farm trials, assisting with the research, development, and adaptation of CA systems within a commercial farming context of the Ottosdal area.

KEYWORDS

on-farm trials, soil health, crop rotations, cover crops, livestock integration

THE DEVELOPMENT OF CONSERVATION AGRICULTURE SYSTEMS ON A FARM IN THE ARID, SANDY NORTH-WESTERN FREE STATE, SOUTH AFRICA

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INTRODUCTION

Cobus farms in the Viljoenskroon area of the north-western Free State Province. The area has four seasons, with summer from October to the end of March. It has an average annual rainfall of 550 mm, mostly in summer. The soils are sandy-loam with a clay % of 4 to 12% in the topsoil.

The soils are freely drained, apedal or poorly structured red and yellow-brown between 800 to 1400 cm deep, classified as Avalon, Bainsvlei, Tukulu and Westleigh soil forms (according to the SA soil classification system). The commercial farming comprises grain cash crops (maize, soya, sunflower), cover crops, natural and planted perennial pastures, livestock (cattle and sheep), backgrounding and a feedlot.

CA JOURNEY AND SYSTEMS

Cobus started farming in 2000 with conventional tillage and a crop rotation of maize and sunflower. He began with minimum-tillage in 2006 with a minimum tillage planter (with a tine of 24 cm). He used roundup as a burndown and crop rotation (maize, soya, sunflower) with limited grazing on fields after harvesting. In 2016, he planted multi-specie summer cover crops for the first time. He utilised them with lite grazing with livestock and sprayed it with herbicide (roundup) in April, whereafter it was rolled flat.

In 2018, he started with multi-specie winter cover crops, which he utilised with high-density grazing with sheep and backgrounding weaner calves. Winter cover crops are planted after harvesting sunflower and soybean. These fields are followed up with summer cover crops, and then, in the follow-up year, a cash crop. In 2024, he started with a multi-specie intercropping system for maize and sunflowers. Cobus is also doing scientific on-farm CA trials for the Maize Trust, coordinated by ASSET Research.

IMPACT

The most significant success is the massive reduction in wind and water erosion. Other impacts are better water infiltration and soil water holding capacity, improved soil structure (primarily due to biomass of cover crops and livestock grazing), less soil compaction, and better control of soil temperatures. The planting window is longer (starts earlier with less rain and plants a week or two later). There is a decrease in fertiliser use, but weed control is still challenging.

CONCLUSION

According to Cobus, farmers must convert to CA in this area if they want to be resilient, profitable, and sustainable in the medium to long term.

FARM MANAGEMENT OR THE ENVIRONMENT: WHAT DETERMINES WHETHER CROP DIVERSIFICATION WORKS?

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INTRODUCTION

Crop diversity is a key ingredient of Conservation Agriculture (CA). However, successful diversification is not always straightforward. Farmers must consider many factors when deciding whether and how to diversify, including land and labour availability and market access. A central concern is the effect of diversification on productivity: will yields go up or down, and for which crops? Yield responses to diversification are highly variable, and the causes of the variability are poorly understood.

In this study, we investigated how the local environment and farm management influenced the effect of diversification on crop yields and land use efficiency for smallholder farmers in Zambia. We applied this knowledge to identify the optimal diversification strategy for farmers in different locations.

MATERIALS & METHODS

We used three years of data from an on-farm trial network testing different diversification strategies on 29 farms in four locations across Zambia's Southern and Eastern Provinces. These three years and four communities (12 site-years) provided a rainfall gradient from 448 mm to 1034 mm in the growing season. Rainfall was recorded by farmers using rain gauges, then cross-checked among farmers within a community to detect errors and calculate the average rainfall for each community. We explored the effect on relative maize and legume yields in different cropping systems of total seasonal rainfall (mm/season) and rainfall variability within the season, measured as the coefficient of variation (CV) of daily rainfall (mm/day).

Seven cropping system treatments were tested on each farm. The first two comprised maize monocultures managed under CA (CA-mono) and the other under conventional tillage practices (CP-mono). The subsequent two treatments were a maize-legume intercrop, with alternating rows of maize and legumes managed under CA (CA-1-row) and conventional tillage (CP-1-row). An additional three diversification strategies were tested under CA only: a two-row maize-legume strip crop (CA-2-row), a four-row maize-legume strip crop (CA-4-row), and a maize-legume rotation (CA-rotation). Legume species differed between provinces, so the most suitable species for each region was groundnut in the Southern and soybean in the Eastern.

In all CA treatments, weeds were cleared from plots before planting using glyphosate at 2.5 litres ha-1. In CP treatments, plots were tilled with an animal-drawn plough. Weed control after that was done with hand hoes for both CA and CP treatments. All plots on all farms received the same amount of NPK fertiliser (16.5 kg N, 33 kg P, 16.5 kg K ha-1) at seeding, and all treatments containing maize also received a urea top-dressing at 4-5 weeks after planting (92 kg N ha-1). Pesticides were applied only in the case of severe outbreaks using recommended rates.

Row spacing and plant population were intended to be the same between farms, with all treatments designed to achieve a maize plant population of 44,444 plants ha-1 (legume populations differed between species and in the rotation vs intercrops). However, in practice, row spacing varied substantially between farms, providing an inadvertent gradient in plant populations and allowing us to explore the effect of this aspect of crop management on yields in diversified systems.

Mixed regression models explored how maize and legume yields and land use efficiency differed between treatments, seasons, villages, and farms. The land equivalence ratio (LER) was used to quantify land use efficiency.

RESULTS AND DISCUSSION

Overall, across all site years in the study, mean maize yields were highest in the CA rotation and CA monoculture and lowest in the CA four-row strip crop and the CP monoculture. Mean legume yields were highest in the CA rotation and lowest in the CP intercrop.

However, in all treatments, yields varied substantially between seasons, locations, and farms (no treatment had consistently higher or lower yields than others). Some yield variation could be explained by differences in rainfall between seasons and villages and in plant populations between farms. For maize, under conditions of lower total rain (550 mm) and higher rainfall variability (CV = 2.3), the benefit of the CA-rotation was approximately 20% above the average yield. At the same time, the CP-mono and the CA-4-row had the lowest yields at approximately 15% below the average. These differences were reduced when total rainfall was high (950 mm), and rainfall variability was low (CV = 1.7); mean yields for all treatments were within 10% of the average maize yield.

Legume yields followed a contrasting pattern, with the most significant differences observed between treatments under high total rainfall and low rainfall variability. In these conditions, legume yields in the CA-rotation were near twice the average of all treatments, both strip crops were close to the average, and the CA- and CP-1-row yielded barely above half the average. In drier conditions with variable rainfall, these differences reduced to 25% above and 10% below, respectively, although the overall ranking of treatments remained the same.

Although the CA-rotation generally had the highest yields for maize and legumes when considering crop yields per ha, all intercrop and strip crop treatments had a higher land use efficiency than the rotation. The LERs for the intercrop and strip crop treatments averaged around 1.5 and did not change significantly in relation to rainfall.

Maize plant populations in the trials were intended to be 44,444 plants ha-1, but farmers only achieved 36,160 plants ha-1 on average. The expected 44,444 plants ha-1 was only sometimes achieved and rarely exceeded. Increasing the plant population from 36,160 to 44,444 had a meaningful effect on relative yields only under conditions of high total rainfall and rainfall variability. In these cases, a higher plant population increased the relative yields of both maize and legumes in the CA rotation. Higher yields in the rotation, but not the intercrops or strip crops, reduced the land-use efficiency of the intercrops and strip crops compared to the rotation. At 44 444 plants ha ha-1, the LERs were around 1, indicating no land efficiency advantage of intercropping or strip cropping.

Although rainfall and plant population helped to explain some variation in mean yields, models accounting for treatment, total rainfall, rainfall variability, maize plant population, and legume species type could only explain 33% and 56% of the variation in maize and legume yields, respectively. A further 16% and 17% could be attributed to differences between communities and years not accounted for by the rainfall variables. In comparison, 52% of the variation in maize yields and 27% in legume yields were related to differences between farms within communities and years. This suggests that to optimise the choice of diversification strategy further, the priority should be to investigate differences between farms in more detail regarding management practices and soil type.

CONCLUSIONS

Our study demonstrated that the amount and variability of rainfall alters the relative yields and land use efficiency of different cropping systems. However, only the magnitude of the differences between treatments changed, while the overall pattern of lowest to highest yields did not. The CA-rotation consistently achieved the highest yields of maize and legumes when each crop was considered separately. At the same time, the four intercropping and strip cropping systems consistently had the highest land use efficiency. This suggests that farmers throughout our study site should use intercrops or strip crops if the land is limiting and a rotation if the land is not. However, intercrops and strip crops can become less land-use efficient at higher plant populations if rainfall is both high and variable.

Our results also shed light on competition dynamics between maize and legumes. Legume yields were highest in the CA-rotation, intermediate in CA-4-row and CA-2-row, and lowest in CA-1-row and CP-1-row, indicating a gradient of competition associated with closer proximity to maize. Differences between treatments were much more substantial under higher rainfall, suggesting that wetter conditions intensify the competition imposed by maize on legumes. This is likely because higher water availability allows maize to grow faster and larger so maize restricts light availability to the intercropped legumes more than in drier conditions. The broader gaps created by the strip intercrop designs mitigate this effect.

KEYWORDS

crop diversity, crop yields, intercrop, rotation, smallholder, weather

WESTERN AUSTRALIAN NO-TILL FARMERS CONTINUE TO INCREASE WATER USE EFFICIENCY

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INTRODUCTION

The rapid adoption of no-till farming in Western Australia's rainfed farming systems has increased profitability and sustainability across ~18 million hectares of cropped land. Herbicide-resistant weeds have become a management priority in Western Australian (WA) no-till farming systems (Walsh et al. 2019). Consequently, in recent decades, substantial changes have been made to rotations, with significant reductions in areas of pasture and grain legumes. These have been replaced by canola and more frequent cereal plantings (Harries et al. 2015; Harries 2023). We hypothesised these changes to the farming system will likely affect other biophysical variables, including plant pathogens and crop nutrition.

MATERIALS AND METHODS

A survey of 184 fields over 6 years, totalling 3730 field visits, was used to monitor a wide range of biophysical variables and obtain accompanying field management data from fields across south-west WA (Figure 1). Knife-point seeding and retained stubble were employed in 97% of these fields, and detailed methods can be found within (Harries et al. 2021).

RESULTS AND DISCUSSION

Weed populations were low in most fields. This was despite 92% of fields containing weeds resistant to at least one herbicide chemistry. This was achieved using integrated weed management practices, including herbicides and changed rotation towards wheat and canola, those land uses with lower weed density (Figure 2) (Llewellyn et al. 2009; Harries et al. 2020). Rotation affected grass weed density (plants/m2), with grass weeds increasing when cereals were grown in successive years; the first wheat having 11.6 (±1.2), second wheat 10.4 (±1.4), third wheat 22.4 (±6.8) and fourth wheat 35.2 (±23.6) and was lowest in wheat crops grown after canola at 8.1 (±1.0) grasses/m2.

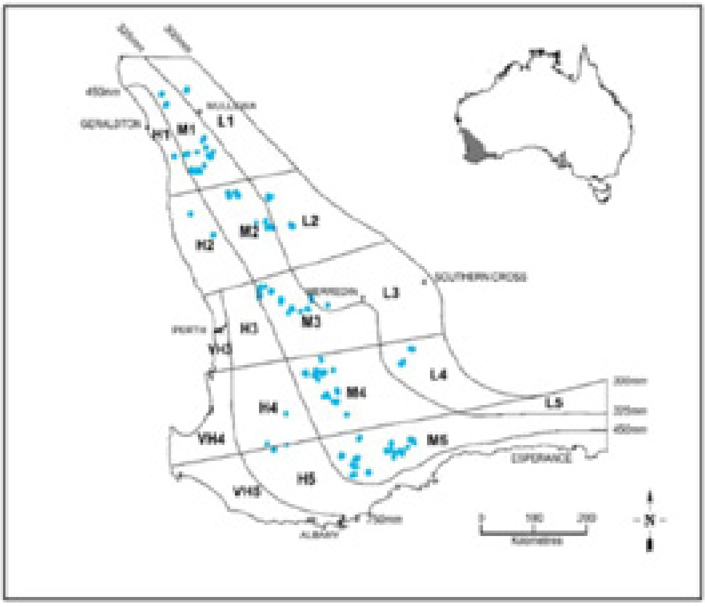

Figure 1. Location of 184 survey fields (blue dots) from 2010 to 2015 in the south-west of WA. Boundaries depict agroecological zones according to rainfall. Letters refer to rainfall zones: VH, very high; H, high; M, medium; L, low. Numbers refer to regions: Northern (1 and 2), Central (3 and 4) and Southern (5) Agricultural Regions.

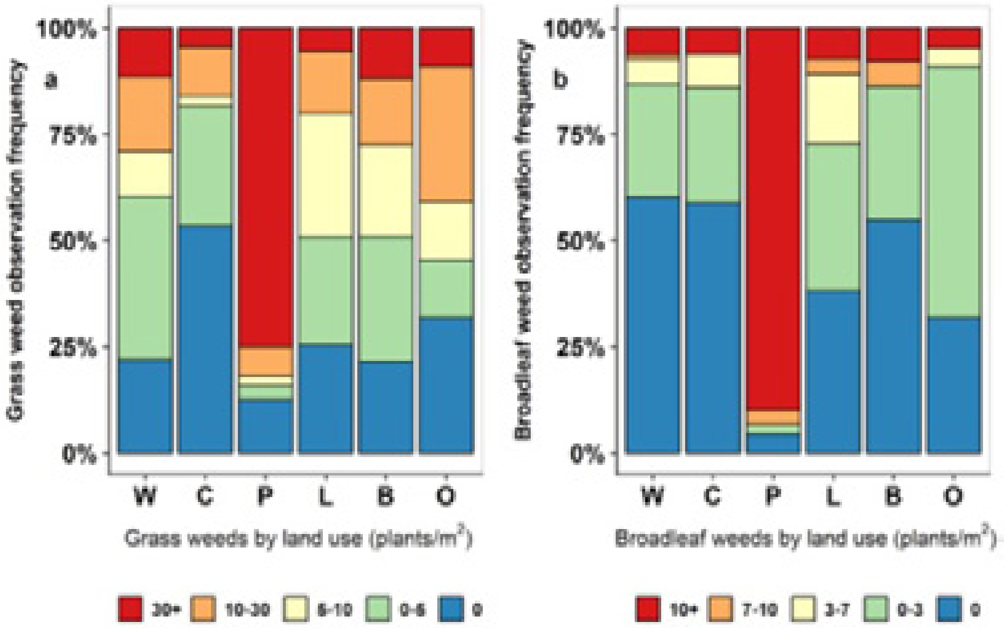

Figure 2. Frequency of crop weed occurrence at anthesis, by density categories and land use for a) grass weeds and b) broadleaf weeds, (W=wheat, C=Canola, P=pasture, L=Lupin, B=Barley, O=Other).

Nitrogen fixation was calculated using empirical relationships between shoot biomass, with root multiplication factors applied (McNeill and Fillery 2008; Unkovich et al. 2010) (Table 1). The amount of atmospheric N estimated to be added by legumes was low compared to previous studies (Reeves 2020) due to the low legume content of pastures (Figure 3) and the high harvest index of grain legumes (Harries et al. 2021).

This was particularly the case for the NAR. Pastures' low biomass and legume content result from reduced regeneration after long crop phases and active weed management in spring to reduce herbicide-resistant weeds setting seed, reducing the seed set of pasture legumes.

Despite low legume nitrogen inputs, a positive partial N balance (mean = 2.8 kg N/ha.year) was achieved throughout the study in NAR fields. Conversely, negative balances were observed in CAR (7.0 Kg N/ha.year) and SAR (15.5 kg N/ha.year). Maintenance of nitrogen in the NAR was achieved by using similar amounts of fertiliser nitrogen as the other regions while harvesting less grain, with more details in Harries et al. (2021).

Table 1. Nitrogen fixation (Nfix) and balance (Nbal) for pastures and grain legumes.

Region	Pasture		Lupin		*Other grain legume	
	Nfix (kg/ha)	Nbal (kg/ha)	Nfix (kg/ha)	Nbal (kg/ha)	Nfix (kg/ha)	Nbal (kg/ha)
NAR	6	3	139	39	113	59
CAR	65	67	177	65	181	110
SAR	50	51	161	44	273	184

**Chickpea, field pea and faba bean.*

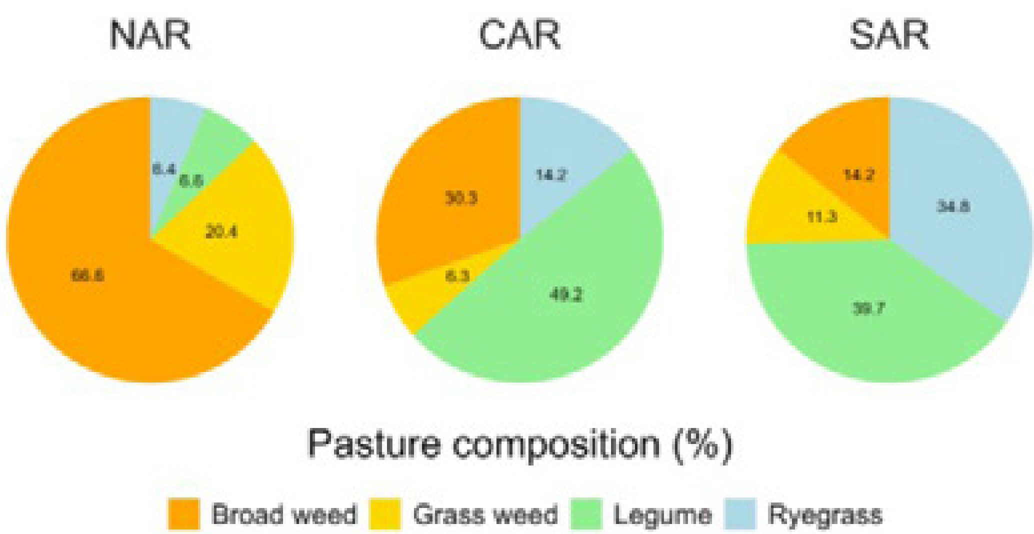

Figure 3. Pasture composition, represented as % of plants within the four categories (legume plants, annual ryegrass plants, broadleaved weeds and grass weeds), across three agricultural regions (Northern (NAR), Central (CAR) and Southern (SAR)).

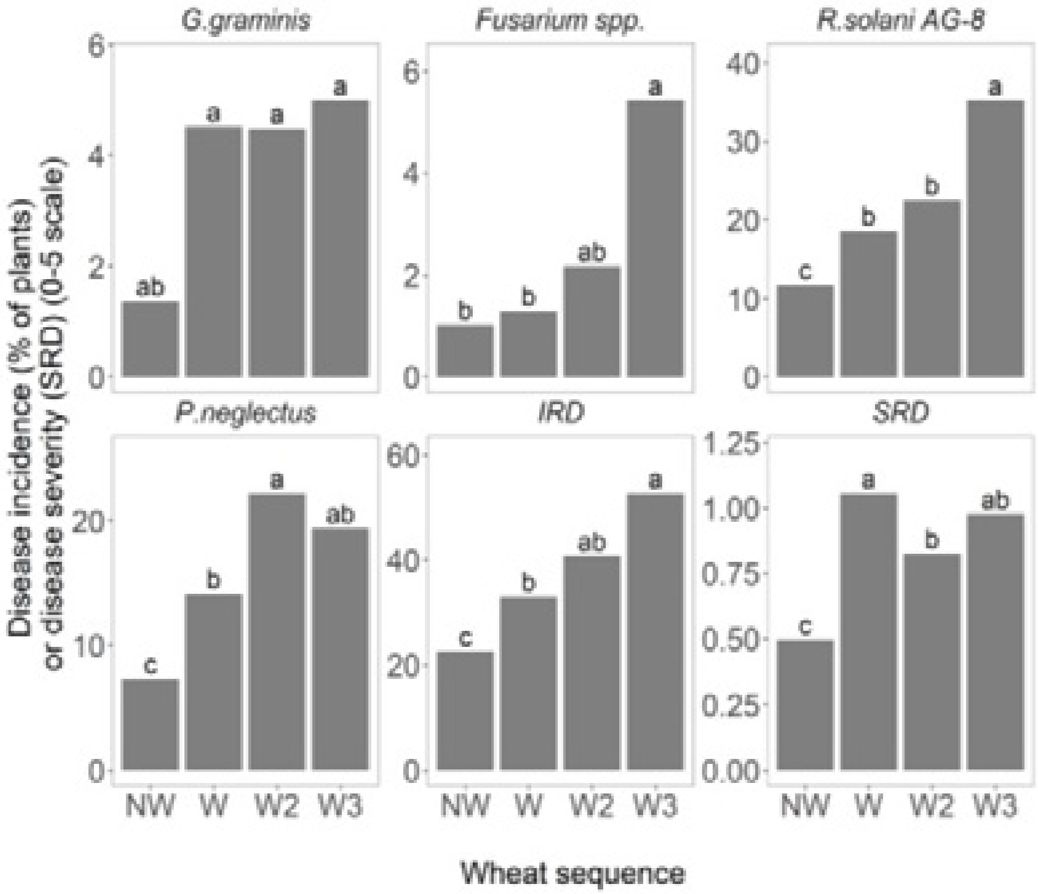

Figure 4. Mean percentage of plants taken in spring with diseased symptoms or symptoms of at least one root pathogen (IRD). The severity of root damage (SRD) from spring samples assessed using a 0-5 rating scale: 0 (no disease), 1 = 1–5% (trace disease), 2 = 6–25% (low amount of brown lesions), 3 = 26–50% (medium amount of brown lesions, similar amounts of healthy and necrotic), 4 = 51–75% (most of the roots covered in brown lesions, little healthy root left) and 5 = 75–100% (all or nearly all roots covered in brown lesions or short brown stumps). NW = Non-wheat, W = first wheat crop, W2 = second wheat in succession, W3 = third wheat in succession.

Analysis was conducted to determine drivers of water use efficiency (WUE). WUE for wheat production averaged 10.7 kg.mm/ha. After a break crop or pasture, this increased to 12.5 kg.mm/ha while reducing to 8.4 kg.mm/ha in the fourth successive wheat crop (Figure 5) (Harries et al. 2022a).

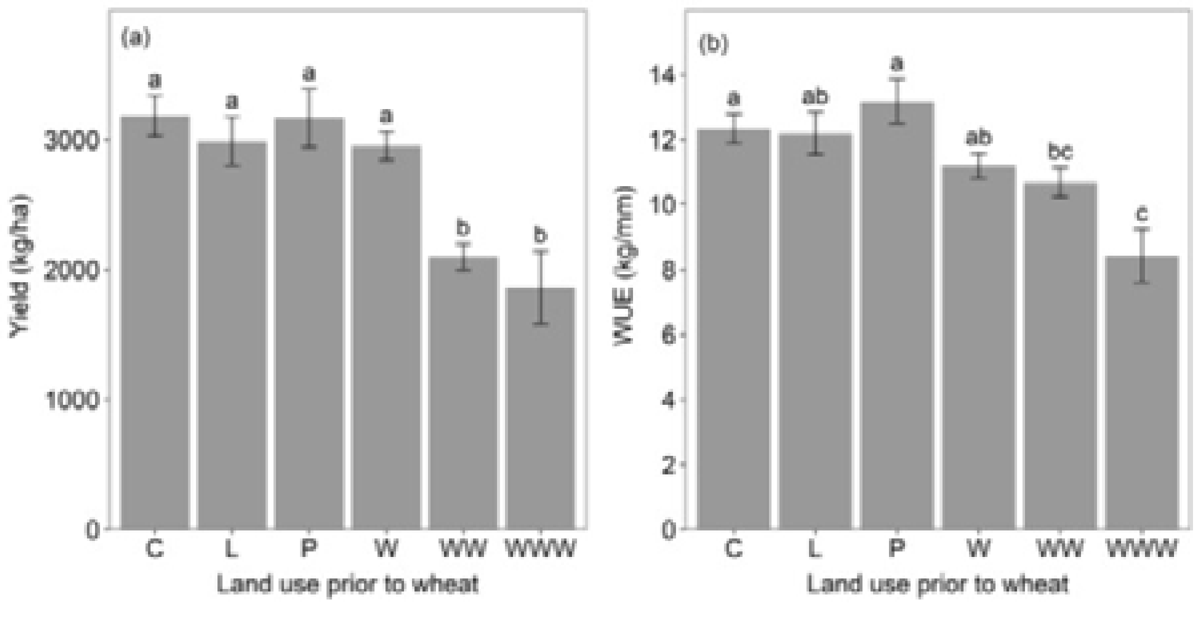

Figure. 5. (a) Yield and (b) Water use efficiency (WUE) of wheat grown after other land uses; C = canola, L = lupin, P = pasture, W = wheat, WW = wheat/wheat, WWW = wheat/wheat/wheat.

A French and Schultz style boundary function indicated low evaporation (45 mm) and high mean transpiration efficiency (25 kg/mm) for fields with the highest WUE, with improved WUE compared to previous studies in southern Australia (Figure 6).

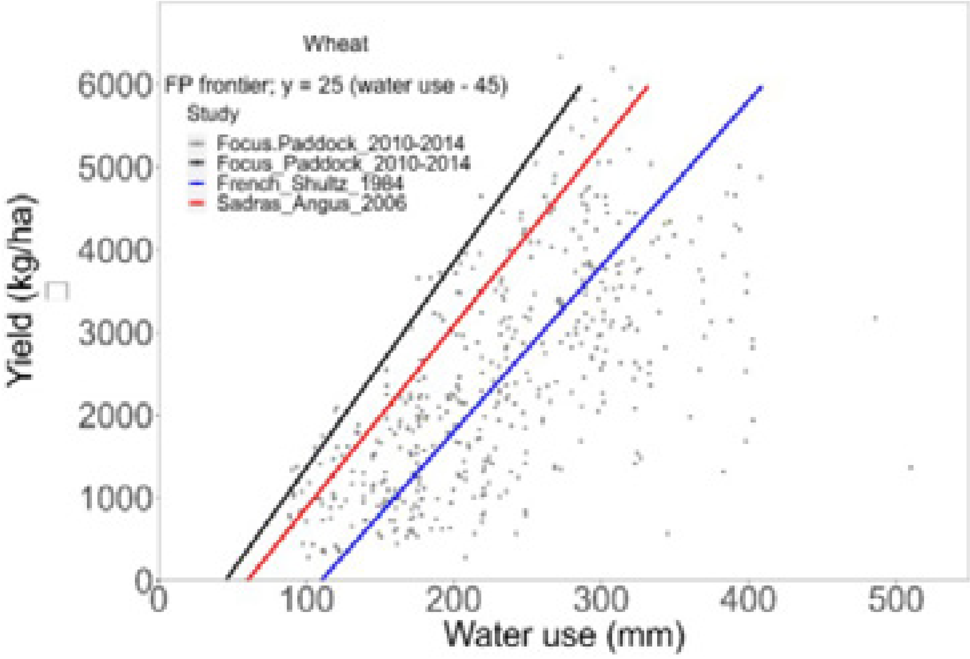

Figure. 6. Wheat yield plotted against water use for the Focus Paddock dataset (south-west Australia 2010–2014). Water use (WU) was calculated from 0.25 x summer rain plus growing season rain. The frontier equations depict water-limited yield (Ywl) potential. The blue line represents French and Schultz (1984) frontier, with x-intercept (estimated evaporation) = 110 mm and slope = 20 kg grain/ha.mm; the red line represents Sadras and Angus (2006) frontier, with x-intercept 60 mm and slope 22 kg grain/ha.mm; and the black line represents current (Focus Paddock) frontier, with x-intercept = 45 mm and slope = 25 kg grain/ha.mm. Inset equation is of our Focus Paddock study.

CONCLUSION

We determined that because weeds, disease, and nutrition were, in the main, well managed, in most instances, yield increases of wheat crops sown immediately after legume crops and pastures were modest. This occurred because external inputs and management are partly substituting for traditional functions provided by break crops and pastures.

Yet crop and pasture rotation remains the foundation of this conservation agriculture system. The inclusion of break crops and pastures minimises long sequences of monoculture wheat, which is critical to ensuring high WUE in this dryland farming environment. It is concerning that the need to manage herbicide-resistant weeds has led to a move away from biological nitrogen fixation. This is at odds with a key principle of sustainable intensification: to rely less on external inputs while engaging ecological processes to supply nutrients (Cassman and Grassini 2020; MacLaren et al. 2022). These findings are relevant to no-till production in other Mediterranean climates.

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KEYWORDS

Water use efficiency, wheat, break crop, canola, legumes, rotation, dryland.

THE STATUS OF CONSERVATION AGRICULTURE DEVELOPMENT IN IRAN'S DRYLAND FARMING SYSTEM

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IINTRODUCTION

Crop management can be important in sustainability, considering the climatic conditions and production instability in Iran's drylands. The current cultivation pattern of crops in dryland areas should be changed. Using the high capacity of fallow land, the area under cultivation of alternative crops and in the rotation of cereals should be increased.

The development of the cultivated area of alternative crops will promise the development of sustainable and conservation agriculture in Iran's drylands. One of the most critical pillars of conservation agriculture is observing suitable and economical crop rotations in each region. Studies on conservation agriculture in DARI started in 1995, and by 2024, 112 final reports on various aspects of conservation agriculture will have been published.

DISCUSSION

The projects implemented in the field of determining different tillage methods in the production of dryland crops, the effects of tillage methods on the physical characteristics of the soil, management of residues and straw and stubble in different tillage systems, planting methods and determining the appropriate tools about obtaining the stability of production and maintaining humidity, determination of nitrogen and phosphorus fertilizer feeding in rotation and different tillage methods, crop management such as the amount of seed and fertilizer for the conservation agriculture system, evaluation of precipitation productivity and yield in other cultivars.

SYNERGISTIC EFFECTS OF CONSERVATION AGRICULTURE AND BIOCHAR ON NITROUS OXIDE EMISSIONS, BIOLOGICAL N2-FIXATION, AND SOIL N DYNAMICS IN CONTRASTING SOILS

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INTRODUCTION

Conservation agriculture (CA) and biochar (BC) applications are potentially important components of climate-smart agriculture. They may increase soil nitrogen (N), which is one of the limiting factors affecting crop production in sub–Saharan Africa (SSA). Low soil N in SSA is related to the depletion of soil N stocks due to continuous nutrient mining without replenishment during farming.

Soil N availability and crop yields in SSA have wide margins for improvement through legumes in crop rotations. N_2-fixation has been estimated to be the largest source of N input to low-input farming systems, where inorganic N fertilizer use is low. Symbiotic dinitrogen (N_2) fixation by legumes is a critical ecosystem function that increases the soil N pool and is a net input to the soil-crop system.

Therefore, redesigning and rebuilding legume-based cropping systems to solve various problems related to disconnects in N supply, demand, and recycling should consider drought-tolerant legumes (e.g. pigeon pea (Cajanus cajan L. Millsp.). Besides N_2-fixation, pigeon pea is a superior choice for biochar production due to a significant amount of woody biomass. Biochar, a C-rich product made by pyrolysis of organic waste, is relatively stable in soil, thus contributing to carbon sequestration.

The amendment of soils with biochar is attracting much attention and has been suggested as a promising solution to regulate the soil N cycle and increase soil water retention. In addition, biochar increases soil pH, which is significant in the tropics where soils are generally acidic due to the leaching of bases, thus influencing nutrient availability and nitrous oxide (N_2O) emissions.

Agriculture and forestry account for more than 50 % of N_2O emissions worldwide and is particularly important in low-pH soils. In SSA, increased agricultural production is primarily reached by expansion of agricultural land rather than intensification. Both are associated with loss of soil organic carbon, shifts in microbial communities and increased decomposer activity. Although some studies suggest that N_2O emissions are enhanced threefold in croplands compared to natural forests, emission inventories in SSA are constrained. With a limited number of studies, there is a need for further investigations as this region has considerable impacts on the global greenhouse gas (GHG) budget.

Here, we investigated two climate-smart agricultural practices, conservation agriculture and biochar, on N_2O emissions and the biological N_2-fixation of pigeonpea. The objectives were to determine the effect of crop rotation, reduced tillage, and biochar on (1) N_2O emissions, (2) biological N_2-fixation of pigeonpea, (3) roots and aboveground biomass, and (4) soil nitrogen dynamics (total soil N %, N stocks and soil δ15N), in contrasting soils in Uganda.

MATERIALS AND METHODS

The research was conducted at CLIMSMART in-depth experimental sites in Gulu, Alebtong (Northern Uganda) and Mubende (Central Uganda). The Mubende and Alebtong trials were established in August 2021, and the N2-fixation experiment was carried out during the April – July seasons of 2022 and 2023.

The Gulu trial was established in 2023, and the N_2-fixation experiment was conducted in the April – July 2023 season only, while the N_2O emissions were measured from May 2023 to January 2024. Soils in Gulu have relatively low organic C levels ranging from 0.5 to 1.5% and total N levels from 0.05 to 0.12 %. By contrast, soils in Alebtong and Mubende have moderate organic C (1.5 – 3%) and total N levels (0.12 – 0.25%). In a double cropping system (April – July and September – December, respectively), maize (Zea mays L.), as the main crop, was rotated with pigeon pea.

Inorganic fertilizer was not applied in this experiment since the smallholder farmers in Uganda do not apply inorganic fertilizers, and we did not want fertilizer to mask the effect of biochar and conservation fertilizer. In addition, it is common for smallholder farmers in Uganda not to apply chemical fertilizers. The following treatments were investigated in a completely randomized block design with four replications: planting basins + biochar + maize-pigeon pea rotation (CABCPP), planting basins + maize-pigeon pea rotation (CAPP), conventional tillage + maize-pigeon pea rotations (ConventPP), and conventional tillage + maize monocropping (ConventMM).

Biological N_2-fixation was determined using the 15N natural abundance method, where maize and two weed species, thatch grass (Hyparrhenia rufa) and blackjack (Biden pilosa) were used as non-fixing reference crops. The samples were analysed using an isotope ratio mass spectrometer using an EA1110 elemental analyzer, coupled to a Thermo Scientific Delta V Isotope Ratio Mass Spectrometer via a Thermo Scientific ConFlo IV universal continuous flow interface (Thermo Fischer Scientific, Waltham, Massachusettes, USA), at the Catholic University of Leuven, Belgium.

When calculating nitrogen fractionation derived from the atmosphere (%Ndfa), the B value was equal to the smallest δ15N obtained from each season. N_2O fluxes samples were collected from the Gulu site only, and the samples were collected every 2 weeks, both between and inside planting basins, using custom-made PVC static chambers. For each flux estimate, chamber temperature was recorded, and four gas samples were drawn from the chamber headspace at 1-, 15-, 30- and 60-minute intervals using a 20 mL polypropylene syringe equipped with a three-way valve. The samples were analyzed on a gas chromatograph (GC; model 7890A, Agilent, Santa Clara, CA, USA) connected to an auto-sampler (GC-Pal, CTC, Switzerland) at the Norwegian University of Life Sciences, Norway. Upon piercing the septum with a hypodermic needle, ca. 1mL of sample was transported via a peristaltic pump (Gilson minipuls 3, Middleton, W1, USA) to the GC's injection system before reverting the pump to back-flush the injection system. The GC is configured with a Poraplot U wide-bore capillary column connected to an electron capture detector (ECD) to analyse N_2O.

RESULTS AND DISCUSSION

In Mubende, CAPP significantly fixed more N than ConventPP, and there were no significant differences between CAPP and CABCPP during the 2022 season. In 2023, the biomass and corresponding N2-fixation rates were low due to prolonged drought; despite this, the highest N2-fixation was recorded in CFBCPP, and the lowest was recorded in ConvetPP and CFPP. In Alebtong, neither CAPP nor CABCPP significantly affected N2-fixation in 2022 and 2023. In Gulu, pigeonpea grown under CABCPP fixed significantly more atmospheric N (up to 112 kg N ha-1) than CAPP and ConventPP treatments. It has been reported that root nodulation is stimulated by P availability, which is enhanced by applying biochar. Biochar also enhances the availability of other nutrients such as boron, molybdenum, potassium, and calcium, which are all essential for biological N2-fixation. In general, across sites, pigeon pea grown in Gulu fixed more N compared to Alebtong and Mubende.

In Gulu, pigeonpea grown under CAPP and CABCPP derive 95 % of the aboveground N content from N2-fixation, while those grown under ConventPP obtain most of their aboveground N from soil N mineralised in the soil. However, in Alebtong, most aboveground N was derived from the soil rather than N_2-fixation. N_2-fixation is expensive, requiring more energy for the reaction and maintaining an oxygen-poor intracellular environment for nitrogenase, the enzyme responsible for N fixation. Plant N acquisition through symbiotic fixation is more costly than soil N acquisition, and plants preferentially take up N from the soil if readily available, thereby downregulating N_2-fixation. Therefore, N2-fixation may be only an advantage to plants in low N soils.

Significantly more N_2O was emitted within planting basins than inter-rows, and hourly fluxes correlated with soil moisture and water-filled pore spaces (WFPS). Cumulative N_2O emissions from basins and conventional plots were relatively small. The emissions ranged from 0.79 to 1.33 kg N_2O-N ha-1 yr-1 and were lower than the default emission factor of IPCC. N_2O emissions were significantly higher in CAPP and CABCPP than ConventPP and ConventMM, probably due to increased soil moisture and enhanced biological N2-fixation.

In addition, CABCPP significantly increased root biomass, aboveground biomass at flowering and harvesting, as well as grain yields, compared to CAPP and ConventPP, across all sites. The treatments did not affect the soil N pool in the initial two years. However, the N % and δ15N were relatively low in Gulu compared to Alebtong and Mubende. Low δ15N at Gulu was probably due to tight cycling of N (and little N loss, due to either leaching of NO_3- or gaseous emissions resulting from denitrification (dinitrogen (N_2), nitrous oxide (N_2O) and nitric oxide (NO)).

CONCLUSION

Our findings indicate that N_2O emissions were low despite significant treatment effects. In addition, biochar and CA increase biological N2-fixation, especially in soils with low C and N, thus supporting climate-smart agriculture goals in low-input systems where soil nutrient mining without replenishment is high.

KEYWORDS

climate-smart, nitrogen, low-input systems, biochar, conservation agriculture

DRIVING CONSERVATION AGRICULTURE ADOPTION IN THE WESTERN CAPE, SOUTH AFRICA

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INTRODUCTION

The Western Cape's Conservation Agriculture (CA) journey, a significant turning point in farming practices, commenced in the early 1980s. Initially, adoption was driven by farmers, with minimal research support. However, full-fledged research efforts were initiated in 1996. While adoption rates were sluggish initially, a transformative shift occurred in 2000, thanks to research, initial extension, and locally produced machinery. This paper delves into the successes and challenges that persist for full adoption.

MATERIALS AND METHODS

The information for this contribution, crucial for shaping the narrative, was gleaned through insightful conversations with early adopters, farmers, and industry role players, who played a pivotal role in the Conservation Agriculture journey.

RESULTS AND DISCUSSION

Although CA only found traction in the early 1980s, the conservation effort in the Western Cape started much earlier. Soil erosion due to continuous tilling was becoming a problem in the Western Cape cereal production areas. In the 1970s, the government launched a subsidized program to install contour ridges to curb water erosion with some success. Although the ridges helped, continuous soil disturbance and bare fallow fields still harmed the soil. Only in the early 1980s, following severe rainfall events, the first farmers consciously decided to change their practices in the southern production area, and CA found a foothold in this part of South Africa.

Initial scepticism about direct seeding and the retention of residues in the field slowed the adoption rate. Producers were used to the conventional plough. At that stage, no-till machinery was not readily available in South Africa, so adapted sowing machines were developed with help from some Western Cape Department of Agriculture engineers. Increased adoption started in the early 2000s when locally manufactured machinery became more readily available, and these machines were financially competitive. The adoption of the three CA pillars varied in the different production areas. The southern Cape was more familiar with a rotation system since lucerne was used as a pasture phase followed by cereal production. The western part of the production area mainly produced mono-culture wheat. The adoption of the no-till pillar of CA in numerous areas was due to the possibility of applying herbicides during the planting process because producers struggled with weeds becoming more and more resistant. Introducing break crops such as canola and lupin (to a much lesser extent) and other cereals such as oats for the breakfast market and barley for beer further improved CA adoption. Conservation Agriculture Research through the introduction of long-term CA trials (since 1996) has also shown the financial benefits of CA adoption. Establishing a local CA forum (2012) with an annual conference and walk-and-talks in the long-term trials and CA producers' farms has also strived to improve awareness and adoption.

The Western Cape Government has played a crucial role in promoting the adoption of CA as best practice in its SmartAgri plan to mitigate and combat climate change risk in the province. The SmartAgri plan, the first such strategy in the Agricultural sector in South Africa, includes [specific initiatives or policies related to CA adoption]. This proactive stance by the government has encouraged farmers to adopt CA and set a precedent for other provinces and countries to follow.

A previous survey indicated that the cereal-producing areas of the Western Cape have reached a 51% adoption rate of the complete CA package. Most producers own a no-till seeder, but not all practice rotations with more than two crops or retain their residues year-round. Numerous crop-only producers still bale their residues to sell as animal feed or to orchards and vineyards as mulch on the tree and vine rows. Residue burning is still practised in some areas, and producers' comments on why they burn the residues include weed seed control and preventing blockages during the planting process. Disc seeders are minimal, although all CA trials have converted to using disc seeders to maintain the residue load, including the systems with an animal factor.

Crop options and the availability of markets restrict some of the challenges facing higher adoption rates. With its Mediterranean climate, the Western Cape is limited to a single cash crop per year, limiting crop choices. Very little irrigation water is available, and cereal production is therefore rainfed. The use of cover crops (although it is gaining popularity) is also limited because most producers will have to replace a cash crop to include the cover crop, which has financial implications. Increased problems with herbicide resistance are putting pressure on no-till. Viable alternatives in biological weed, pest and disease control are often cited as a concern for CA going forward, especially with banning agricultural remedies.

Other challenges include [specific challenges related to CA adoption in the Western Cape, such as soil health, farmer education, or policy support].

Research funding is currently minimal, and the number of researchers focusing on CA could be higher. This lack of support makes addressing CA challenges in specific areas difficult. The number of extension practitioners has dwindled, and most of the extension is currently being done by fertilizer and chemical companies, which are not necessarily pro-CA. We must recognise the importance of research and policy support in driving CA adoption. Financial support must be provided for producers who wish to change their practice, and the cost associated with conversion is another potential limiting factor.

We must act now to provide the necessary resources and support for CA adoption to continue and thrive.
A coherent National Policy on Conservation Agriculture is needed to allow countrywide adoption progress.

CONCLUSIONS

Even though CA adoption in rain-fed cereal production systems has reached a nominal value of 51%, more must be done. Increased research efforts to address local challenges will help to improve adoption, not only in cereal production but also in other agricultural commodities.

KEYWORDS

Conservation Agriculture Western Cape, conferences, extension, LTEs, research

DETERMINANTS OF NO-TILL CONSERVATION AGRICULTURE ADOPTION IN MAIZE AND BEAN CULTIVATION IN LESOTHO

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INTRODUCTION

Araya et al. (2024) assert that the common farming practices in Sub-Saharan Africa (SSA) that include intensive and repeated tillage, complete crop residue removal and biomass burning create risks of soil degradation. Conservation Agriculture (CA) uses minimal soil disturbance, crop residue retention and crop rotation to reduce risks of soil degradation. The United States of America has credit for pioneering the use of such practices far back in the 1930s.

CA spread globally into South America, Australia, Europe, Asia and Africa. In Africa, the significant use of CA started in the 1970s in Zimbabwe, following the introduction of economic sanctions which forced farmers to use economic production techniques that minimised machinery wear and fuel use in cropping. In Lesotho, the pioneer of the promotion of CA is Rev. Basson, who was passionate about improving local agriculture, and he set out to identify farming practices that relied on low external inputs but were suitable to the local socio-economic conditions (Silici, 2010).

He travelled to South Africa in 2000, where he learnt more about CA, which he eventually started to promote in Qacha's Nek with a Sesotho name 'Likoti', through an NGO called Growing Nations (Silici, 2010). Since 2002 conservation agriculture captured the interest of local and international actors in Lesotho– that included, among others, the Food and Agricultural Organization (FAO), the World Food Programme (WFP), the National University of Lesotho (NUL) and several NGOs. Conservation agriculture (CA) has been promoted to address low agricultural productivity, food insecurity, and land degradation in Southern African countries, Lesotho included. However, despite significant experimental evidence on the agronomic and economic benefits of CA and large-scale investments by the donor community and national governments, smallholder adoption rates remain below expectation. Within this landscape, this study embarks on a journey to explore the determinants of no-till CA adoption among maize and bean producers in Lesotho.

MATERIALS AND METHODS

The research used a quantitative design, meaning that it utilized numerical data coded and analysed through Statistical Package for Social Sciences (SPSS). It was cross-sectional, meaning that data were collected at one point. This study was conducted in seven (7) districts of Lesotho to determine the factors that influence the adoption of CA, specifically narrowing down the focus of the survey to the CA principles. It used a dataset collected from 807 farmers through a structured questionnaire. A systematic random sampling technique was used to collect data from the households picked from the villages in the districts sampled purposively. This was the most appropriate sampling method because it ensures that the districts included in our study represent the regions where no-till CA practices are most relevant. The study aimed to capture the most pertinent data for our analysis by selecting specific districts renowned for maize and bean cultivation. This method further allows the concentration of resources where CA practices were of significant interest, thus maximizing the accuracy and applicability of the findings (Giller et al., 2009).

The data was analysed through descriptive statistics (such as frequency count and percentages) and a multinomial regression analysis. Data analysis assessed the impact of various factors, such as demographic profiles, economic status, and farming characteristics, on adopting three CA principles and four CA practices. The study used a multinomial regression analysis to investigate the determinants of no-till CA adoption in Lesotho. The choice to employ multivariate regression models was driven by the interconnected nature of variables affecting the adoption of CA principles. Unlike univariate models, multivariate models enable us to consider multiple factors and their interactions simultaneously. This approach acknowledges the interdependencies between variables, providing a holistic view of the adoption process. Utilizing multivariate regression enables the study to conduct a comprehensive analysis, delving into how various factors influence the three fundamental principles of CA—minimum soil disturbance, permanent soil cover, and crop diversification.

RESULTS AND DISCUSSION

The multivariate regression results show that the adoption of Minimum Soil Disturbance ($B = 0.089$, $p = 0.007$) and Permanent Soil Cover ($B = 0.068$, $p = 0.016$), showed a significant positive association with gender, where males were more likely to implement this practice. This indicates that gender affects the decision to adopt the CA principle. Interestingly, a higher level of education correlated negatively with the Minimum Soil Disturbance principle ($B = -0.046$, $p = 0.023$), suggesting that more educated farmers might prioritize other innovative farming techniques over traditional CA practices. The findings contradict research results which reported that farmers with higher formal education are more likely to adopt CSA technology than others (Fadina and Barjolle, 2018). In other studies, the reason for these findings was attributed to the fact that higher education is associated with increased specialisation of technical skills. Therefore, educated farmers are more interested in other livelihood opportunities than farming (Esabu and Ngwenya, 2019).

The effect of field size was negative (B = -0.006, p = 0.016), indicating that farmers with larger fields might find it challenging to maintain minimal soil disturbance across extensive areas. These findings align with those of Ntshangase et al. (2018), who reported that farmer adoption of CA negatively correlates to farm size. Notably, training on Minimum soil disturbance CA emerged as a strong positive predictor (B = 0.402, p < 0.001), training remained a crucial positive influence for the permanent soil cover principle (B = 0.242, p < 0.001). Training again proved to be a significant facilitator of crop diversification principle (B = 0.207, p < 0.001). This highlights the effectiveness of extension services in facilitating the adoption of CA, underscoring the importance of targeted educational programs in promoting CA practices. The findings are in line with Abdoulaye et al. (2014), who stated that farmer participation in training programmes positively influences the adoption of CA as it facilitates the uptake of new technologies.

Conversely, access to credit was negatively associated with adopting soil cover (B = -0.104, p = 0.036), possibly reflecting financial constraints that prevent farmers from investing in necessary resources for maintaining soil cover. These findings confirm the importance of formal and informal institutions that provide credit to small-scale farmers. Access to credit is important because farmers facing financial constraints may be unable to optimize production (Sikwela, 2013). Demographic factors less influenced Crop Diversification but showed a significant negative correlation with age (B = -0.002, p = 0.038), indicating that younger farmers are more likely to diversify their crops.

This implies that age has a positive influence on the decision of the farmer to adopt CA principles. The negative coefficient of the variable indicates that a 1-year increase in age decreases the odds of a farmer adopting a CA principle by 0.0023, holding all the other variables constant. The findings align with Owomboh and Idumah (2015), who reported that older farmers are less likely to engage in land conservation, a long-term perspective and are less likely to adopt CA than younger farmers. Experience in farming positively impacted diversification (B = 0.057, p < 0.001), which could be attributed to more knowledgeable farmers understanding the benefits of diversification in risk management and soil health.

CONCLUSIONS AND RECOMMENDATIONS

This study reveals complex interplays between socio-economic factors and the adoption of CA principles and practices. Effective promotion of CA requires educational interventions and consideration of demographic and economic factors that could inhibit or encourage farmers. The results underscore training as a pivotal factor in all three CA principles and practices, suggesting that comprehensive educational initiatives could substantially increase CA adoption rates. The varied influence of credit access across different principles points to the need for financial products tailored to support distinct aspects of CA. The analysis further highlights that gender, education level, and farming experience significantly influence the adoption of CA practices. These factors affect different practices in varying degrees but collectively emphasise the importance of tailored educational and support programs to foster broader adoption of CA practices and principles. Providing comprehensive training on CA principles and specific practices can significantly enhance their adoption. Tailoring these programs to address specific regional needs and existing farming practices can improve their effectiveness. Utilizing the expertise of experienced farmers as champions for CA principles and specific practices can help mentor less experienced farmers and showcase the benefits. Strengthening the link between agricultural education and CA practice adoption through formal education and community outreach programs can facilitate a deeper understanding and quicker uptake of these practices.

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COMPATIBILITY BETWEEN CONSERVATION AGRICULTURE AND THE SYSTEM OF RICE INTENSIFICATION

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INTRODUCTION

The rice industry is deeply intertwined with issues like food insecurity, poverty, and climate change on a global scale. Its cultivation is globally relevant as a staple for half the world's population and a lifeline for over a million people. However, wetland rice cultivation significantly contributes to environmental issues and is responsible for many greenhouse gas (GHG) emissions and freshwater depletion.

Moreover, traditional practices like ploughing and puddling disrupt soil structure, leading to further problems. It's becoming increasingly clear that rice production rates won't sustain global food security by 2050, especially given technological limitations and climate trends. Therefore, there's a pressing need to develop strategies that increase grain production while minimizing environmental harm.

The reason for introducing complementary SRI practices into rice-based CA systems, or conversely for moving SRI practices toward CA soil and water management, is to further increase their respective contributions to rice production and the natural environment, compared with the usual present practice of ploughing and puddling rice fields. Researchers accustomed to exploring the consequences of introducing a single agricultural practice would need to assess the implementation of combinations of these.

MATERIALS AND METHODS

The work involved critically reviewing the multiple on-the-ground adaptations of CA+SRI systems found worldwide. An analysis of the possible adjustments required to adopt each basic principle of CA and SRI systems represents a crucial part of this work.

RESULTS AND DISCUSSION

At first glance, SRI appears incompatible with CA because some of its practices, such as performing weeding operations with a surface soil-disturbing mechanical weeder, are contrary to those of CA. Also, SRI accepts farmers' usual methods for land preparation, such as ploughing and puddling their fields. Further, SRI does not maintain permanent cover on the soil with biomass materials as prescribed for CA. Rice monoculture leaves the ground bare between seasons and does not promote species diversity in rice paddies, a fundamental part of CA cropping and management. Despite these differences, combining CA with SRI elements is possible and desirable. Following is an analysis of how CA and SRI principles and practices interact.

AVOIDING MECHANICAL SOIL DISTURBANCE

Soil puddling, a common practice in wetland rice cultivation, is avoided in rice-based CA systems due to their detrimental effects on soil structure and biology. Instead, a widely adopted alternative is no-till, direct-seeded rice (DSR), where rice seeds are planted directly into untilled soil. This method aligns with SRI, emphasizing early and healthy plant establishment without disturbing the roots. By combining no-till DSR with SRI's principle of reducing plant density to minimize competition for resources, rice plants can develop larger canopies and deeper root systems, thriving in biologically active soils with good structure and high biomass carbon levels. Adjusting plant spacing is facilitated by CA practices, naturally promoting vigorous growth in fertile soil environments.

Various approaches to implementing SRI principles without tillage exist worldwide, utilizing different levels of mechanization. In lowland areas, CA promotes using permanent raised beds for growing irrigated or rainfed wetland rice without disturbing the soil extensively (Asif, 2011). Cultivating rice and other crops on raised beds with suitable machinery allows for adopting agronomic practices aligned with both SRI and CA systems on a large scale. Construction and spacing of raised beds are designed to enable tractor tyres to navigate between furrows without disrupting the beds, facilitating optimal water percolation.

WATER MANAGEMENT

Conservation Agriculture (CA) and the System of Rice Intensification (SRI) prioritize nurturing soil organisms' abundance and diversity. Flooding even one crop in a rotation compromises soil structure and biota by creating anaerobic conditions. Conversely, aerobic soil conditions, advocated by both approaches, foster healthier root systems and support beneficial aerobic soil organisms (Jagannath et al., 2013; Kassam et al., 2022). With their more extensive root systems, CA crops and SRI-grown rice plants are more resilient to water stress and benefit from CA's soil management, which reduces compaction. The shift from flooded rice paddies in CA systems enhances soil health, reducing water requirements. Drip irrigation, sprinklers, and alternate wetting and drying (AWD) water management are compatible with CA and SRI. Maintaining aerobic soil conditions in low-lying, clay-heavy fields poses challenges. Raised beds with furrows provide a solution by allowing lateral water supply to porous beds, ensuring adequate moisture for plant roots. This method enhances water use efficiency and reduces methane emissions, contributing to sustainable rice production under CA and SRI principles (Asif, 2011).

PERMANENT SOIL COVER

The widespread burning of rice straw after harvest in Asia, where 90% of the world's rice is grown, carries significant environmental, economic, and health drawbacks. Both SRI and CA emphasize enriching soil with organic matter. While CA advocates for a permanent biomass soil cover, which aligns well with SRI principles, SRI typically involves mechanical disturbance to incorporate organic matter into the soil. However, maintaining a permanent soil cover, such as mulch, is compatible with both approaches and aids in maintaining aerobic soil conditions. In a CA-based rice system, the mulch layer must be thick enough to shield the soil from sunlight, inhibiting weed germination and lowering the need for chemicals. This synergises with CA practices like no-till and crop diversification, reducing weed occurrence (Sims et al., 2018).

DIVERSIFICATION OF THE CROPPING SYSTEM

Crop associations are fundamental to Conservation Agriculture (CA) systems, particularly prevalent in smallholder farming setups. They serve as strategies to diversify species, enhancing crop resilience against various stresses and boosting overall land productivity. However, conventional irrigated rice farming tends to rely on monoculture practices due to the unsuitability of flooded fields for associated crops that cannot tolerate oxygen-deprived soil (Bunch, 2019).

Under CA+SRI management, avoiding anaerobic soil conditions and the wider spacing between plants create an environment conducive to intercropping and mixed cropping practices. In CA+SRI cropping systems, integrating multi-purpose cover crops and green-manure cover crops into rotations or associations, as already practised in CA systems, can significantly increase organic matter in the soil while preventing bare soil and enhancing biodiversity. These cover crops stabilize soil moisture and temperature when main crops are not cultivated. This fosters a favourable soil biota habitat that contributes to stabilises soil structure and function.

Agroforestry practices and other perennial systems are viable options within irrigated rice farming areas under CA, thanks to the aerobic soil conditions maintained during rice cultivation. Incorporating trees into the cropping system offers additional benefits such as increased biodiversity, improved land use efficiency, higher farm yield, enhanced carbon sequestration, and better ecosystem services (Wangpakapattanawong et al., 2017).

CONCLUSION

The urgency to reduce the adverse environmental impacts of food production, particularly GHG emissions, is more pressing than ever, and revising rice farming methods is an opportunity to increase staple food production and contribute to diminishing the acceleration of climate change. Capitalizing on the synergies of agroecological practices could help address the negative externalities of rice farming while increasing crop resilience against the effects of climate change. CA-based rice cropping systems are already being practised in some countries, either in paddies or in raised beds with furrow irrigation. SRI crop management can be adapted to converge with CA so that the rice production entails little or no soil disturbance, has permanent biomass mulch covering of the soil, crop diversification, maintains mostly aerobic soil conditions, and optimizes spacing between plants for more remarkable growth of roots and tillers. The specific practices need to be adapted to local contexts, as is always recommended with both CA and SRI. CA and SRI methods have already been successfully combined in several areas of the world as diverse as Pakistan, USA, and China, so converging the two systems with appropriate adaptation is feasible and attractive for farmers.

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KEYWORDS

Agroecology, GHG emissions, Cropping systems, Mulch cover, Synergies

TWO CROPS ARE BETTER THAN ONE FOR NUTRITIONAL AND ECONOMIC OUTCOMES OF ZAMBIAN SMALLHOLDER FARMS BUT REQUIRE MORE LABOUR

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INTRODUCTION

Amid the ever-changing climate and declining soil fertility, it is imperative to develop solutions that counteract the devastating effects that threaten food security and the livelihoods of millions of smallholder farmers in southern Africa. Thus, smallholder farming systems need to be sustainably intensified to narrow existing yield gaps by improving agricultural productivity economically and without compromising environmental health (Godfray et al., 2010; Silva et al., 2023).

An example of such an approach is implementing a Conservation agriculture (CA) system based on minimum soil tillage, crop diversification, and soil cover using organic material. For crop diversification, many options exist, but identifying those that fit specific farming systems remains a challenge (Madembo et al., 2020; Mhlanga et al., 2021). For example, intercropping is a form of diversification that can be used in some farming systems in southern Africa. Still, it may result in crop competition and require spatial arrangements that reduce adverse effects on yields.

This study tested the performance of different maize-legume diversification strategies (single-row intercropping, strip cropping, and crop rotation) with sole-cropped maize under conventional ploughing and CA. We hypothesized that (a) individual crop yields are higher in strip crops compared to single-row intercrops and similar to sole maize, (b) the increased yields of both maize and legumes in strip crops will provide more calories, protein, and higher gross margins than other cropping systems, and (c) strip crops will have comparable effects on environmental indicators to other cropping systems.

We expected that these advantages, along with the ability to grow maize each season, would be attractive to farmers, leading to our final hypothesis that (d) strip crops are rated more favourably by farmers than rotations, single-row intercrops, or sole crops.

MATERIALS AND METHODS

The study was initiated in the 2019/20 growing season, and in this study, data up to the 2021/22 growing season is reported. The study was conducted in four Zambian communities (camps) in four districts in the Eastern and Southern Provinces. Two communities were located in Southern Province, in the districts of Choma (Simaubi Camp) and Mazabuka (Dumba Camp), and two were located in Eastern Province, in the districts of Sinda (Nyanje 1 Camp) and Chipata (Chinjala Camp). All these sites are in Zambian Natural Region IIA, but there is an increasing rainfall gradient from the south to the north.

We compared the diversification options using the Sustainable Intensification Assessment Framework (SIAF), with metrics representing productive (crop grain yield, crop biomass, and total system), economic (net benefit, and returns to labour and inputs), human (protein and energy), social (rating), and environmental (temporal change in total soil carbon and pH) dimensions using data collected from on-farm trials over three growing seasons. Linear mixed models were used to assess the effects of the different diversification options on the different SIAF performance indicators.

A Principal Components Analysis explored the relationships between productivity (crop yield), human (nutrition), economic, and environmental indicators across cropping systems. We used radar plots to visually assess the relative trade-offs between the diversity options. All data analyses were carried out using R software.

RESULTS AND DISCUSSION

There was no significant effect on crop yield amongst the diversification options on individual maize and legume grain yield and biomass across growing seasons. Most of the variance in the data was explained by the random effects of season and location.

However, more variation was associated with the season as the main effect or in interaction with the location. Substantial economic and nutritional benefits of intercropping systems were observed, likely due to the simultaneous growing of two crops instead of one. Maize-legume intercropping strategies (single-row intercropping and strip cropping) resulted in higher energy and protein yield when analysed as a cropping system than sole maize and maize-legume rotation, which has positive implications for human nutrition.

Although increased labour requirements for activities such as planting, weeding, and harvesting the strip crops were observed, intercropping and strip cropping systems had higher net benefits, returns to labour, and inputs than the other cropping systems. This may be attributed to the higher income from the two crops grown in these systems, which outweighed the higher production costs compared to other systems.

However, despite these benefits, farmers did not prefer the intercropping systems over the maize-legume rotation or sole maize, most likely because labour and availability are as necessary for farmers in the intervention areas as overall cropping system benefits. Labour is one of the primary limiting resources for farmers in Zambia and, hence, at the top of many farming decisions that they make.

It is also essential that farmers consider the benefits from a systems perspective. From an environmental perspective, there were no significant differences in temporal changes in soil organic carbon content and soil pH between the cropping systems. Still, decreases were observed across all diversification options.

CONCLUSION

Overall, the results indicate that maize-legume strip cropping and single-row intercropping can increase food and nutrition security and net benefits from farming. However, these systems require more labour for different activities throughout the growing season, such as planting, weeding, and harvesting, due to the two crops involved and the arrangement of the crops in some of the diversification options.

These labour requirements may be addressed through, e.g., appropriate-scale farm mechanization, if intercropping or strip cropping systems are to become a viable option for labour, not land, constrained farms in Southern Africa. Further research to unpack the effects of growing season and location is necessary to better tailor the diversification options to different environments, such as location and growing season combinations.

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KEYWORDS

Conservation agriculture; Integrated assessment; Mbili Mbili; On-farm Trials; Sustainable intensification

EFFECT OF BIOSTIMULANT APPLICATION WITH RHIZOGLOMUS SP. AND AZOTOBACTER SALINESTRIS ON PRODUCTION AND QUALITY OF DURUM WHEAT UNDER DIRECT SEEDING CONDITIONS AND REDUCING FERTILIZER DOSES

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INTRODUCTION

Soil is constantly degraded, mainly due to poor agricultural practices that destroy the ecosystem. This is one reason why increasing crop yields under certain conditions is challenging, compromising productivity and agriculture sustainability [1]. Nitrogen (N)-rich fertilizers are one of the main inputs to ensure crop productivity. They are economically and environmentally costly, as these fertilizers contaminate water bodies and contribute to greenhouse gas (GHG) emissions in the atmosphere [2-3].

Not all the fertilizer added to the soil is absorbed by the crop. In the case of N, it can also accumulate persistently in the soil in different ways, developing a biocidal effect [4]. To improve N use efficiency, agricultural practices must be modified to meet environmental and agri-food requirements. One alternative to improve nitrogen use efficiency is the use of a biostimulant. A biostimulant is any substance or microorganism applied to the plant to improve nutritional efficiency or stress tolerance [5]. Crop productivity and grain quality are closely linked to soil fertilization and/or nutrient availability.

Previous studies showed that biostimulants help reduce fertilizer dose, improving and / or maintaining crop production and grain quality [6]. This study aimed to evaluate if the application of biostimulants [a mixture of Rhizoglomus sp. (a mycorrhizal fungus) and Azotobacter salinestris SIP 46 (a nitrifying bacterium)] could improve plant growth variables (NDVI), yield and grain quality in wheat under no-tillage and semi-arid conditions in southern Spain with different doses of N fertilisation.

MATERIAL AND METHODS

The experimental farm where the biostimulants were tested is located at the University of Cordoba (South of Spain), at the Rabanales Experimentation Farm. The field experiment was developed under direct seeding and no-tillage in semi-arid conditions. 5 blocks and six treatments (randomly distributed) were part of the experimental design (10 m long and 2 m wide, the experimental unit).

Treatment 1 (T1) was the application of 100% N fertiliser (N dose recommended in the area); Treatment 2 (T2), the application of 100% N fertiliser (N dose recommended in the area) plus the application of the biostimulant based on Rhizoglomus sp. and Azotobacter salinestris; Treatment 3 (T3), application of 70% N fertiliser (N dose recommended in the area), Treatment 4 (T4), application of 70% N fertiliser (N dose recommended in the area) plus the application of the biostimulant based on Rhizoglomus sp. and Azotobacter salinestris; (T5) application of 35% N fertiliser (N dose recommended in the area); Treatment 6 (T6), application of 35% N fertiliser (N dose recommended in the area) plus the application of the biostimulant based on Rhizoglomus sp. and Azotobacter salinestris.

The fertilisation doses for T1 and T2 were 120 nitrogen fertiliser units or kg of N per ha, while, for T3 and T4, it was 80 kg of N per ha, i.e. 30% less than for the previous treatments. Then, for T5 and T6, it was only 42 kilograms. The dose of the biostimulant based on Rhizoglomus sp with Azotobacter salinestris is 250 g ·ha-1 in 4-6 true leaf stage.

Table 1. Treatments tested in the experimental field. The NFU are the Nitrogen Fertilizer Units, i.e. the actual N supplied to the crop.

Treatment		Background Fertiliser (kgN ·ha-1)	Surface Fertiliser (kgN ·ha-1)	Rate of biostimulant (g ·ha-1)
T1	100% of the recommend N dose	42	78	0
T2	100% of the recommend N dose + Biostimulant	42	78	250
T3	70% of the recommend N dose	42	43	0
T4	70% of the recommend N dose + Biostimulant	42	43	250
T5	35% of the recommend N dose	42	0	0
T6	35% of the recommend N dose + Biostimulant	42	0	250

The Normalised Difference Vegetation Index (NDVI) was used to monitor the crop. Measurements were taken every 15 days. NDVI values were collected using a Trimble GreenSeeker. In addition, plant material was collected using a 0.5 x 0.5m frame when the grain was mature; one sample of plant material was taken from each treatment and each block to analyze yield and grain quality (protein content).

RESULTS AND DISCUSSION

The NDVI (Figure 1) shows the crop's evolution after applying the different treatments. In the fourth measurement, it was possible to see differences between treatments. T5 and T6 were the treatments with the lowest NDVI values and slope according to the obtained curve. On the contrary, T2 and T4 had the highest NDVI values and the highest slope of the NDVI curve. However, it is worth noting that T1, from the fifth to the sixth measurement, showed a considerable peak in NDVI, while T3 remained close to the values of T2 and T4. A higher NDVI could be seen for T2, T4 and T6 (treatments in which biostimulants were applied) compared to T1, T3 and T5 (treatments in which biostimulants were not applied). Therefore, the application of biostimulants, when considering the same N dose, enhanced plant development, measured as NDVI.

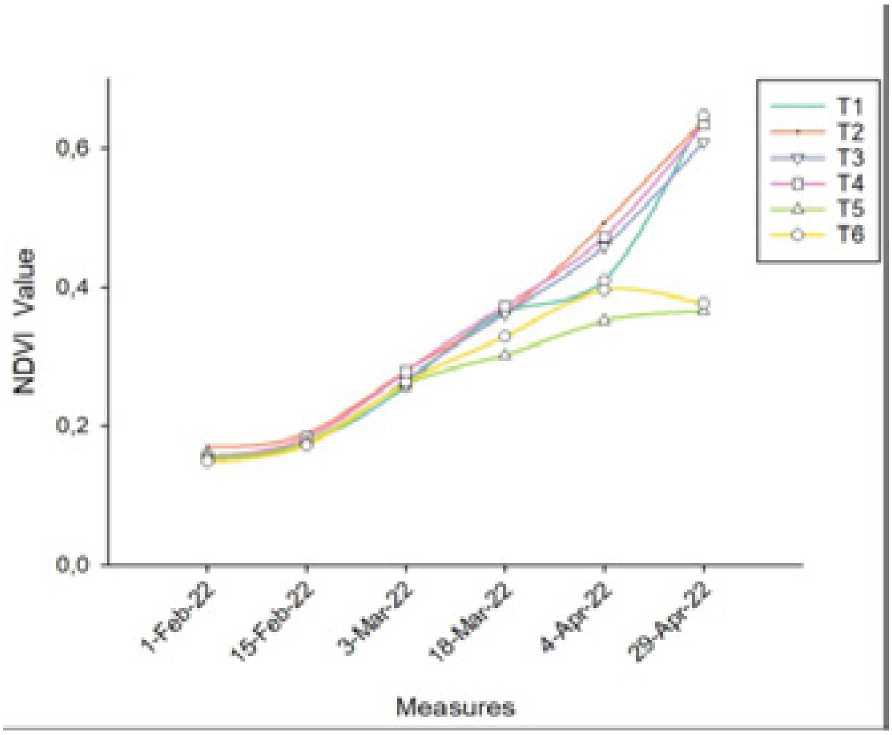

Figure 1. NDVI as a function of the sampling time and treatment. Where T1 is the treatment with 100% N fertilization, T2 is the treatment with 100% N fertilization and biostimulant. T3 is the treatment with 30% N reduction, and T4 is the treatment with 30% N reduction plus biostimulant application. T5 is the control treatment, and T6 is the control treatment using biostimulants.

Figure 2 shows the yield at harvest. Significant differences (according to the one-way ANOVA) were only found between T1/T2/T3/T4 and T5/T6. However, the treatment with biostimulants (T2, T4 and T6) yielded higher (20.5%, 4.7% and 4.0%) than its counterparts without biostimulants (T1, T3 and T5). Another point to note is that a treatment with biostimulant and a 30% reduction in the N dose (T3) produced a similar yield to the treatment with the highest N rate (T1). Although not statistically significant, our results align with previous results in which the use of biostimulants improved grain yield in durum wheat when algae extracts and amino acids were applied [7].

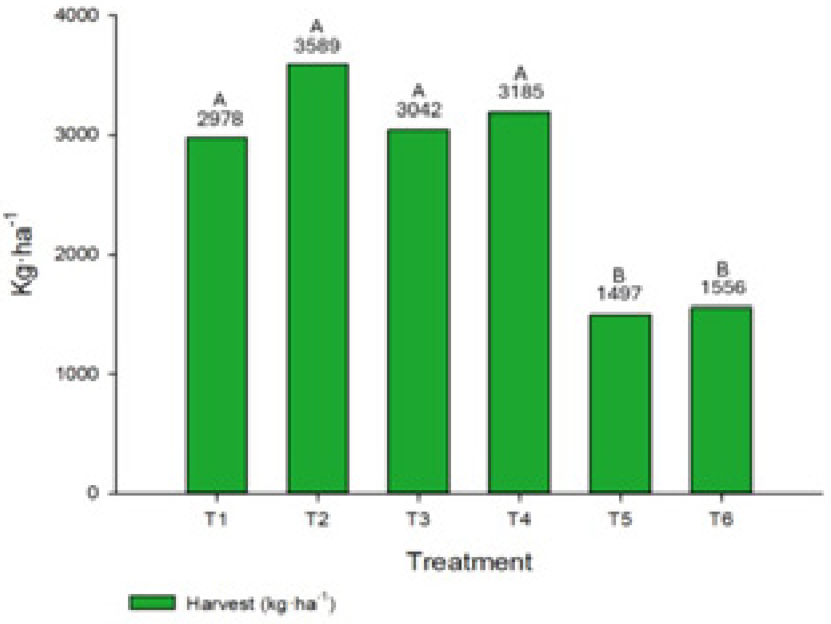

Figure 2. Yield is harvested as a function of the treatment. T1 is the treatment with 100% N fertilization, and T2 is the treatment with 100% N fertilization and biostimulant. T3 is the treatment with 30% N reduction, and T4 is the treatment with 30% N reduction plus biostimulant application. T5 is the control treatment, and T6 is the control treatment using biostimulants.

As seen in other studies, the use of biostimulants improves wheat quality, including protein [8]. However, the protein content in wheat grain was not significantly affected by the application of biostimulants in our study (Figure 3). Additionally, the reduction in N fertilization up to 30% (T3 and T4) did not cause any decrease in grain protein content in comparison with the treatments that received the recommended N dose (T1 and T2). Still, this quality parameter was dramatically affected when only 35% of the recommended N dose was applied (T5 and T6).

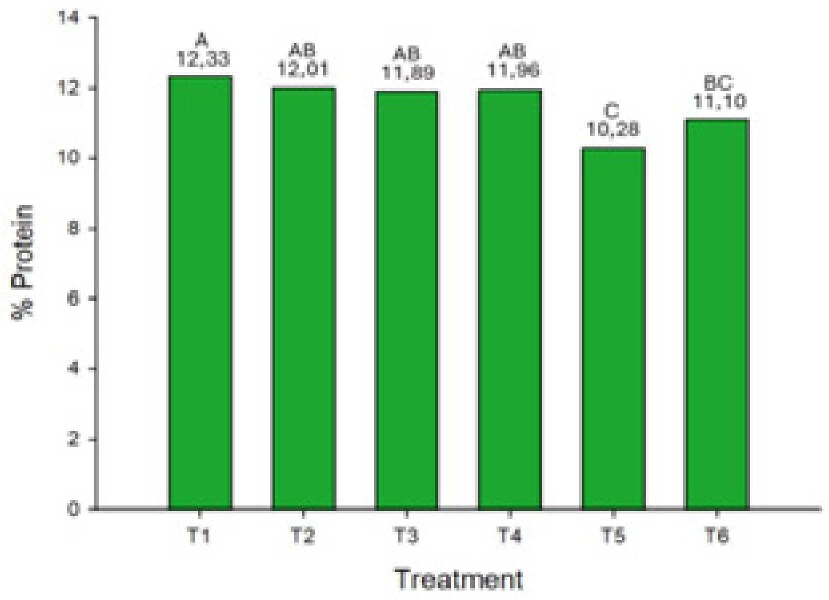

Figure 3. Grain protein content as a function of the treatment. T1 is the treatment with 100% N fertilization, and T2 is the treatment with 100% N fertilization and biostimulant. T3 is the treatment with 30% N reduction, and T4 is the treatment with 30% N reduction plus biostimulant application. T5 is the control treatment, and T6 is the control treatment using biostimulants.

CONCLUSIONS

The use of the biostimulant based on Rhizoglomus sp. and Azotobacter salinestris, under no-tillage conditions, increases (non-significantly) or maintains (significantly) the productivity of the wheat crop when compared between treatments with the same fertilisation strategy (N dose). Those treatments with biostimulants produced higher NDVI values and yields than their counterparts. The biostimulant tested in this study seems promising, but more work is needed.

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KEYWORDS

Conservation agriculture, Soil fertilisation, Direct seeding. Biostimulant. Efficient fertilisation.

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IMPROVING CROP PRODUCTIVITY, RESILIENCE, AND SUSTAINABILITY THROUGH CONSERVATION AGRICULTURE SYSTEMS IN EASTERN CAPE, SOUTH AFRICA

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INTRODUCTION

In sub-Saharan Africa, greater than 20% of the population is underweight, more than any other region in the world, and this number is rising. This alarming trend is partly the result of low crop productivity when water is scarce, highlighting the need to build drought resilience to feed the region's population and support its economy. The most significant potential increases in crop productivity are in rainfed areas where many of the world's poor live and where managing water is critical (Molden, 2007).

The Eastern Cape province in South Africa is one such region, and it has the highest proportion of rural-based population in South Africa, estimated at 75%. However, poor crop productivity resulting from water scarcity has led some small farmers to abandon agriculture altogether (Mandiringana et al. 2005), and agriculture makes only a modest contribution (<10%) to household incomes in the region (Aliber 2009, Hebinck and Monde, 2007). Research is needed to build more resilient crop production systems in places like the Eastern Cape province. Developing and promoting conservation agriculture (CA) techniques is one way to accomplish this goal.

Low crop productivity in sub-Saharan Africa results in large part from three water-related deficiencies: insufficient rainfall relative to crop water requirements, poor soil water holding capacity and infiltrability that lead to runoff, and erratic rainfall distribution due to short and prolonged dry spells (Falkenmark and Rockström, 2008; Fig. 1). The presence of prolonged dry spells in Eastern Cape has significant negative impacts on crop yield than the total amount of rainfall. CA is a way to build resilience against drought and soil degradation by increasing productive transpiration (green water) and crop yield while reducing runoff (blue water) and soil erosion. Drastic changes in global temperature and precipitation are widely predicted by the end of this century. In South Africa, dry spells are predicted to become more frequent, and temperature is expected to increase by an average of 2.6 °C (Cairns et al. 2012).

The effects of these changes may be especially severe in subtropical regions such as South Africa because these regions already experience high temperatures and low and highly variable precipitation (Bryan et al., 2009; Twomlow et al., 2008; Kurukulasuriya et al., 2006; Peel et al., 2007; Stockton and Meko, 1983). CA has the potential to counteract each of these deficiencies (World Bank, 2022) through its promotion of (1) minimum mechanical soil disturbance, (2) permanent organic soil cover, and (3) diversified crop rotations in the case of annual crops or associations in the case of perennial crops.

Each of these core principles of CA can increase the water available for crops, thereby increasing drought resilience and crop productivity. For example, reduced tillage and increased crop residue can increase rainfall infiltration, reduce runoff, reduce soil evaporation (Fig.1 and 2, Araya et al., 2016b; Opolot et al., 2014; Rockström, 1997) and improve nutrient availability (Hobbs et al., 2008; Hulugalle et al., 1997). While these CA practices can help farmers better use the available water, further vulnerabilities arise from increasingly insufficient and erratic precipitation caused by climate change and variability.

Agriculture is a primary contributor to human-induced global warming (Lal, 2010; Dyer et al., 2012), accounting for 9% of greenhouse gas emissions in South Africa (UNFCCC, 2009), but agriculture can also be one of the primary means of combating this looming threat (USDA-ERS, 2022). Climate change may cause changes in rainfall amount, distribution, and timing; loss of precipitation to runoff during extreme events; increased evaporative demand; and unpredictable soil water storage.

However, CA practices can slow, or even reverse, global warming by reducing the loss of existing soil carbon and promoting soil carbon sequestration (World Bank, 2022). CA practices increase soil organic carbon (SOC) storage by increasing crop residue input and reducing the SOC turnover rate (Stöckle et al., 2012; Araya et al., 2016a; Deen and Kataki, 2003). Still, while CA shows promise to build crop resilience and increase productivity, adoption of CA practices among South Africa's small landholders remains low.

Maize (Zea mays L.), wheat (Triticum aestivum L.) and soybean (Glycine max L.) are some of the most important food and economic crops in Africa, and each has potential for use in CA systems (Kihara et al., 2011; Aulakh et al., 2012). However, most smallholder farmers in South Africa currently grow only maize, a practice that has contributed to soil degradation, poor drought resilience, and low farm productivity. A more diversified crop rotation is essential to improve the performance of smallholder farms.

For example, soybean has immense potential to contribute to food, feed, and nutrition security because it can improve soil N-fertility through biological N-fixation and reduce fertilizer requirements. This is a particularly pressing issue in the maize-based systems of the Eastern Cape Province where soils are limited in N (Mandiringana et al., 2005). Demonstrating the enhanced food security and economic benefits of CA could increase the acceptance of these practices and improve the performance of small-scale farms (Giller et al., 2011; Murungu, 2012).

While climate-smart CA practices can potentially increase drought resilience and crop productivity, several key questions remain unanswered. For example, one potential benefit of CA is improving soil water storage through reduced tillage and increased crop residue, but the potential amount and duration of increased soil water storage is unclear for subtropical climates, such as those in South Africa. Additionally, the degree to which improved soil water storage can positively affect rainfed maize, wheat, and soybean yields in this region is unclear.

While CA may increase the resilience of agricultural production systems, this potential has not been adequately evaluated in terms of increasing soil fertility and soil water conservation in long-term experiments. Finally, the logistical challenge of educating and convincing small-scale producers in South Africa of the benefits of CA practices remains. Therefore, we aim to evaluate how CA practices benefit crop resilience and productivity and soil water dynamics in Eastern Cape Province, South Africa. The main objective of this study was to assess the effects of CA systems on soil water storage, SOC, and soil productivity, long-term experiments (2012-2021) were carried out in Alice and Phandulwazi Jozini in the Eastern Cape in South Africa.

MATERIALS AND METHODS

Field experiments

A field experiment was initiated at the UFH Farm (32o 47' S and 27o 50' E) (Alice Jozini ecotope) and Pandulwazi High School (32o 39' S and 26o 55' E) (Pandulwazi Jozini ecotope, Fig. 3) during the 2012 summer growing season. The UFH site is at an altitude of 508 masl with a subtropical climate and an average annual rainfall of about 575 mm. The Pandulwazi study site is at an altitude of 750 metres above sea level with a subtropical climate, and the soil is a sandy clay loam (Nciizah and Wakindiki, 2014).

Experimental layout and treatments

The experiment was laid out in a split-split-plot design with 16 treatment combinations and three replicates per treatment (Table 1). The main plot was allocated to tillage at two levels: no-till (NT) and conventional tillage (CT). The subplot was allocated to crop rotation at four levels, maize-fallow-maize (MFM), maize-fallow-soybean (MFS), maize-wheat-maize (MWM) and maize-wheat-soybean (MWS) and the sub-sub-plot was allocated to crop residue management at two levels, residue removal (R-) and residue retention (R+). Table1. A summary of the factors for the 2X4X2 field experiment

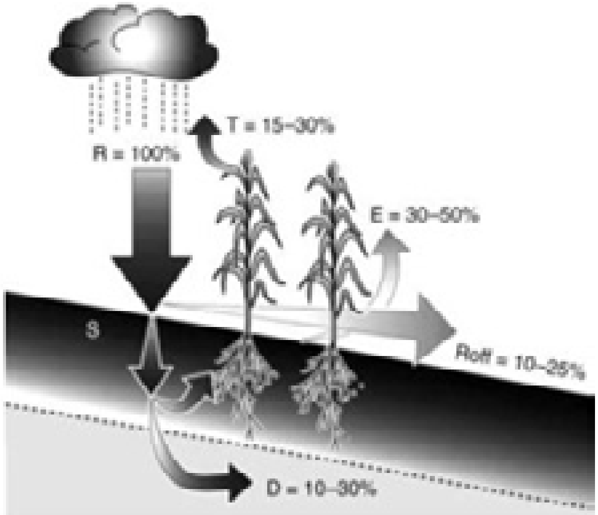

Figure 1. On-farm rainfall partitioning in dryland cropping systems in sub-Saharan Africa (SSA) (Falkenmark and Rockström, 2008). The percentages given for the different water balance components are a synthesis from research by the authors in SSA. R is rainfall, T is transpiration, E is evaporation, S is soil-moisture storage, Roff is runoff, and D is drainage (or deep percolation out of the root zone).

Figure 2. Reducing tillage and crop residue increases infiltration and reduces soil loss and runoff (Sayre, 2008) in 2008 at El Batán, Mexico.

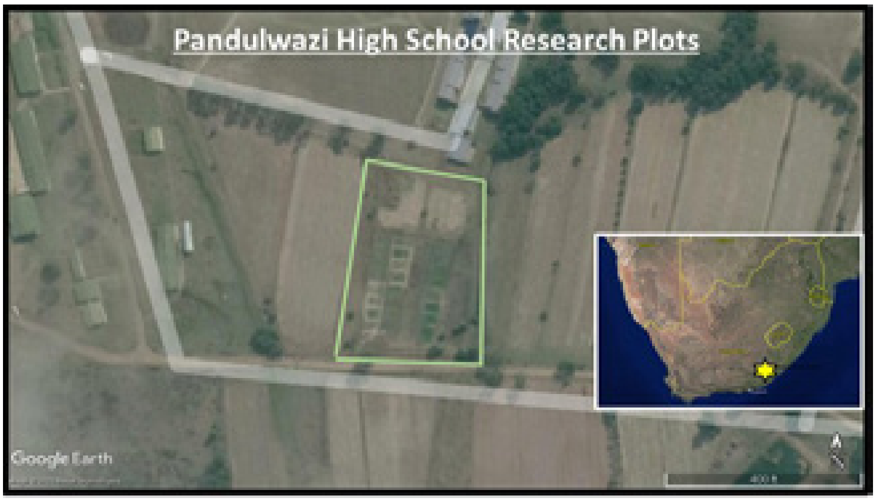

Figure 3. Conservation agriculture research plots during September 2017 (green box) at the Phandulwazi High School, located approximately 16 km northeast of Alice, South Africa. The Map insect shows the location of the research plots in South Africa. (Aerial imagery courtesy of Google Earth).

Table1. A summary of the factors for the 2X4X2 field experiment

Factor	Treatment	Level
Main plot	Tillage	Conventional tillage (CT) No-tillage (NT)
Sub plot	Crop rotation	Maize-fallow-maize (R1) Maize-fallow-soybean (R2) Maize-wheat-maize (R3) Maize-wheat-soybean (R4)
Sub sub-plot	Residue management	Residue retained (R+) Residue removed (R-)

The effects of these CA components applied singly have been researched widely and are well understood. However, given that smallholder farmers tend to adopt CA in bits and pieces (Giller et al., 2009), the benefits of practising each principle individually or in combination must be adequately evaluated. In this regard, a component omission experiment, as described above with a sub-sub-plot experiment, is designed as a useful tool in this study. This approach can lead to the identification of informed and sustainable key entry points for potential adoption by the farmers (Valbuena et al., 2012; Thierfelder et al., 2013).

A short season and prolific maize variety (BG 5785BR) were planted at a spacing of 40 cm in-row and 100 cm inter-row, targeting a population of 25 000 plants ha-1, recommended for low moisture conditions. Dryland spring wheat variety (SST 015) was planted during the winter of 2013 at a seeding rate of 100 kg ha-1, whilst soybean (PAN 5409RG) was sown, targeting a population of 250 000 plants ha-1. Fertilizer was only applied to the summer maize at a rate of 90 kg N, 45 kg P and 60 kg ha-1 K in all plots for a target yield of 5 t ha-1.

All the P, K and a third of the N fertilizer was applied at planting as a compound (6.7% N; 10% P; 13.3% K + 0.5% Zn) and the rest (60 kg) as LAN 6 weeks after planting by banding. The soybean was inoculated with Rhizobium leguminosarium before sowing. The field trial was maintained as a dry land with irrigation only to ensure crop germination. Crop residue management treatments were retained soon after harvesting of each rotational crop (Fig. 4).

Data collection

Soil properties measured include soil texture, hydraulic conductivity, field capacity, permanent wilting point, microporosity, soil plant nutrients, SOC, soil water content, and bulk density at 0–10, 10–20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm soil depths. Crop residue production and grain yields were measured for each crop.

Soil water content was measured using DFM capacitance probes at six soil depths. 48 DFM capacitance probes were installed following the manufacturer's guidelines. Each DFM probe sensor was calibrated individually using sensor water content readings, and soil water content was measured by soil sampling at six randomly selected times. The soil moisture data were collected daily for three years at the UFH site (2013 – 2015).

RESULT AND DISCUSSION

Effects on soil water content

Soil moisture was affected by tillage practices but was not consistently the same throughout the year (Fig. 4). No-tillage has more soil moisture content between 70 DOY and 240 DOY. This is because freshly tilled soils have a higher infiltration rate and, thus, less runoff than NT systems. However, CT systems form soil crust after a few rainfall events during the rainy season that decrease infiltration rate and increase runoff. For example, CT systems in the topsoil (0-10 cm) have more soil moisture content than NT between 1 DOY and 50 DOY.

Figure 4. An example of conservation agriculture practices (no-tillage, high residue, corn-winter wheat rotation) at the University of Fort Hare Farm in Alice, South Africa, in 2015 after the winter wheat harvest.

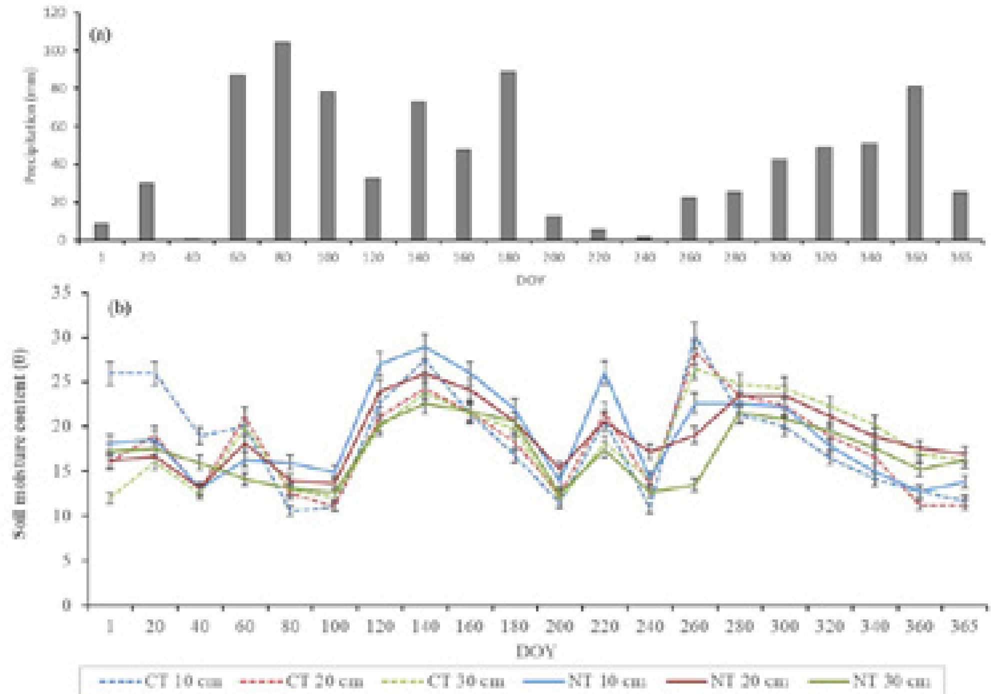

Figure 5. Rainfall (a) and (b) short-term effects of no-till (NT) compared with conventional tillage (CT) practices on soil moisture content at three soil depths (0-10, 10-20 and 20-30 cm) at Alice, Eastern Cape Province, South Africa.

With a similar trend to 2013 (Fig. 5), NT systems have a higher soil moisture content than CT systems between 70 DOY and 250 DOY, while the soil moisture content was higher in CT systems than NT systems between 1 DOY and 70 DOY and 360 DOY and 365 DOY (Fig. 6).

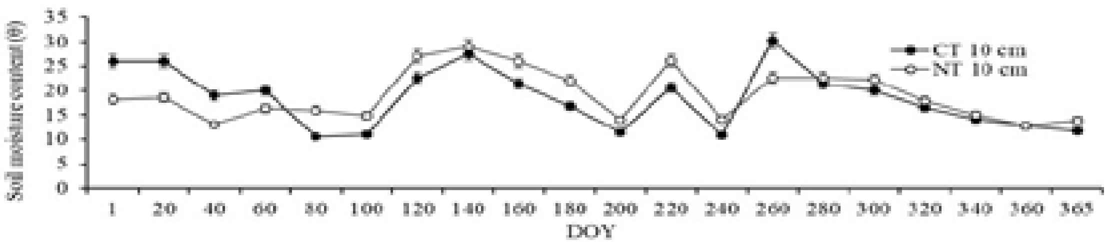

Figure 6. Daily soil moisture content was increased under no-till (NT) compared with conventional tillage (CT) in 2014 at the University of Fort Hare experimental farm, Eastern Cape Province, South Africa.

The cumulative soil water content was higher in the maize-wheat-soybean (MWS, R4) crop rotation systems at the topsoil (0-10 cm) under NT systems with crop residue retention (Fig. 7) compared to maize-wheat-maize (MWM, R3) rotation systems.

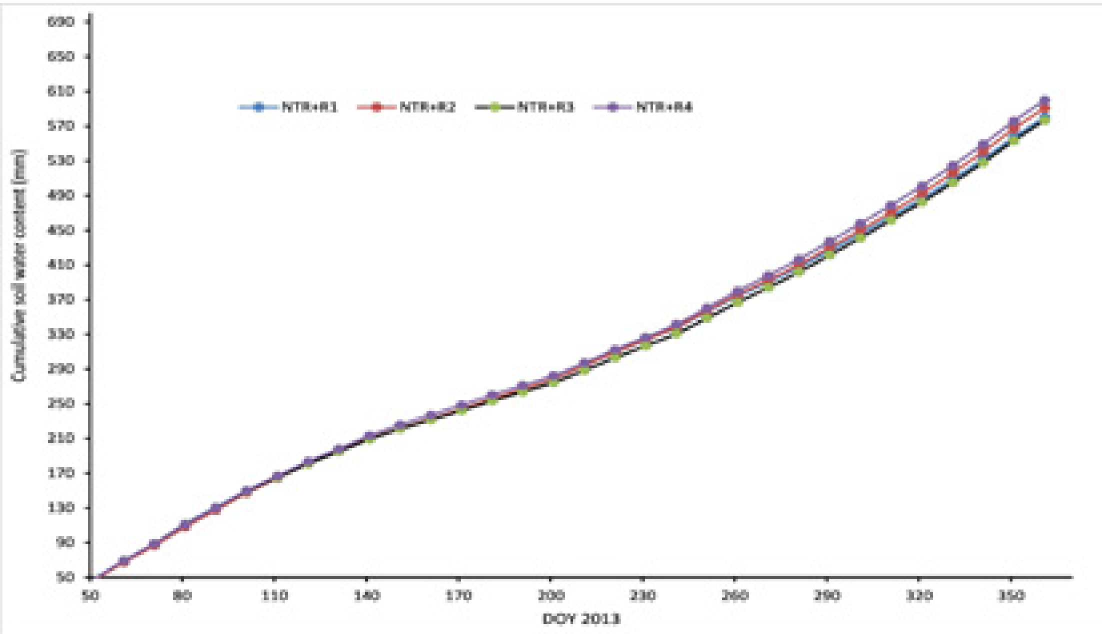

Figure 7. Short-term effects of crop rotation and crop residue retention under no-tillage systems on the cumulative soil water content in the topsoil (0-10 cm) at the University of Fort Hare experimental farm in 2013.

In the absence of crop residue, the cumulative soil water content was lowest in MWS compared to the other three crop rotation systems under conventional tillage systems.

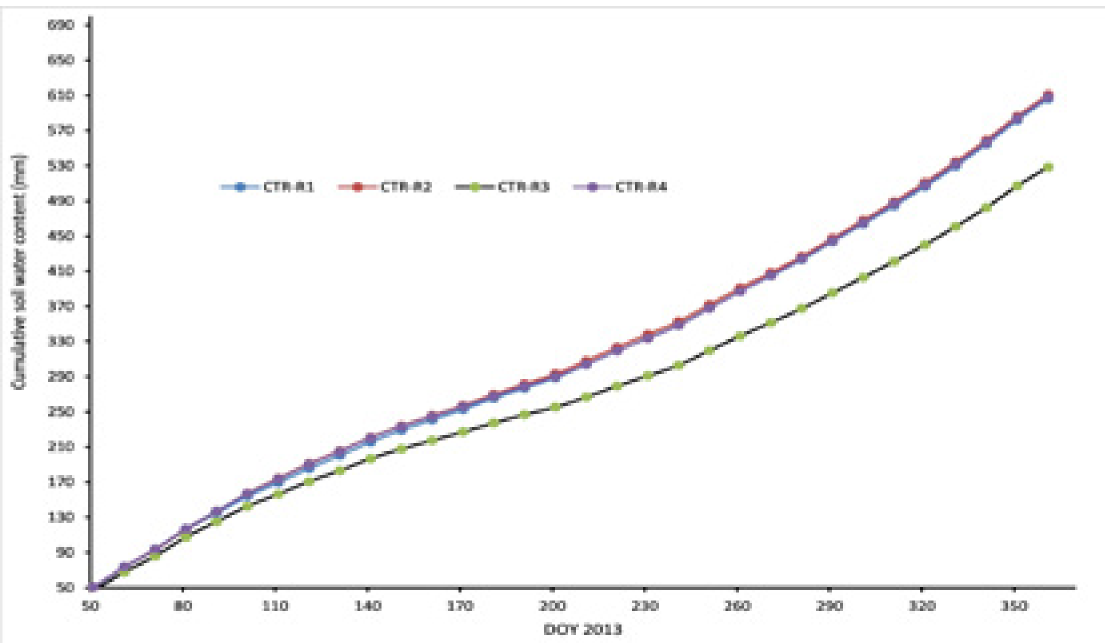

Figure 9 shows the effects of crop rotation under NT systems in the absence of crop residue on soil water content in the topsoil (0-10 cm). The soil moisture content was higher in MWS rotation systems and lowest in MWM rotation systems. This was similar to the other crop rotation in the NT systems in both with crop residue retention and removal. MWS rotation systems enhanced soil water content as compared to monocropping systems (maize-fallow-maize, MFM), maize-fallow-soybean (MFS) and MWM rotation systems.

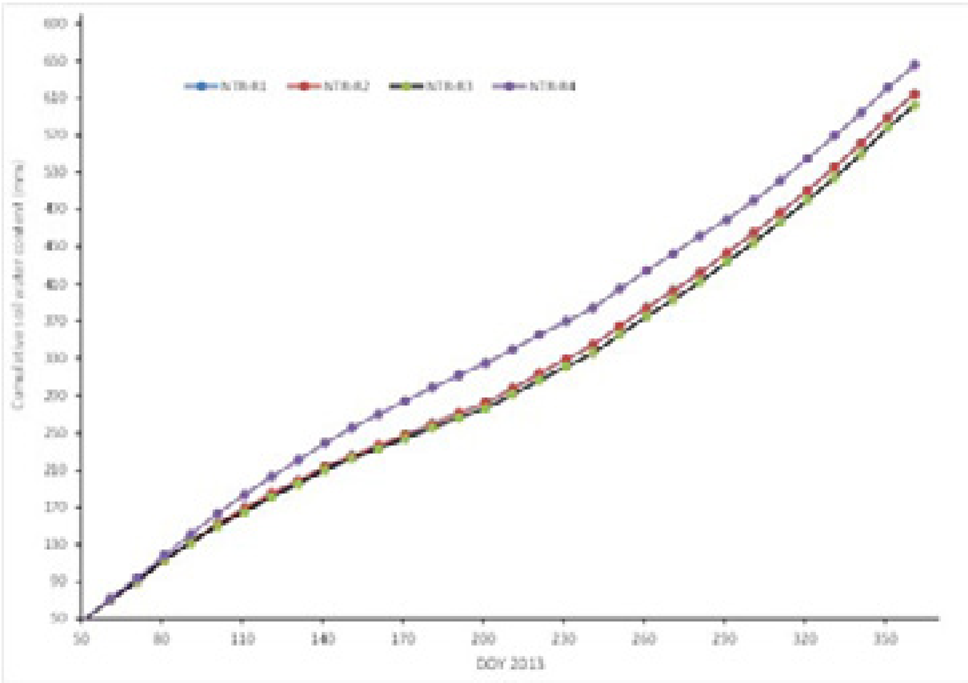

Figure 9. Short-term effects of crop rotation and crop residue removal under no-tillage systems on cumulative soil water content in the topsoil (0-10 cm) at the University of Fort Hare experimental farm in 2013.

Effects on Crop Yield

Figure 10 shows the effects of tillage practices on maize yield in 2013. Maize yield was higher in NT systems than in CT systems.

Figure 10. Maize performance was increased under no-till (NT) compared with conventional tillage (CT) at the University of Fort Hare Farm in Alice, Eastern Cape, South Africa, in 2013.

CONCLUSION

Crop residue retention, crop rotation and tillage practices affect soil water conservation. No-tillage practices enhance soil moisture content but not throughout the growing season and year. Conventional tillage practices increase the soil moisture content of the fresh tillage at planting and land preparation from about December to mid-February, while the soil moisture content is higher after February than that of CT systems in the topsoil.

Cumulative soil water content was highest in MWS rotation systems compared to MFM, MFS, and MWM rotation systems and consistently in all tillage systems and crop residue management. The lowest cumulative soil moisture was observed in the MWM systems, which indicates the reduction of soil moisture due to wheat growing during the winter growing season.

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KEYWORDS

Conservation agriculture, no-tillage, crop rotation, maize, climate change

EVALUATING AGRONOMIC AND ECONOMIC PERFORMANCE OF 4WT BASED MECHANIZED CONSERVATION TILLAGE SYSTEMS IN ETHIOPIA

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IINTRODUCTION

Mechanization is a reemerging development topic in SSA. It has several benefits (e.g. increasing productivity and timeliness), improving drudgery and improving input use efficiency, and plays an important role in contributing to the economy (Pan et al., 2017; FAO & AUC, 2018; Adu-Baffour, Daum and Birner, 2019; Ma et al., 2023). In recent years, increased tractors and associated tillage implement importation have been reported (Berhane et al., 2020). However, intensive tillage worsens soil degradation by depleting soil nutrients, contributing to lower SSA yields (Rockström et al., 2009). Alternatively, mechanized conservation tillage systems could be used.

Previous studies in Ethiopia have only considered the hand tool, draft animal conservation agriculture practices (Astatke, Jabbar and Tanner, 2003; Awoke, Kebede and Hae K, 2015; Kebede et al., 2023), and two-wheel tractors (Awoke et al., 2020; Mupangwa et al., 2023). Using two-wheels for small-scale farming may be an alternative technology, but the technology is niche-specific (Baudron et al., 2015; Omulo et al., 2022) and limited to light soils. In recent years, increased prices of rural wages, oxen and idle maintenance costs resulted in reduced availability of draft animal power in the country (Belay et al., 2022). Thus, tractor use is on the rise (Berhane et al., 2020) but alternative performance of mechanized practices was not explored.

The experiment was established for two seasons in two locations. This study assesses the short-term impact of the four-wheel tractor (4WT)-based mechanized conservation tillage systems on maize and wheat yields and economics compared to conventional mechanized tillage. Therefore, this research may contribute significantly toward meeting the objectives of sustainable intensification of African agriculture (Pretty, Toulmin and Williams, 2011) and the CA adoption process that requires testing/validation of available technologies, including reduced (ripping), no-tillage systems for subsequent knowledge transfer. Thus, smallholder farmers, service providers, private agricultural machinery manufacturers, importers, development and governmental institutions, and CA policy advocates can use mechanised conservation agriculture.

MATERIALS AND METHODS

Mechanical no-till seeders, disc ploughs, harrows, rippers, knapsack sprayers, and (50 and 120 hp) tractors were obtained from 1 Melkassa Agricultural Research Center's Agricultural Engineering Research (http://www.eiar.gov.et/marc/index.php/anrl-research/agricultural-engineering) and 2Kulumsa Agricultural Mechanization Research and Training Centre (https://www.giz.de/en/worldwide/18908.html). Soil laboratory facilities in the centres were used to undertake laboratory and desk-based studies, including data analysis of soil moisture and agronomic measurements (plant density, pod, plant height, biomass, and yield).

The experiment was conducted in two locations representing semi-arid and sub-humid agroecologies with maize-legume and wheat-legume cropping systems. The on-station trials with three treatments were laid on Randomized Complete Block Design (RCBD) with three replications in 2022 and 2023. Conventional tillage (CT) treatment; primary tillage with disc plough once and secondary tillage with disc harrow twice and manual hand seeding, covering with a traditional plough; Reduced tillage (RIPT) treatment; ripping with a ripper tyne once and manual hand seeding; Conservation Agriculture (CA) treatment; direct seeding (No-till) with the mechanical planter for maize and no-till seed drill for wheat. Maize and wheat were the main crops, and haricot bean and faba bean were rotation crops, respectively. The farm was divided into two main plots for two crops per site. The experiments were conducted on a 30 m x 7.5 m individual plot used at Melkassa, whereas a 30 m x 10 m individual plot was used at Kulumsa. Soil moisture measurements were taken before tillage, ripping, and seeding at 5,10,15, and 20 cm depth using a 5 cm diameter steel core sampler. Conventional tillage was done 3-4 weeks before seeding. Reduced tillage and no-tillage treatments were conducted on the same day of seeding. Seeding was done for all treatments on the same day.

Maize (Zea mays L., cv Melkassa II), and haricot bean variety (Phaseolus vulgaris L., cv. SER) (as a rotation crop for maize) were used. Wheat variety (Triticum aestivum L., cv Daka), and faba bean variety (Vicia faba L. cv. Wolki), (a rotation crop for wheat), were used. Seeding spacings were (75 x 25) cm for maize, (40 x 10) cm for haricot bean and faba bean, and (17-20) cm for wheat. Manual weeding occurs twice a season after weeds grow more than 10 cm (Mupangwa et al., 2017). All necessary pre- and post-emergence chemicals were sprayed using a knapsack sprayer using approved chemicals by the Ministry of Agriculture (MoA, 2021).

Glyphosate was applied for RIPT and NT treatments 15 days before ripping and zero till at Kulumsa in both years. However, Melkassa was dry in both seasons, and pre-emergence application was not required. Grain and biomass yields were collected at three locations within the centre rows of 45 m2 for maize, 24 m2 for haricot bean and faba bean, and 15 m2 for wheat from each plot for each treatment. The economics for each treatment was determined using standard enterprise budgeting (CIMMYT, 1988). Effects of tillage treatments on yield were evaluated using Analysis of Variance (ANOVA) using RCBD experimental design (Gomez and Gomez, 1984). Shapiro Wilk test was used for the normality test. LSD test of significance at ($p < 0.05$) to test the difference between treatment means.

RESULTS AND DISCUSSION

CT had the lowest soil moisture at Melkassa at 20 cm, but at Kulumsa, the lowest recorded was at 5 cm depth before seeding in 2022. The significant ($p < 0.05$) maize and haricot bean grain yield findings from CA (RIPT and NT) indicated that the soil moisture at the upper 5 cm layer of the CA (RIPT and NT) treatments was comparable or slightly lower than that of the CT treatment in both seasons at Melkassa. However, the CT treatment exhibited lower soil moisture than the CA treatments at a 15 to 20 cm depth at the planting time. This suggests that soil moisture was lost, possibly due to evaporation, surface erosion, or a combination of both, in the CT treatment in both seasons at Melkassa. Better soil moisture availability was reported on hand hoe no-till (Liben et al., 2017), oxen-drawn rippers (Temesgen et al., 2009; Awoke, Kebede and Hae K, 2015), and reduced tillage using 2WT (Awoke et al., 2020) experiments in Ethiopia. Conversely, the uniform rainfall availability at Kulumsa may explain the lack of a significant difference ($p< 0.05$) in wheat grain yield in both years.

However, RIPT had the highest profitability due to lower total variable cost and better returns to labour cost and returns to total variable cost per US$ invested. On average, 34.87% of the total variable cost of CT was attributed to land preparation in wheat production. However, this figure was lower for RIPT (10.38%) and NT (14.67%). Consequently, it appears that RIPT has the potential to conserve moisture in semi-arid and be profitable in sub-humid areas in the short term.

CONCLUSION

In semi-arid agroecology, where rainfall is highly variable, this study has shown that significant yield increments can be attained through the reduction of intensive soil inversion and improved soil moisture conservation over two seasons. Furthermore, in mid-highlands with sufficient rainfall, our results demonstrated that profitability can be maintained by reducing the operating cost. Thus, ripping could be a potential practice to promote mechanized CA for policy advocates and implementers through hiring service provisions. However, long-term research is required to understand yield stability and profitability.

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KEYWORDS

agronomic performance, disk ploughing, mechanized conservation agriculture, no-till seeder, ripping

ADOPTION OF CONSERVATION AGRICULTURE IN SOUTH AFRICA – FROM CURRENT INSIGHTS AND INITIATIVES TOWARDS FUTURE NEEDS AND RESPONSES

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INTRODUCTION

Two studies were used to develop insights and initiatives towards future needs and responses for adopting conservation agriculture in South Africa. The first study (Study 1) properly assessed CA adoption within the annual cropping system farming communities in South Africa to fill the data gaps and clear up the uncertainty around the status quo, trends and spread of CA in the country (FAO, 2021). The second study (Study 2) assessed producers' experiences during the transition period to conservation agriculture. It was conducted by ASSET Research during the 2023-24 season and funded by The Maize Trust in South Africa. The results of these two studies were used to identify gaps and opportunities for developing appropriate responses for CA in the future.

RESEARCH METHODS

Study 1:

The research applied used a survey approach based on one-on-one telephonic interviews. The following steps were taken:

1. Identified the most suitable *spatial unit*
2. A Magisterial District was identified as the most practical and smallest spatial map unit for this purpose
3. Identify local <u>key informants</u> for each of the Magisterial Districts or broader regions (comprising several districts) who are knowledgeable about farmers' use (adoption) of different farming systems in the districts.
4. Select several *<u>enumerators</u>* to assist with data collection from the key informants in the various Provinces of South Africa
5. Collect the CA adoption figures per Magisterial District. The CA definition used was:
    - No-till planting (either disc or tine no-till planter)
    - (strip-till or any other tillage does not qualify) Crop residues (>30% soil cover)
    - At least two crops or more in rotation
6. Aggregate data on a Magisterial District, Provincial and National level.

The survey results were then analysed and discussed, alluding to significant CA adoption stories and patterns and trends observed. Conclusions and strategic recommendations were gleaned from the survey results and analyses that are relevant and informative for future needs and responses.

Study 2:

The study aimed to investigate the CA producers' transition to CA journey and gather insight on how they navigated the J-curve. The study used a qualitative survey (a short online 15-minute questionnaire) to assess the experiences of selected CA farmers concerning their conversion from conventional tillage (CT) to no-till or conservation agriculture (NT/CA).

The questionnaire included sections on their practice region, motivating factors to change, familiarity and experience with the J-curve, challenges faced during the transition period, solutions to overcoming them, and support.

A total of 25 CA farms(er)s in the different production regions were identified. It should, therefore, be noted that the response in this questionnaire is from experienced and knowledgeable CA farmers. The questionnaire link was shared with them via email and WhatsApp where applicable. These were first shared at the beginning of June 2024, and a couple of follow-ups were done thereafter.

Data was collected, compiled, and analysed upon the survey's due date. A total of 21 responses were received. No discrepancies were found when capturing and analysing the data.

RESULTS AND DISCUSSION

Study 1:

This study found that CA is applied on 1 607 081 ha, comprising 25% of the total area under commercial annual crop-livestock systems in South Africa. This is a significant increase from any other figure used in the past, by far the biggest in

Africa and 12th on the list of all countries worldwide. Areas with high adoption rates were found in the Western Cape, KwaZulu-Natal, North West, Mpumalanga, Limpopo and Gauteng Provinces. The Western Cape has a 51% adoption of CA comprising 804 866 hectares, the North West Province with 37% and 330 464 hectares, Mpumalanga Province with 24% and 205 598 hectares, Free State Province with 3.35 % and 73 519 hectares, KwaZulu-Natal Province with 38% and 62 957 hectares, Eastern Cape Province with 2% and 3 194 ha, Limpopo Province with 27% and 68 834 hectares, Gauteng Province with 33% and 57 649 hectares.

Figure 1 shows the spatial distribution of CA adoption in South Africa in 2021. Areas with higher adoption rates are clearly visible, especially in the Western Cape, KwaZulu-Natal, North West, Mpumalanga, and Limpopo Provinces.

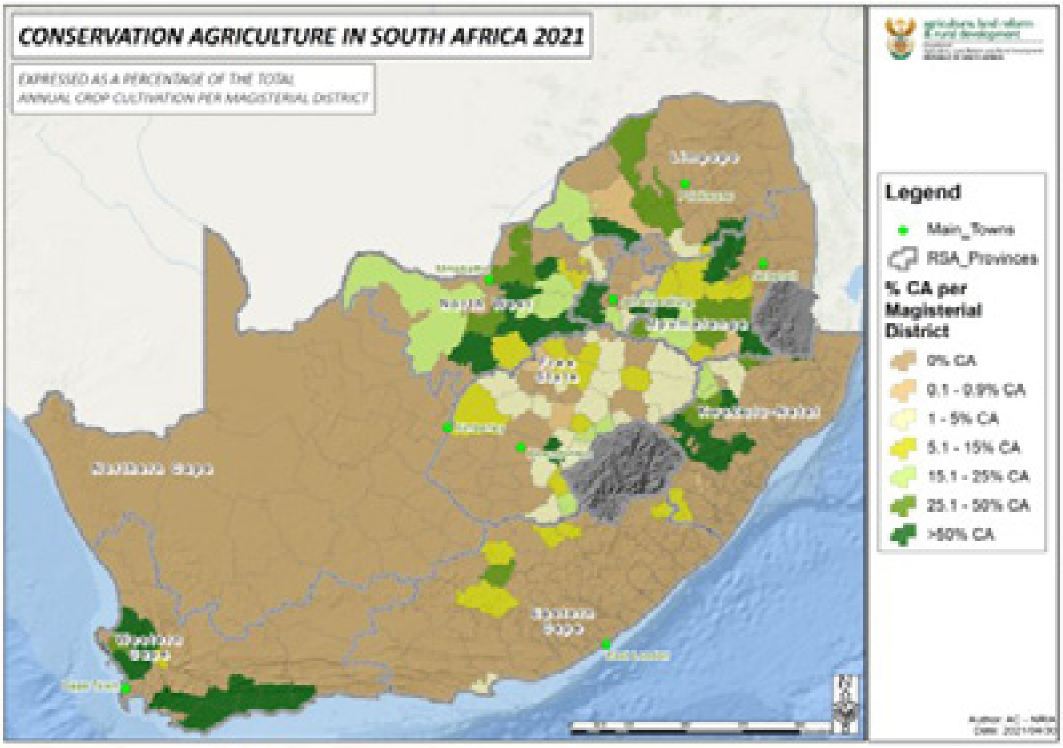

Figure 1. The spatial distribution of CA adoption in South Africa in 2021 expressed as a percentage of the total cultivated area under annual crop-livestock systems (from FAO, 2021)

CA farmer pioneers and innovators, together with their structures, played a key role in adopting and spreading CA in South Africa. Other factors that played a key role are local CA equipment manufacturers promoting equipment as part of the whole CA system, local study groups and awareness events, local research initiatives where farmers, researchers and other key stakeholders collaborate, international success stories and cross-visits, international pioneer CA farmers, prominent international and local CA scientist, local service providers and agribusiness.

Study 2:

General challenges faced during the transition period

Farmers indicated that their biggest challenges during the transition period were making mistakes to implement CA correctly and soil-related challenges. Contrary to expectation, affected productivity (yields), financial constraints, and weather-related challenges imposed the least challenge on most of the farmers—Figure 2.

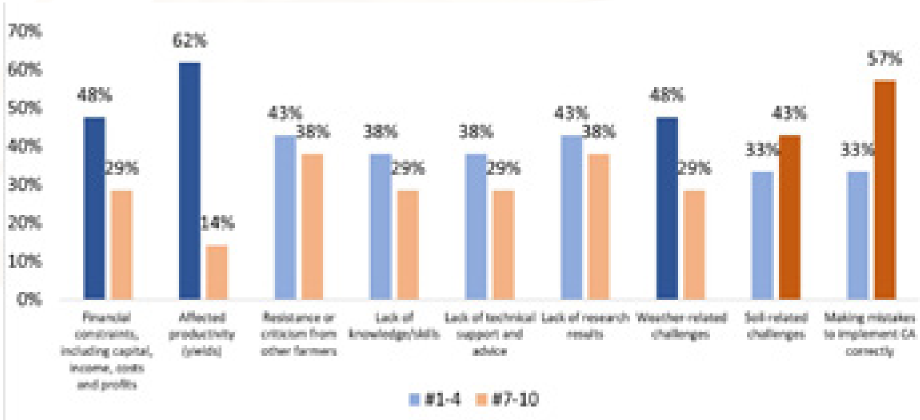

Figure 2. General challenges faced during the transition period.

Level of difficulty farmers faced with different CA practices during the transition period

More specifically, farmers were asked to indicate their difficulty faced with different CA practices during the transition phase. The following principles were rated most difficult: integrated weed management, living roots in the soil, integrated soil fertility and acidity management, and soil cover. Of the principles, most farmers rated livestock integration, cash crop rotation, and access and use of CA machinery/implements to be, on average, the least difficult to implement – Figure 3.

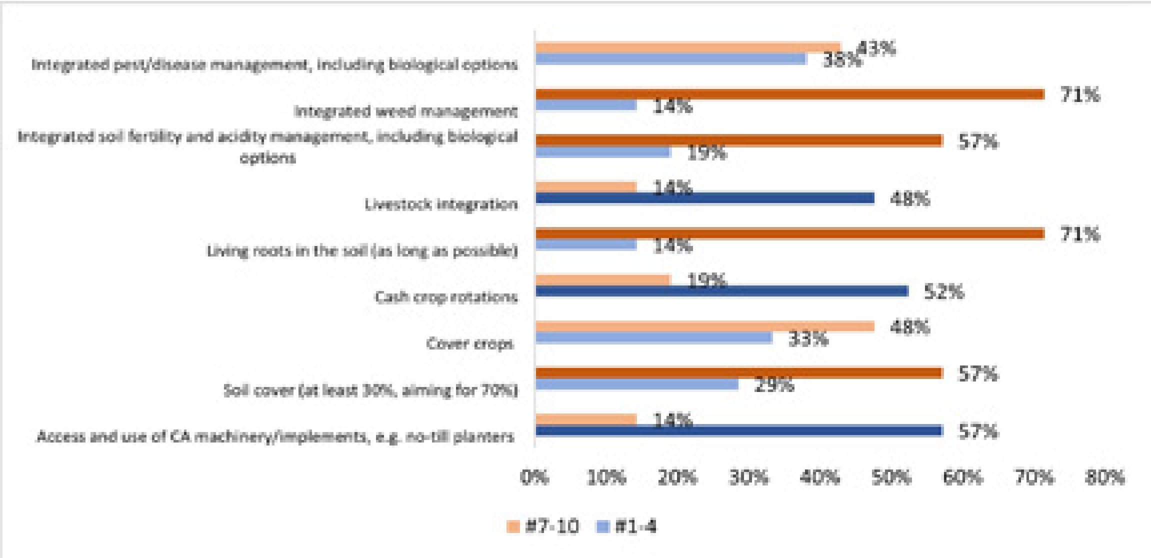

Figure 3. Level of difficulty farmers faced with different CA practices during the transition period.

How farmers managed to overcome the above challenges during the transition phase

Farmers were asked to indicate how they overcame common challenges in the transition phase (see Figure 4). To this, improvement of farmer's knowledge and skill; (on-farm) testing and adapting of CA practices, regular monitoring and evaluation of results; forming or joining partnerships/networks for support; and seeking assistance from research / technical experts were used most to manage or overcome challenges during the transition phase. The following strategies were the least commonly used to manage or overcome challenges during the transition phase: using other sources of income and selling of other assets.

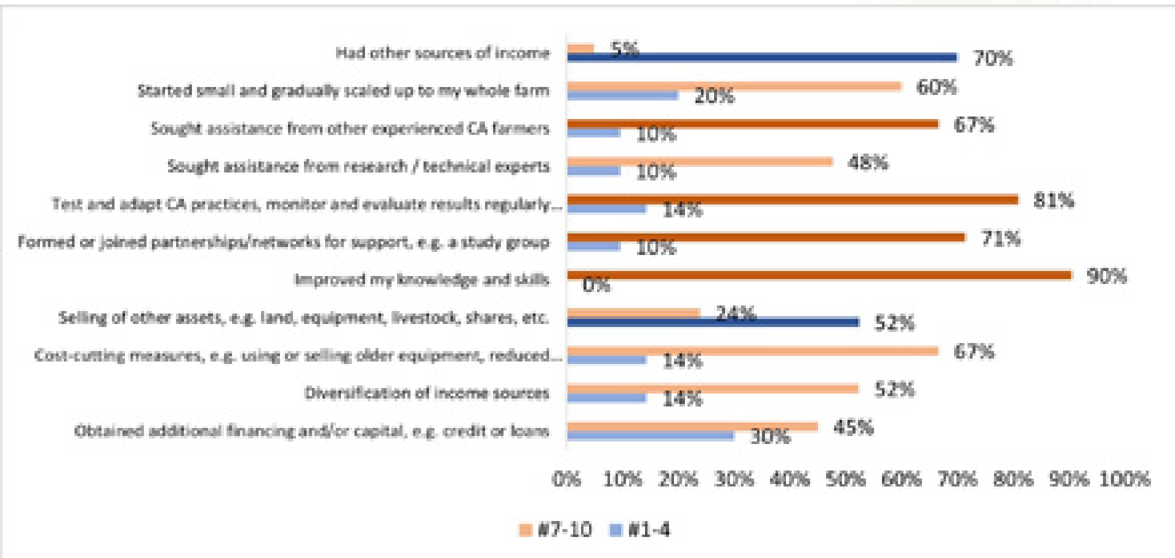

Figure 4. How farmers managed to overcome the above challenges during the transition phase (J-curve)

CONCLUSIONS

The existing CA farmer-led structures (e.g., clubs and groups) created by farmers and other stakeholders that successfully spread the adoption of CA in the various regions in South Africa as assessed in these studies, should be supported and used as ideal platforms to implement, strengthen and scale out/up CA initiatives, such as awareness, research and extension, to other farmers, stakeholders and regions.

To avoid making mistakes in implementing CA correctly, farmers must take at least one year to build enough knowledge to start the transition journey. Integrated weed management, living roots in the soil, integrated soil fertility and acidity management, and soil cover practices were found most difficult by farmers.

The biggest way farmers managed or overcame challenges during the transition phase was through improved farmer knowledge and skills, with 90% of farmers rating this very highly. This further reinforces the significance of this factor to farmers' overall success in implementing CA.

A farmer's ability to test and adapt CA practices and monitor and evaluate results regularly (e.g., through on-farm trials, trial-and-error) is the second most rated way in which farmers manage and overcome challenges. Indeed, this shows that an on-farm learning and adapting approach is most effective when backed up or informed by constant monitoring and evaluation.

Knowledge seeking/sharing and interaction with other farmers have also been shown to be essential aspects of success. Hence, most farmers rated farmer-to-farmer partnerships/networks for support, e.g., a study group, very high as well. This was also rated very high under support and resources most helpful for information and advice during the transition phase.

Overall, most CA practices translate a positive change or benefit between 1 and 5 years, a few between 6 and 9 years, and even fewer after 9+ years. This may be due to multiple factors, such as those that are on-farm and region-specific. Across the board, CA farmers indicated that positive impact can be experienced sooner and not much later.

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KEYWORDS

CA farmer pioneers and innovators, CA farmer-led structures, equipment manufacturers, local research initiatives, J-curve, transitioning

BENEFITS OF COVER CROPS IN COMMERCIAL MAIZE-BASED CONSERVATION AGRICULTURE PRODUCTION SYSTEMS OF SOUTH AFRICA

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INTRODUCTION

In recent decades, the agricultural landscape has witnessed a paradigm shift towards sustainable and environmentally conscious practices. CA has emerged as a transformative approach. FAO Strategic Framework for 2022-31 (FAO, 2021) is focused on supporting the transformation to a more efficient, inclusive, resilient, and sustainable agrifood system for better production, better nutrition, a better environment, and a better life.

One of its Programme Priority Areas, the BP1 - Innovation for Sustainable Agriculture Production, focuses on supporting countries, family farmers, and small producers in integrating sustainable agriculture, technologies, policies, and innovations to enhance crop, livestock, and forestry productivity while optimizing agricultural system structure and functionality and minimizing inputs. It was agreed to use the area under CA as an indicator. To meet this requirement, FAO is analysing the evolution of CA.

MATERIALS AND METHODS

A global survey gathered CA data on practices, challenges, and opportunities. The survey, available from https://conservationagriculturesurvey.org, was distributed to FAO-hosted Global CA Community of Practice members, ensuring a proper understanding of expert opinions.

RESULTS AND DISCUSSION

In 1990, CA covered 11 M ha of cropland, growing to 67 M ha by 2000. Since 2008/2009, the CA cropland area globally has expanded to over 10 M ha annually, a notable increase from the 5 M ha per year between 1990 and 2008/2009. By 2015/2016, CA encompassed 180.4 M ha, constituting 12.5% of global cropland. In 2018/2019, the total area reached 205.4 M ha, accounting for 14.7% of global cropland (Kassam et al, 2022). The most recent results (2022/2023) will be available for the 9WCCA.

CONCLUSIONS

The evolution of CA has demonstrated the adaptability of its 3 Principles (FAO, 2023) to diverse regional contexts. Different parts of the world have developed and implemented CA strategies tailored to their specific agroecological conditions, cropping systems, and socioeconomic dynamics. Several key conclusions can be drawn for CA: increasing recognition of its benefits, diverse regional approaches, enhanced resilience to climate change, economic viability, and productivity gains for any farmers.

Yet, adoption faces challenges, such as the need for initial investment, knowledge dissemination, and overcoming ingrained tillage practices. Addressing these requires a multi-stakeholder approach involving farmers, researchers, policymakers, and extension services.

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KEYWORDS

survey, experts, no-tillage, groundcovers

HARVESTING SUSTAINABLE FUTURES: GLOBAL PERSPECTIVES ON THE ADOPTION OF CONSERVATION AGRICULTURE

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KEYWORDS

survey, experts, no-tillage, groundcovers

CONSERVATION AGRICULTURE IN THE EUROPEAN COMMON AGRICULTURAL POLICY (CAP): THE ECO-SCHEMES IN SPAIN.

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INTRODUCTION

The Common Agricultural Policy (CAP) is a standard policy of all the countries of the European Union (EU), aimed at the agricultural sector and the rural environment, articulating measures to offer a reasonable standard of living to farmers and livestock farmers and to guarantee food security through a sustainable production model in environmental, social, and economic terms. Over the years, the objectives of the CAP have been adapted to the challenges of the agricultural sector and the new needs of citizens through successive reforms. Initially, the aim was to ensure the security of supply and improve farmers' incomes. The objective is to produce the following standards that enable us to face today's environmental challenges, such as climate change, soil degradation, and water pollution.

A new element introduced in the latest CAP reform is the so-called eco-schemes. These measures are linked to the payment of practices related to carbon farming or agroecology, which aim to improve the soil structure and increase its carbon content, reduce erosion and desertification, reduce greenhouse gases, and promote biodiversity associated with agricultural areas, landscapes, and the conservation of natural resources. They are voluntary and designed to go beyond the mandatory requirements already prescribed by the cross-compliance system contemplated in the CAP to be eligible for basic income. In Spain, the Ministry of Agriculture, Fisheries and Food has designed each eco-schemes for which farmers are eligible under the CAP 2023-2027. Aware of the environmental challenges facing the country and, in particular, of the climate commitments acquired in the framework of European legislation, Conservation Agriculture (CA) has been considered a fundamental tool for these purposes. It has been included as an agricultural practice in six eco-schemes. This is the first time CA has had an income for its implementation at the national level, which is a milestone in the legislative support for this type of soil management system in Spain.

THE ECO-SCHEMES OF CONSERVATION AGRICULTURE IN SPAIN

Three CA practices are considered in the eco-schemes of the new CAP in Spain: one in herbaceous crops (No-tillage) and two in woody crops related to Groundcovers (GC) (Sown or spontaneous grass cover crops and pruning residues) (Table 1). Table 1. Practices included in the CAP 2023-2027 eco-schemes in Spain (in bold, CA practices).

Eco-scheme	Main objective	Practices	Land use
Low-carbon agriuclutre	To improve soil structure, reducing erosion and desertification, increasing the carbon amount and reducing emissions.	Intensive grazing	Permanent pastures and permanent grasslands.
		No-tillage	Arable land.
		Spontaneous or sowed vegetation cover.	Permanent crops.
		Inert vegetation cover.	Permanent crops.
Agroecology	To favour biodiversity associated to agricultural areas, landscapes, and the conservation and quality of the natural resources, water, and soil.	Sustainable mowing and the establishment of biodiversity isles.	Permanent pastures and permanent grasslands.
		Crop rotations with improver species.	Arable land.
		Establishment of biodiversity areas or sustainable management of the sheet of water.	Arable land and permanent crops, including woody crops.

These three practices apply to three different types of areas, making up the nine CA eco-schemes in force in Spain. The farmers who wish to benefit from one of the eco-schemes that includes CA practices are based on the three principles promoted by the FAO for this type of management system. Table 2 shows a summary of these requirements and the amounts received by the farmer according to the kind of area in which the eco-scheme is applied. A supplement of € 25/ha must be added for each year the farmer undertakes to maintain the area under CA.

Table 2. Requirements, types of areas and amounts applicable for CA eco-schemes.

CA practice	Requirements	Land use	Tramo 1		Tramo 2	
			Umbral (ha)	Amount (€/ha)	Umbral (ha)	Amount (€/ha)
No tillage	Not working on the soil and stubble maintenance on the field in ≥ 40% of the corresponding arable land. Crop rotation in areas where conservation agriculture is performed.	Arable land: dry land	≤70	47.67	>70	36.91
		Arable land: damp dry lands	≤30	70.52	>30	49.36
		Arable land: irrigated land	≤25	139.53	>25	97.69
Spontaneous or sowed vegetation cover	Vegetation cover (sowed or spontaneous), alive or scorched, on the field during the whole year. The cover must remain alive, at least, for 4 months between the 1st of October and the 1st of April. Minimum space of the vegetation cover (>40% of the free width of the crown projection) high land slope field covers must be one meter wider. Vegetation cover management through mechanical mowing or weeding. The cuttings are left on the field so that the initial space taken up by the vegetation cover is covered. The use of phytosanitary products over the vegetation cover is not allowed, with some exceptions	Woody crops: slope < 5%	≤15	61.07	>15	61.07
		Woody crops: slope 5-10%	≤15	113.95	>15	113.95
		Woody crops: slope > 10%	≤15	165.17	>15	115.62
Inert vegetation cover.	Crushing the pruning remains and place them on the field. Farm register: date of pruning. Minimum space of the pruning remains inert cover (>40% of the free width of the crown projection). The use of phytosanitary prod-ucts over the pruning remains inert cover is not allowed, with some exceptions	Woody crops: slope < 5%	≤15	61.07	>15	61.07
		Woody crops: slope 5-10%	≤15	113.95	>15	113.95
		Woody crops: slope > 10%	≤15	165.17	>15	115.62

RESULTS AFTER THE FIRST SEASON OF IMPLEMENTATION

After one season of implementation of the new CAP, it can be said that the CA eco-schemes have succeeded in terms of the number of hectares they covered. According to provisional data from the Ministry of Agriculture, Fisheries and Food, the area under the NT eco-schemes amounted to 1.3 M ha, the area under the Spontaneous or sowed vegetation cover eco-scheme was 1.9 M ha, and the area under the Inert vegetation cover eco-scheme was almost 433 000 ha. According to previous national statistics, in the season 2021/22, 985 556 ha of arable crops were under no-tillage, and 1.45 M ha of woody crops were under cover crops. Thanks to the eco-schemes, the area under CA increased by 52% in the last year, with the no-tillage area being 34% and that of cover crops by 63% (Figure 1).

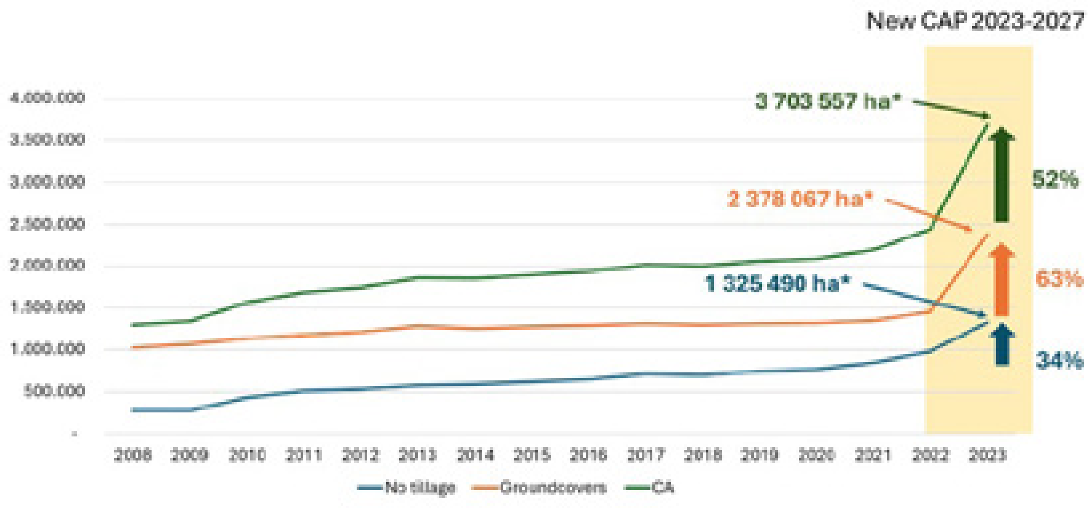

Figure 1. Evolution of the area of CA in Spain (Source: Years 2002-2022, ESYRCE (2023), Year 2023: MAPA (2023) *Provisional data)

The budget dedicated to the CA eco-schemes in this first campaign was 751.13 M €, with NT accounting for 443.57 M € and GC for 307.56 M €. This represents almost 68% of the total budget of the eco-regimes, which gives an idea of the important investment made in the CAP framework to promote SD and CG in Spain.

CONCLUSIONS

Conservation Agriculture has demonstrated environmental, economic, and social benefits worldwide for many years. In Spain, farmers' conviction has led them to adopt management systems, such as direct sowing in herbaceous crops or cover crops in woody crops. This has allowed Spain to become a leader in this type of practice in Europe, although a slowdown in the area's growth under CA has been observed in recent years.

Based on the results obtained after the first year of the implementation of the CAP 2023-2027, it can be affirmed that eco-schemes have proved to be a powerful tool for the promotion of this type of practice among farmers, giving a new boost to the area under CA in Spain. This should not be to the detriment of alternative measures to support this type of management, such as training and knowledge transfer, complementary to the economic incentives provided by eco-schemes.

Undoubtedly, these experiences should be helpful to governments that want to promote CA at the national level when designing a support plan for this type of management system. In any case, the plan should be comprehensive, including not only incentive measures but also training and counselling programs and monitoring tools.

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KEYWORDS

No-tillage, Groundcovers, Common Agricultural Policy, Eco-schemes

BIOPHYSICAL AND SOCIAL CONSTRAINTS RESTRICT ADOPTION, YIELD AND ECONOMIC GAINS FROM LONG-TERM CONSERVATION AGRICULTURE IN INTENSIVE RICE-BASED SYSTEMS

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IINTRODUCTION

Conservation Agriculture (CA) is practised on over 220 million ha worldwide (Kassam et al. 2019), mainly on non-rice, rainfed crops and highly mechanized large farms. In the Eastern-Gangetic Plains (EGP), CA practice for over 40 consecutive crops during 14 years in each of three long-term experiments and on farms confirmed that there are multiple long-term benefits (improved soil quality, nutrient balance, irrigation water use efficiency, and reduced GHG emissions and weed seed banks) for smallholders. However, converting rice to minimum soil disturbance establishment remains a challenge. Here, we examine the bio-physical and social constraints to on-farm adoption of CA in the EGP.

MATERIALS AND METHODS

Since 2010, three rice-based cropping systems in Rajshahi and Mymensingh districts of Bangladesh comprising a legume-dominated system (lentil (Lens culinaris Medik.) – mung bean (Vigna radiata (L.) R. Wilczek) – monsoon rice (Oryza sativa L.)) and two trials of cereal-dominated systems (wheat (Triticum aestivum L.) – mung bean –monsoon rice) were evaluated. The experiments were laid out in a split-plot design and replicated four times (in Rajshahi) and three times (in Mymensingh).

Crop establishment following Conservation Agriculture (CA) and conventional tillage (CT) treatments were in the main plots, and two levels of crop residue retention (high crop residue retention and low crop residue retention) were assigned to the sub-plots. For an in-depth study of NPKS budgets in CA vs. CT, the sub-plots were split to accommodate 2-3 nutrient rates. In the case of CA, all non-rice crops were established using a single pass with the Versatile Multi-crop Planter (VMP, Haque et al., 2017), whereas non-puddled transplanting (Haque et al., 2016) was followed in the case of rice.

For CT, 3-4 tillage passes followed by seed broadcasting and land levelling were followed to establish non-rice crops. In contrast, soil puddling followed by manual transplanting of rice seedlings was followed for rice establishment.

RESULTS AND DISCUSSION

Benefit From Long-term CA

The long-term practice of CA confirmed reduced crop production costs, similar or higher grain yield and increased profit by 48-460% relative to current practices (Miah et al. 2017). This was consistent with another long-term experiment conducted on the Bangladesh Agricultural University (BAU) Farm in 2012, where the rice equivalent yield of 9 crops increased by 0.9 t ha-1, which was significantly higher for CA than CT in the rice-wheat-mungbean cropping pattern (Kader et al. 2022).

Compared with CT, considerably higher soil organic carbon (SOC) was reported in CA at 0-10 cm depth after 3-5 years of cropping (Islam et al. 2022; Alam et al. 2019). Practising CA for 4-5 years with upland crops and non-puddled transplanting for rice crops decreased life cycle greenhouse gas emissions by 4.2 and 3.8 t CO_2-eq ha-1 in the Rajshahi experiments, respectively (Alam et al. 2019).

In the BAU Farm, a significant increase in SOC concentration was observed in the 0–5 cm soil layer between CT (1.58%) and CA (1.83%) after 8 years of CA practice. In the same experiment, SOC concentration at 0–5 cm depth was not altered by the level of crop residue retention, N fertilization, or their interactions with crop establishment systems. There are also positive improvements in nutrient balance, particularly for potassium, phosphorus, sulphur and nitrogen, and increases in nutrient use efficiency when practising CA for 12 years (Kumar et al. 2022; Islam et al. 2023).

Constraints Restricting Adoption of CA:

Challenge to changing mind-set:

Land preparation using intensive tillage operations and cleaning all residue/stubble from fields are deeply embedded practices for crop cultivation by smallholders. Farmers are criticized as lazy in their community if the crop fields are not well-tilled and clean. A strong motivation, supported by on-farm demonstrations of the benefits and training, is required to shift significant numbers of farmers to minimum soil disturbance and retention of crop residues, two central pillars of CA.

Limitation of affordable and user-friendly CA machinery:

Smallholders' average fields are typically small (~1000 m2) and fragmented in the EGP. Available 4WT-based CA machinery is generally too large to manoeuvre and provide effective services at acceptable costs for smallholders. Infrastructure for field access of the CA machinery is lacking in landscapes occupied by smallholding farms in the EGP. Diverse cropping patterns and intensive cropping (3-4 crops per year) are other limiting factors to machinery used in small and fragmented lands. Since 1990, Bangladesh has led Asian 2WT-based planter R&D. However, there are only a few 2WT-based planters suitable for CA systems, including the VMP (Araujo et al. 2020).

Challenge of residue retention:

While retention of crop residue is one of the main principles of CA, they are valuable resources for smallholders with alternative uses, including feed for animals, which hinders the retention of increased amounts of residue in the field. In intensive cropping systems, to ensure optimum planting time, farmers need to make the turn-around time as short as possible (even 0 days) before establishing the next crop. Successful operation of small, lightweight and low horsepower CA machinery in freshly retained crop residue (from previous crop) plots is challenging.

Standing fresh residue plus the regrowth of the previous crop (particularly from rice) creates shading and depletes nutrient availability for the early growth of the next crop. Seedling mortality due to root disease may increase (in the case of lentils) as the soil remains moist for longer when residue is retained. Early-stage nutrient deficiency symptoms in direct-seeded rice (DSR) in CA plots are common due to nutrient immobilization by decomposing crop residue. Later, the CA crops extended their growth by 7-10 days, delaying the establishment of the next crop. Due to poor seed- or seedling-soil contact, lower emergence of non-rice crops and increased tendency of rice seedlings to float in non-puddled rice were observed in CA systems. In rice crops, more significant non-effective tiller numbers were reported in CA than in CT.

Non-puddled- and direct seeding establishment of rice:

The development of a cost-effective and reliable system of rice establishment without puddling soil is one of the barriers to wider scale adoption of CA in rice-based systems. As in northwest India, where zero-till was widely adopted for wheat and other Rabi (winter season) crops, but not in rice, in Bangladesh, the benefits of CA are now well demonstrated for Rabi season crops (Bell et al. 2018). Non-puddled transplanting for wetland rice is promising for some soil types, especially mechanized transplanting (Haque and Bell 2019). However, DSR cultivation packages in CA systems are not yet sufficiently reliable for on-farm practice.

Weed infestation is one of the major constraints for the initial years of CA adoption, particularly for DSR. Repeated tillage (3–4 operations in a single field) and/or ponding of water in the fields are effective practices in CT to kill pre-planting weeds. Farmers lose the benefits of tillage as one of the tools for initial weed control by switching from CT to CA. Although post-planting herbicides are widely used in intensive rice-based systems (Haque and Bell, 2019), knock-down herbicides such as glyphosate are still uncommon. Farmers and service providers hired to plant crops using CA are initially not aware of the need for vigorous pre-planting weed control, especially in the case of heavily weed-infested plots, to establish crops using minimum soil disturbance. Much training of farmers, service providers and extensionists is needed to ensure appropriate doses and timing of herbicide application, calibration of sprayers, selection of appropriate sprayers and nozzles, safety issues of herbicide use, etc. (Haque et al. 2018).

Changes in hydrology:

Long-term CA practices involving minimum soil disturbance for rice establishment are likely to alter soil water regimes by increasing the permeability of the plough pan. This is beneficial for non-rice crops such as wheat, e.g. Mahmud (2021) reported 11-33% water savings and higher water productivity of wheat in CA. However, altered hydrology creates new risks and uncertainty regarding the best time of establishment, optimum weed control methods, drought risk and nutrient leaching. Risks and uncertainties will differ among the different rice seasons. The adoption of CA at scale may impact soil hydrology and recharge to groundwater. Key research questions that require investigation for CA adoption to proceed at scale relate to - the frequency of waterlogging events during the early monsoon season when DSR establishment would occur; the number of irrigation events will be required to maintain water levels for wetland rice; the risk of excessive drying of the profile during periods with limited rain and during the rice ripening period.

CONCLUSION

Almost two decades of research, much of which was funded by the Australian Centre for International Agricultural Research, demonstrated wide-ranging benefits from the adoption of CA in rice-based farming systems in the EGP. However, the adoption is still patchy and mostly centred on higher land supporting mostly non-rice crops.

Further investments are required in CA research and development for smallholders' user-friendly rice cultivation systems, machinery development and out-scaling, and training and demonstration for researchers, extensionists, and farmers. Government policy interventions for CA R&D and out-scaling are also essential in intensive rice-based systems in EGP.

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KEYWORDS

Benefit of CA, Direct seeded rice, Non-puddled rice, Nutrient budget, Versatile Multi-Crop Planter (VMP), Weed infestation

EFFECT OF INTERCROPPING DRY BEAN WITH INDIGENOUS CUCUMIS MYRIOCARPUS AND CLEOME GYNANDRA ON SOIL PHYSICOCHEMICAL PROPERTIES UNDER REGULATED DEFICIT IRRIGATION (RDI)

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INTRODUCTION

Intercropping is an agricultural practice that involves growing two or more crops in proximity, often to improve yield and sustainability. Dry beans (Phaseolus vulgaris), a staple legume, are known for fixing atmospheric nitrogen and enriching soil fertility. Deficit Irrigation (RDI) is an irrigation strategy that supplies water below full crop water requirements during specific periods of the growth cycle, aiming to improve water use efficiency.

Soil physicochemical properties contribute to soil health, which is essential in the ecosystem by sustaining plants, animals and humans by connecting agricultural, soil and sustainable supply chain management (Lehmann et al., 2020). Intercropping systems were developed to increase yield from agro-systems in the past; however, recently, the cultivation of crops has been more aimed at safeguarding the long-term sustainability of soil health and plant growth (Yang et al., 2020).

Therefore, this study investigated the effects of intercropping dry beans with Cucumis myriocarpus and Cleome gynandra under RDI on soil physical and chemical properties, assessing the compatibility between these crops and the potential for reduced water inputs without detrimental impacts on soil health. The growing demand for sustainable agricultural practices necessitates innovative approaches to crop management that enhance productivity while conserving resources.

Conservation practices such as intercropping, mulching, and minimum tillage have indicated advantages in improving soil, water and air quality as well as ameliorating costs of crop operations (Bhatt, R. and Arora, 2019). Intercropping and RDI are two such strategies that can potentially optimise resource use. However, the compatibility of dry beans with indigenous crops like Cucumis myriocarpus and Cleome gynandra and their combined effect on soil physical and chemical properties under RDI remains underexplored. Determining whether intercropping these crops can maintain or improve the selected soil physicochemical properties while reducing water consumption is crucial, thereby contributing to sustainable agricultural practices. The hypothesis was that intercropping dry beans with indigenous Cucumis myriocarpus and Cleome gynandra would not affect the selected soil physicochemical properties.

MATERIALS AND METHODS

Study area

The study was conducted at the University of Limpopo Experimental Farm (UL Farm), South Africa (23053'10" S, 29 o 44'15" E). UL Farm is located in a semi-arid area in Limpopo (Polokwane Municipality), with winter temperatures ranging from 16-18 minimum and 20-30 maximum and summer temperatures, 18-22 minimum and 28-38 maximum and minimum humidity of 30-40 and maximum humidity of 85-95 (www.weathersa.co.za). The soil was classified as Bainsvlei soil form, developed from a granite parent material (Phadu 2019; Soil Classification Working Group, 1991).

Study Design

The experiment was achieved in an open field as a split-split plot design of 4x5x3 with three replications to estimate experimental variability (give a better estimate of error) and for precision purposes. Seeds of dry beans and two indigenous crops (Cucumis myriocarpus & Cleome gynandra) were sown in the soil immediately after field capacity. The full irrigation (FI) and two deficit levels (75% and 50%) treatment were based on meeting the crop water requirements in full and consisting of charging the upper depth of the soil profile to field capacity before planting, followed by recharging this part of the profile to field capacity every other day. (Averbeke& Netshithuthuni, 2010). 4= growth stages (grid 1, 2, 3 & 4): 1 all growth & 3 different growth stages, i.e. vegetative stage, reproductive stage, maturity stage. Legume= (Dry bean, DB) Indigenous plant= (cleome gynandra, CL) & cucumis myriocarpus, CM).

Data Collection

A composite soil sample was randomly collected at 0-30 cm depth. The samples were crushed and sieved through a 2 mm sieve. Selected physical properties, such as soil texture analysis, were determined using the hydrometer method (Bouyoucos, 1962). Soil bulk density was defined as the ratio of oven-dry soil mass to its volume (Blake and Hartge, 1986). Selected chemical properties (pH, EC, P, K+, Ca2+, Mg2+, Na+) that influence the productivity of Dry beans (Phaseolus vulgaris) Indigenous crops such as Cucumis myriocarpus and Cleome gynandra were assessed. The pH and electrical conductivity of soil samples were determined in 1: 2.5, soil: water suspension as outlined in (Jackson 1973). The ammonium acetate extraction procedure determined exchangeable cations (K+, Ca2+, Mg2+, Na+) (Peech, 1965). Available P was extracted using the Bray-1 Method (Bray and Kurts, 1945).

Data analysis

The data were analysed using the Statistix 10 statistical package. They were subjected to split-split plot factorial analyses of variance (ANOVA) and summarized using descriptive statistics. Turkey's HSD test was used to calculate mean differences at p = 0.05 to check which treatments differed significantly.

RESULTS AND DISCUSSION

There was a significant difference in Mg and P levels under cropping systems x irrigation levels, whereby an increase in soil chemical properties occurred under drybean x cucumis myriocarpus under 75% DI (Mg= 185.75mg/l; P=58.9mg/l). In terms of the cropping system, P was highly significant at P<0.0001, whereby an increase in P (50.6mg/l) levels was observed on drybean x cucumis myriocarpus, whilst pre-harvest values on P ranged from 38.9 to 45 mg/l. EC levels were higher under soils where the dry bean was intercropped with cleome gynandra and Cucumis mericarps than mono-cropped dry bean under full irrigation. Consequently, an increase in K was mainly found under soils where dry bean intercropped with Cucumis mericarps (K= 265,5mg/l) followed by dry bean intercropped with cleome gynandra (K=261.25mg/l) under 75%DI respectively. The results are coherent with studies of Wang et al. (2015), which observed increased chemical properties under intercropped dry beans with maize as opposed to mono-cropped plants. Regarding Ca, significance was found in the interaction of intercropping and growth stages.

Similarly, increased Ca levels were observed during vegetative growth stages under soils where cleome gynandra intercropped with dry beans were planted (Ca=201.67mg/l), significantly higher than the pre-soil analysis. Increased EC levels might have inherently influenced the buildup/increase of these cations (Ca & Mg). However, the study observed decreased pH levels in intercropped cucumis myriocarpus and dry beans under 75% & 50% irrigation levels, respectively. This might have been due to depleted basic cations by harvested crop biomass, leaching and phosphorus fixation (Beshir & Abdulkerim, 2017). Furthermore, it might have been attributed to the fact that the texture of the soil is sandy loam, which consists of large pore spaces that can only hold small amounts of water and nutrients (Lekgoathi et al., 2022; Poorter et al., 2013).

CONCLUSIONS

Intercropping dry beans with indigenous Cucumis myriocarpus improved soil chemical properties such as Ca and Mg. Moreover, a deficit irrigation level of 75% significantly impacted P & K levels under intercropped dry beans with Indigenous crops as opposed to mono-planted Indigenous crops. The study concluded that intercropping dry beans with Cucumis mericarps could improve soil physicochemical properties and save 25% of irrigation water.

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KEYWORDS

deficit irrigation, dry bean, intercropping, indigenous crops, soil physical & chemical properties.

HOW TO IMPROVE THE SOYBEAN GRAIN YIELD AND ROOT SYSTEM IN A LONG-TERM TRIAL OF NO-TILLAGE UNDER SUGARCANE STRAW?

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INTRODUCTION

In the last 59 years, the world production of soybeans has increased by 1.202 % (from 27 to 348 Mt), making Brazil the second biggest producer with almost 148 Mt per year. Brazil has the largest area planted to a sugarcane-soybean cropping system using no-tillage practices. Every year, at least 450 thousand hectares of sugarcane fields are renewed and cultivated with soybeans.

No-tillage soybeans under sugarcane straw have shown many advantages, such as reducing soil erosion by 10 times (Prove et al., 1995), increasing the soil organic carbon stock (Cerri et al., 2011), enhancing the sugarcane root system (Cury et al., 2014), increasing grain and sugarcane stalk yield, and reducing greenhouse gas emissions (Figueiredo et al., 2015).

Despite the well-known benefits of no-tillage under sugarcane straw, the grain yield is lower than the potential of new genotypes because of some obstacles, such as soil compaction and subsoil acidity. Does gypsum improve the soil fertility belowground and increase productivity? Can the type of furrow opener in seed planters reduce the soil compaction and increase the root characteristics in no-till? The objective of this research was to study the effect of gypsum and the type of furrow opener of seed planter on root characteristics and grain yield of two soybean genotypes in a long-term trial for clay soil.

MATERIAL AND METHODS

The study was conducted at the Sugarcane Research Centre of the Agronomic Institute of Campinas (IAC) in Ribeirao Preto City, Sao Paulo State, Brazil. The site is located are 21o 12'10.49" S and 47o 52'32.98" W, and the elevation is 614 m, with mean annual rainfall of 1454 mm. The trial was started in 1998 under a soil classified as a clayey Oxisoil by Soil Taxonomy System (Soil Survey Staff) according to a randomized blocks experimental design, with treatments arranged by split-plot scheme and four replications. The main plots comprise two tillage systems: no-tillage (after spraying glyphosate, soybean is sowed directly) and conventional tillage (moldboard ploughing down to 30 cm followed by offset disk harrowing twice down to 20 cm). The secondary treatments are liming rates (0, 2, 4 and 6 Mg ha-1) always applied before planting soybeans during the renovation of the sugarcane field. These applications were done in 1998, 2003, 2008 and 2018. Since the begging of the experiment, was done four cultivations of soybean and 22 cuts of sugarcane.

In 2018, after harvesting the last sugarcane cycle, the rates of lime were applied, and the tillage was done at conventional treatment. It was used as a seed planter for no-tillage (Tatu Marchesan brand, model COP CA) with nine rows. In the three rows in the centre of the seed planter, the double disc furrow opener was substituted for small tine openers (shank).

For both tillage systems, the same seed planter was used. Immediately before planting soybeans, the gypsum (rate of 2.500 kg ha-1) was applied to the soil surface only in 50% of the plot in each soil tillage and liming rate. This way, optimising the trial and studying the benefits of the soybean root system of amelioration on the soil fertility and the physics attributes was possible.

A short-cycle soybean variety (TMG 7062 IPRO) was sowed in November 2018, and the harvest was done at the beginning of March 2019. It was applied 12, 60 and 60 kg ha-1 of nitrogen, phosphorus and potassium, respectively, and the inoculant for NBF was sprayed on the seed bed mechanically.

The soybean root system was assessed 60 days after planting using the methodology described for sugarcane (Otto et al., 2009), in which steel probes measuring 1.0 m long and 5.5 cm in internal diameter (Sondaterra □) were used to collect soil samples at depths of 0-0.10 m, 0.10-0.20 m, 0,20-0,30 cm and 0.30-0.40 cm in three positions (in the row and two points in each side apart 20 cm). 1.152 samples were collected, washed, and sieved with a 2.0 mm mesh, and the scanner took digitalized images. All the samples were dried before being weighed. The software Safira processed the images - version 1.1., to determine the area, volume, diameter and length characteristics. The grain yield was evaluated in two rows per plot 5 meters long. Statistics analysis was done using AgroEstat software by analysis of variance (ANOVA) using the F-test at 5% significance, and to compare means it was used Tukey's test. Soil characteristics such as soil resistance penetration, bulk density and macronutrient contents were studied but are not shown in this paper.

RESULTS AND DISCUSSION

For both soil managements, the root biomass has increased on average 45%, 18%, 7% and 5 % in the presence of gypsum, respectively, for 0, 2, 4 and 6 Mg/ha of limestone. Independently of the liming rate, the time furrow has increased by an average of 47% the root biomass in no-tillage. The response was very similar for both soybean genotypes.

The results showed that gypsum has increased soil fertility and the nutrient content of soybean plants. Also, it showed that the tine furrow opener could reduce the soil strength up to the levels of conventional tillage. A quadratic trend was observed for all root characteristics, with the highest value obtained at 4,0 Mg/ha of dolomitic limestone.

Regarding the best limestone rate (4,0 Mg/ha), each increase of 1,0 kg/ha on soybean root dry biomass gained 35% on the grain yield. The association of gypsum with tine furrow opener has increased the dry root biomass and grain yield by 35% and 18% (+978 kg/ha), respectively. According to Sartori et al. (2015) and Santos et al. (2019), the tine furrow opener system could increase up to 12% the soybean grain yield and improve the area and volume of roots.

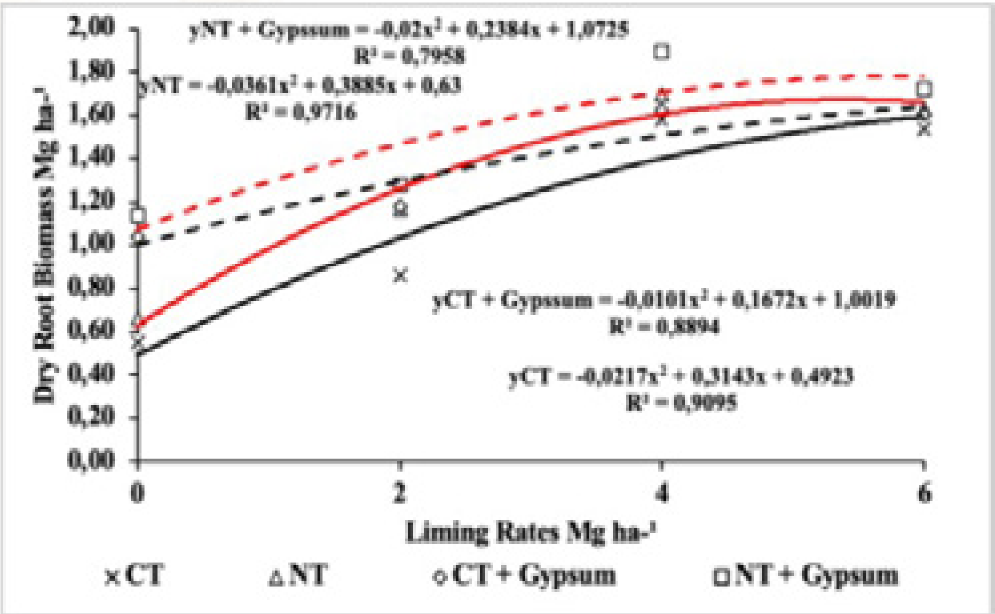

Figure 1. Dry root biomass (kg ha-1) for soybean genotype TMG 7062 IPRO, in no-tillage under sugarcane straw and conventional, with and without the presence of gypsum. Ribeirao Preto, Sao Paulo, Brazil, growing season 2018/2019.

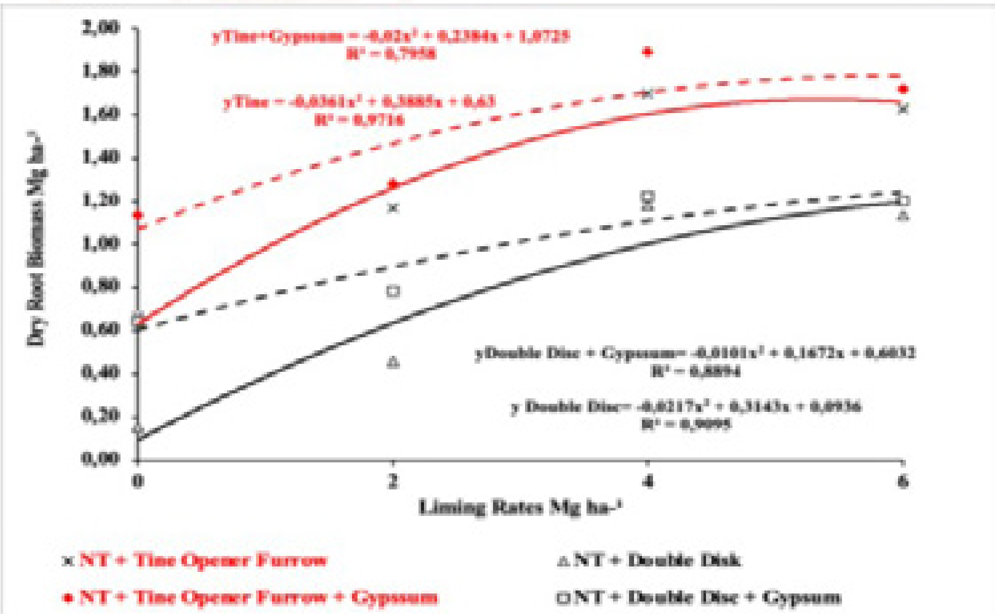

Figure 2. Dry root biomass (kg ha-1) for genotype TMG 7072, in no-tillage under sugarcane straw, with different furrow opener (double disc and tine) in seed planter, with and without the presence of gypsum. Ribeirão Preto, Sao Paulo, Brazil, growing season 2018/2019.

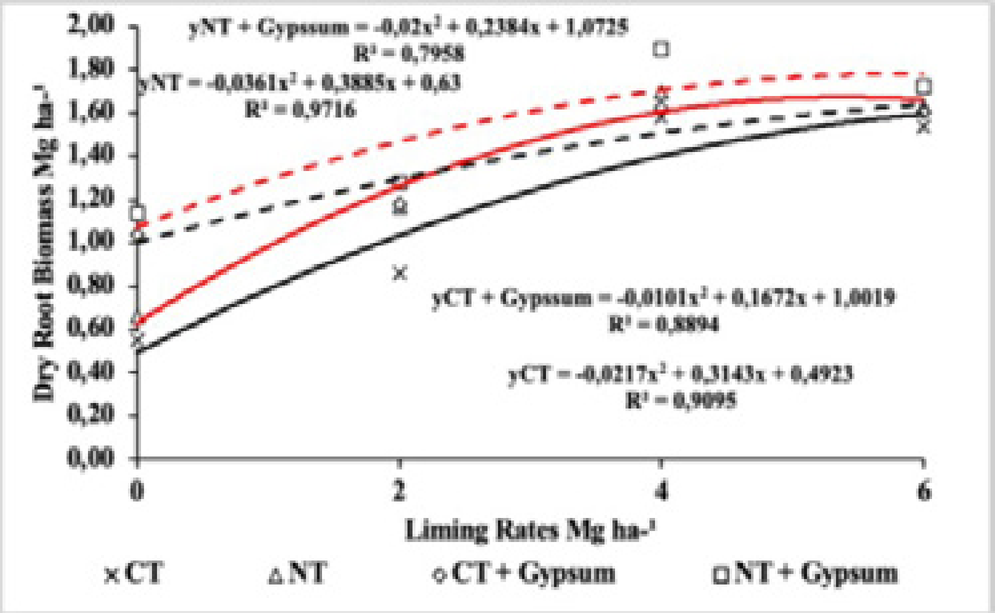

Figure 3. Soybean grain yield (kg ha-1) in no-tillage under sugarcane straw and conventional, with and without gypsum. Ribeirao Preto, Sao Paulo, Brazil, growing season 2018/2019.

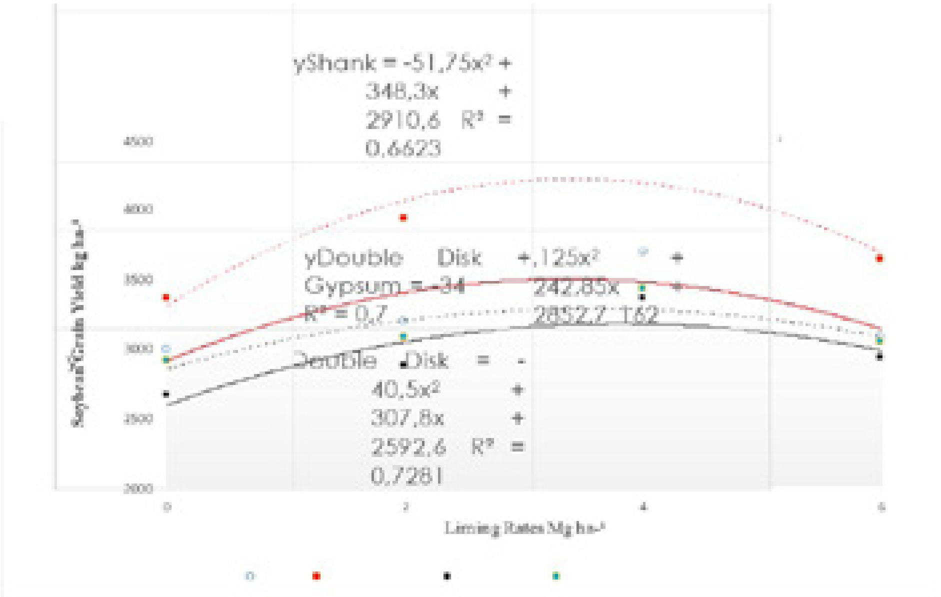

Figure 4. Soybean grain yield (kg ha-1) in no-tillage under sugarcane straw, with different furrow opener (double disc and tine) in seed planter, with and without gypsum. Ribeirao Preto, Sao Paulo, Brazil, growing season 2018/2019

CONCLUSION

Applying 2.500 kg ha-1 of gypsum before planting soybean in no-tillage under sugarcane straw provided a gain of 978 kg ha-1 on the grain yield, mainly when associated with tine furrow opener in seed planters. Dry root biomass was influenced by gypsum only for treatment without lime but was strongly (up to 77% of gain) influenced by the furrow opener system.

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THE NITROGEN AVAILABILITY IN SOIL FOLLOWING LEGUME CROPS AND THEIR EFFECT ON THE SUBSEQUENT CROP

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IINTRODUCTION

With the growing population, there has been a lot of pressure on producers to ensure food security. Nitrogen fertilisers have increased to meet the required yields and provide enough food to be produced. Nitrogen fertilisers have become expensive in terms of both financial and environmental costs. Legumes can fix nitrogen and can, therefore, start to mitigate these problems. The full potential of legumes is not fully understood in the Western Cape crop rotation systems. The study aims to determine the amount of nitrogen fixed by different legumes and the effect on the following year's crop in the Western Cape of South Africa.

MATERIAL AND METHODS

The study was done at Riversdale and Langgewens. In 2021, legumes were planted, followed by wheat in 2022. The treatments included 11 legume cultivars consisting of four peas (Pisum sativum), six lupins (four Lupinus angustifolius and two Lupinus albus), one faba bean (Vicia faba) and a bare plot control (Tabel 1). The legumes and cash crops were established with only 5 kg ha-1 of nitrogen fertiliser, without additional nitrogen fertiliser applications being included throughout both growing seasons. The legumes' nodule index was done around 6 weeks after emergence.

The nodule index was based on three parameters: nodule size (1-3), colour (1-2), and number (1-3). These three values were multiplied to determine the final nodule index (maximum score of 18). Soil samples from 0-150 mm were taken at the end of the legume-growing season of 2021 and the beginning of the wheat-growing season of 2022. This was used to measure the available nitrogen concentration according to the colourimetric determination of ammonium/ nitrate (mineral nitrogen) (Baillie et al. 1990). The wheat yield in 2022 following the legumes of 2021 was also determined.

RESULTS AND DISCUSSION

The nodule index at Langgewens was highest at two lupin treatments. After the legumes were harvested, ammonium and nitrate concentration were highest ($p < 0.05$) at one of the pea treatments; however, it did not differ ($p > 0.05$) from three lupin treatments, another pea treatment, the faba bean as well as the control treatment at Langgewens. mineral nitrogen at the start of the wheat season, however, showed no differences and averaged at 28 mg kg-1 of nitrogen. However, the general amount of nitrogen in the soil increased from the end of the 2021 growing season towards the start of the growing season in 2022. No yield differences ($p > 0.05$) in wheat were found between treatments, which resulted in an average of 2969 kg ha-1.

The average nodule index at Riversdale was 11 ($p > 0.05$). As mentioned by Allito et al. (2020), higher nitrogen fixation is expected to occur with better-nodulated legumes. The highest nitrogen was found at one lupin treatment at the end of the legume season and again at the beginning of the wheat season. At the end of the legume season, the maximum nitrogen concentration was 35 mg kg-1 and increased to 92 mg kg-1 at the start of the wheat growing season, indicative of mineralisation. No wheat differences ($p > 0.05$) were observed at Riversdale, with an average of 3677 kg ha-1. The study was replicated in 2022 with 20 legume treatments, followed by wheat in 2023.

CONCLUSIONS

Various factors could have contributed to no differences in wheat yield between the treatments, especially following a bare plot. One could be that since both these sites have been in long-term conservation, agriculture generally associated with healthy soil might have led to fewer differences between treatments. Differences between treatments might only be significant after the second year of legumes. The high summer and low rainfall, typical of summers in the Western Cape, could extend the mineralisation over a longer timeline. This study did not determine rhizobium species that nodulated the legumes. It could be that the present rhizobium species might be a native species and possibly not as effective in nitrogen fixation (Checcucci et al. 2017)However, the legumes fixed enough nitrogen to produce an industry-comparable wheat yield, with only an additional inorganic nitrogen input of 5 kg ha-1.

Given these results, Western Cape grain producers could benefit from optimising their fertiliser programs accordingly with legumes in the rotation. **Table 1:** Legume varieties as treatments planted in 2021

Treatment	Legume	Cultivar
Pea 1	*Pisum sativum*	Arvica
Pea 2	*Pisum sativum*	Gambit
Pea 5	*Pisum sativum*	Austronaute
Pea 6	*Pisum sativum*	Rif
Lupin 1	*Lupinus angustifolius*	Haags Blaue
Lupin 2	*Lupinus angustifolius*	Lily Bee
Lupin 3	*Lupinus angustifolius*	Mandalup
Lupin 4	*Lupinus angustifolius*	SSL10
Lupin 5	*Lupinus albus*	AG 1120
Lupin 6	*Lupinus albus*	AG 1140
Faba bean 2	*Vicia faba*	Avalon
Control 1	None	Control (Bare soil)

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KEYWORDS

Fertiliser, Legume, Nitrogen, Wheat

SUCCESSFUL ADOPTION OF A RANGE OF PRACTICES WITHIN CA IN SMALLHOLDER FARMING SYSTEMS IN KWAZULU NATAL, SOUTH AFRICA LEADS TO IMPROVED CLIMATE RESILIENCE.

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IINTRODUCTION

The Maize Trust-funded Conservation Agriculture Smallholder Farmer Innovation Programme (SFIP) in KwaZulu Natal (2013-2023) has pioneered the use of agricultural innovation systems as a methodological approach for the promotion of an appropriate smallholder CA farming system and adaptive research into specific elements of this system (Kruger & Smith, 2019).

Farmer-level experimentation, undertaken as collaboratively managed trials (CMTs), has been undertaken with members of village-based learning groups in five villages in the Northern Drakensberg in KwaZulu-Natal. Most of these farmers are women, growing field crops for household food security and feeding poultry and cattle livestock. Field sizes range from approximately 0,25 – 1ha, and most farming operations are done by hand.

The farmers undertake experimentation with a range of practices within the conservation agriculture (CA) system, including pre-plant spraying with herbicides, close spacing of crops, intercropping, comparison of a range of maize and bean varieties, summer and winter cover crop combinations and livestock integration.

The main objectives of this participatory research process are to adapt the CA system to the smallholder farming system in the region as well as to changing climatic conditions. Weather variability in this mountainous region is extreme, with late onset of rain, storms, localised flooding, hail and heatwaves being increasingly common. The impact on crop production and yields has been significant, with an average reduction of yields by 20%, as well as increased disease pressure and new weeds and pests.

MATERIALS AND METHODS

A three-season cycle of adaptive research (2020-2023) has focused on yield improvements, run-off and water use efficiency for this system. Weather data for the Cathedral Peak catchment was provided by the South African Environmental Observation Network Grasslands Node (pers. comm M. Toucher).

The process consisted of 25 collaboratively managed trials (CMTs) and 75 farmer-managed trials, each laid out as ten 100m2 plots/strips, with three replicates of 3 treatments (maize only, maize and bean intercrop and summer cover crops). Conventional Control plots of 1000m2 were planted to a maize monocrop throughout the trial period.

All CMT participants used the same generic planting protocol, including a pre-plant spray of herbicide (either Round-up or Gramoxone) and fertiliser application at planting and as topdressing to provide 40kg of P and 60kg of N per hectare. In- season weeding was undertaken by hand and no pesticides were applied. The maize variety used was a generic hybrid suitable for the region PAN53. The bean variety planted was Gadra, and summer cover crops included sunflower, Sun hemp and fodder sorghum.

Runoff microplot pans were installed for 12 CMTS, with four pans per participant (3 in the trial plot and one in the control plot). Manual recordings of runoff and rainfall were taken after each rainfall event between October and April each year. For water productivity calculations, whole plant and cob sampling, to provide both grain and biomass results, was undertaken for 8 of the participants. Three plants per plot for four trial plots were sampled, and three for the control plot.

RESULTS AND DISCUSSION

Annual rainfall for the 2020-2023 hydrological years has been higher than the historical mean of 1392mm/annum. The mean annual temperature has been above the historical mean and greater than the historical mean by more than 0.5 °C each year. On average, 3-4 heatwaves were recorded each year. On average, runoff in the CA trial plots for the 2020-2023 period was 31% lower than runoff in the control plots. Compared to control plots, 2.4% of total rainfall is saved through reduced runoff in CA trial plots.

The volumetric water benefit averaged at 2,232Kl/annum. The difference in runoff becomes less noticeable as rainfall increases. Water use efficiency averages (2019-2023) were: 1,07kg/m3 for conventionally tilled maize, 2,03kg/m3 for CA mono-cropped maize and 2,54kg/m3 for maize intercropped with beans. The CA trial plots showed an annual increase in water use efficiency. Water use efficiency was significantly higher for CA trial plots when compared to conventionally tilled control plots.

It showed an average volumetric water benefit for intercropped CA plots of 7 million litres/ha more than conventionally tilled plots. Maize yields in mixed cropping CA systems averaged 5t/ha (2020-2023), while maize yields in mono-cropped control plots averaged 2t/ha over the same period. Maize yields in intercropped CA plots averaged 5,5t/ha, while maize yields in mono-cropped CA plots averaged 3,8t/ha, thus a 1,9t/ha difference, indicating a clear yield advantage to intercropping in CA systems.

CONCLUSIONS

Multi-cropping within a smallholder conservation agriculture system has improved maize yields and water use efficiency and has further benefits such as reduced runoff. This has multiple benefits for the environment and livelihoods of the rural poor implementing this system, including improved food security, livelihoods and social agency as well as improved soil health, fertility and water holding capacity, providing evidence for improved resilience to the impacts **of climate change in smallholder farming systems.**

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KEYWORDS

climate resilience, conservation agriculture, innovation systems, run-off, water use efficiency

THE IMPACT OF ULTRA-HIGH-DENSITY GRAZING ON BOTANICAL COMPOSITION, DIVERSITY, AND PRODUCTIVITY

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IINTRODUCTION

Grazing management is crucial in determining rangeland conditions, which numerous studies have widely acknowledged. The concept of non-selective grazing (NSG), introduced by Acocks (1996) and Goodloez (1969), and later refined by Savory, Zietsman, and Lund, has emerged as both a popular and controversial approach in grazing management. NSG aims to increase stocking density while preserving rangeland resilience. It is based on historical large herbivore migration patterns, specifically the so-called "herd effect" and the influence of predation on migrating herds. Although research on its ecological impact is limited, NSG holds promise for significant rangeland improvement.

MATERIAL AND METHODS

In 2019, a long-term research project was initiated at Vanrooyenswoning farm in the eastern Free State of South Africa. The farm employs an ultra-high-density grazing (UHDG) strip grazing system characterized by low levels of selective grazing, making it an ideal setting to study NSG effects. Before this, the farm experienced high levels of selective grazing. Under UHDG, a single herd of approximately 500 cows is moved forward by about 10 meters hourly within a 100-meter-wide strip. The stocking rate in this system is 1.2 hectares per large stock unit (ha/LSU), three times higher than the regional norm of 4 ha/LSU.

The study also includes a second section on a neighbouring farm, which uses a two-camp rotational grazing system, where each camp is grazed alternately for one month. This method encourages high levels of selective grazing (SG), offering a contrasting grazing management approach. The stocking density here follows the governmental grazing capacity norm for the area, set at 4 ha/LSU. The study area lies within the mesic grassland biome, specifically in the "sourveld" region of South Africa, known for its high differentiation between palatable and unpalatable grass species and its susceptibility to selective overgrazing.

Data on grass species composition, forb species composition, grass biomass production, and water infiltration were collected at eight sites in February 2019, February 2021, February 2023, and January 2024. Of these sites, four were in the NSG system and four in the SG system. The sites represent all major terrain areas, including crests, slopes, and valley bottoms. Grass species composition data was gathered using a 100-meter line transect with data collection at 2-meter intervals.

Grass biomass production was measured using a calibrated disc pasture meter along the same transects. Forb species composition and density were recorded within 1x1 meter quadrants, with all species counted in five quadrants spaced at 25-meter intervals along the transects.

Water infiltration capacity was measured using a ring infiltrometer at 25-meter intervals along the transects, recording the time it took for 25 mm (1 inch) of water to infiltrate the soil. This data was then analysed to determine grass species composition, forb species composition, grass biomass production, and water infiltration capacity.

The results were used to track changes at the NSG sites from 2019 to 2024 and to compare outcomes between the NSG and SG management approaches.

RESULTS AND DISCUSSION

The study found that, over the 5-year period, decreaser grass species (palatable perennial grasses) at the NSG sites increased by more than 50% in composition (from 15% to 32%) and by five species (from 9 to 14). Large palatable tufted grasses with rhizomes showed the highest increase in composition (from 27% to 42%). Cool season (C3) grass species rose from 1% to nearly 14% in composition and from 3 to 8 species. Increaser 3 grass species (unpalatable perennial grasses) persisted but decreased by only 4% (from 33% to 29%). Climax grass species increased by about 8% (from 59.8% to 68%), indicating a progression towards a more stable state due to NSG. The total number of grass species recorded rose by 11 (from 23 to 34) during the study period, and the veld condition score percentage (VCS%) improved from 43% to 53%.

At the end of the study, a comparison between the NSG and SG sites revealed 32% (14 species) of decreased grasses at the NSG sites versus 10% (6 species) at the SG sites. Large tufted palatable grasses with rhizomes were particularly abundant at the NSG sites at 27% (compared to 0.5% at the SG sites), while short creeping "lawn" grasses were more prevalent at the SG sites at 26% (versus 3.8% at the NSG sites). Increaser 3 grass species were slightly higher at the NSG sites (22.6%) than at the SG sites (19%). Indigenous legumes were more common at the NSG sites (8.5% and nine species) compared to the SG sites (1.6% and four species). Climax grass composition was also higher at the NSG sites (68%) compared to the SG sites (25%).

Water infiltration at the NSG sites averaged 5 minutes and 31 seconds for 25 mm to infiltrate the soil fully, compared to 13 minutes and 11 seconds at the SG sites. The NSG sites recorded the highest average grass biomass production, with 4,105 kg DM/ha (9.7 kg DM/mm rain), while the SG sites recorded 2,345 kg DM/ha (5.5 kg DM/mm rain). Based on the biomass method, the estimated grazing capacity at the NSG sites was twice as high at 3 ha/LSU compared to 6.2 ha/LSU at the SG sites. This increased grazing capacity at NSG sites is particularly remarkable, given the stocking rate was three times higher than at the SG sites. The botanical diversity index, calculated using the average of the Shannon-Wiener index (H') and the Simpson's index (1/D) models, was highest at the NSG sites (12.2) compared to the SG sites (7.6).

CONCLUSION

After this five-year study, several encouraging outcomes were observed at the NSG sites, including notable increases in grass species numbers, abundance of high-quality grazing grasses, presence of climax grasses, and an increase in C3 (cool-season) grasses, as well as overall improvements in veld condition and grazing capacity. Compared to the SG sites, the NSG sites demonstrated superior performance across all criteria, although to varying degrees. The most significant advantages of NSG included the proportion of high-quality grazing grasses, botanical diversity, water infiltration capacity, grass biomass production and estimated grazing capacity. The smallest differences between the two grazing management approaches were observed in the presence of unpalatable perennial grass species (increaser three species). These differences are primarily due to the resilience of certain unpalatable perennial grass species to NSG. While these species persisted longer than anticipated, significant trampling damage and a gradual decline in their numbers were observed, highlighting the importance of long-term research, especially in the mesic grassland biome, where changes in botanical composition occur slowly.

A RISK ANALYSIS QUANTIFYING THE BENEFITS OF INTEGRATED CROP-LIVESTOCK CA SYSTEMS

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IINTRODUCTION

Data from four scientific on-farm trials in two summer grain crop production areas in South Africa have been used in this study. The on-farm trials were conducted for three seasons (from the 2020/2021 production season), during which the three dominant farming systems, namely conventional tillage (CT), no-tillage (NT), and CA, were compared. The CA system included multi-species cover crop systems grown during, in between or after cash crops established during the summer and winter as part of integrated crop-livestock CA crop rotations or trial treatments.

RESEARCH METHOD

To analyse the above crop production systems or treatments, a risk and resilience barometer was designed using data and calculations from the following parameters measured at the different treatments:

1. An internal risk index based on soil organic matter, water use efficiency and soil cover.
2. An external risk index based on the cost of inputs on a per hectare basis.
3. A profitability index based on the net margin on a per hectare basis.
4. A composite risk and resilience index was calculated, with internal and external risks weighing 25% and profitability weighing 50%.

DISCUSSION OF RESULTS

The results show that CA crop production systems and NT rotations are the least risky and most resilient. The riskiest system is CT. CA is the least risky and most resilient crop rotation over three seasons, including cover crops and livestock each season.

CONCLUSIONS

The results of the three seasons' data show that CA with cover crops and livestock integration has a positive effect on risk and resilience, even in the short term and during a period with above-average rainfall.

This risk assessment will assist in identifying the most resilient and profitable systems in South Africa's Highveld grain production areas. Three years of data analysis showed that integrated crop-livestock CA systems strongly feature in the discussed lowest-risk scenarios.

KEYWORDS

scientific on-farm trials, risk and resilience analyses, integrated crop-livestock CA crop rotations

IMPACTS OF CONSERVATION AGRICULTURE ON QUALITY AND MINERALIZATION OF SOIL ORGANIC MATTER UNDER CONTRASTING HYDRO-THERMAL REGIMES OF RICE-WHEAT SYSTEM IN EASTERN INDO-GANGETIC PLAINS

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INTRODUCTION

Soil organic carbon (SOC) sequestration is important to counteract anthropogenic climate change globally. The traditional rice-wheat (RW) system of Indo-Gangetic Plains (IGPs) is often considered a major GHG emission source. The RW systems have a unique edaphic and climatic scenario, featuring an annual conversion of soil from aerobic to anaerobic conditions and vice-versa, causing several soil physical, chemical, and biochemical changes that directly impact the C and N cycling. The impact of conservation agriculture (CA) on soil C under these highly dynamic edaphic conditions is of great topical interest and needs to be studied in detail.

The changes in the biochemical makeup of SOM can be assessed by studying the configuration of functional groups of humic acids (HA), which undergo a sea change in response to the tillage and crop residue management practices. The dependence of SOM mineralization on hydrothermal regimes and the biochemical stability of SOM should play a very effective role in enhancing SOM through CA adoption in the ever-changing hydrothermal scenario in the RW system and needs to be studied. The hypotheses of this study were: (i) adoption of CA enhances the quantity of SOC and N, along with the quality of SOM, and (ii) mineralization of SOC and N would occur slowly under CA practices and vary under different hydro-thermal regimes.

MATERIALS AND METHODS

We collected soil samples from six combinations of CA and conventional farming (CT) in an ongoing experiment at CIMMYT- Borlaug Institute for South Asia, Bihar, India. The soil is calcareous and falls under the great group Calciorthent. Total soil C and N of bulk soil samples (passed through a 0.2 mm sieve) were determined through a CHN analyser. The SOC was estimated based on equivalent soil mass (ESM). Repeated alkali extractions were carried out for humic acid extractions and characterization. The humic acids were analysed for functional groups through a Fourier transform Infrared (FTIR) spectrophotometer (Perkin Elmer 1600) over the 4000 to 400 cm–1 range at 16 nm s-1. Ratios of different peak heights were used to characterize humic acid. A first-order two-component exponential model was applied to the mineralisation data to determine the kinetics. The cumulative C inputs to the soil were estimated as a summation of C inputs through crop stubbles, roots, rhizodeposition and crop residue retentions as per treatments.

RESULTS AND DISCUSSION

Effect of conservation agriculture on different forms of soil organic carbon

A substantial amount of C input under CA helped in the total SOC build-up. Reduced intensity of tillage operations under double zero-till (ZT) treatments promoted less disruption of soil aggregates and, consequently, greater physical protection of SOC inside macroaggregates. Continuous supply of fresh C input under ZT-ZT+R (residue) resulted in ~64% higher C lability and lability index values than conventional systems (CT-CT). Most of the SOC was present in non-labile form, whereas labile SOC contributed only ~25% to it. Reduced intensity of tillage operations under CA promoted less disruption of soil aggregates and, consequently, greater physical protection of SOC inside macroaggregates.

Slow macroaggregate turnover under CA allowed time for the formation of particulate organic matter (POM) from recent crop-derived organic matter and subsequent encapsulation of this POM by mineral particles and microbial by-products to form stable aggregates containing young crop-derived C. In contrast, the turnover of macroaggregates in CT-CT is faster, providing less opportunity for forming POM and stable aggregates. Continuous supply of fresh C input under CA resulted in ~64% higher C lability values than CT-CT. The dominance of physical protection over chemical stabilization of SOC under ZT-ZT+R and ZT-ZT preserved the lability of SOC instead of oxidizing it towards more chemically recalcitrant pools.

Humic acid characteristics as affected by conservation agriculture

The HA from all the plots registered characteristic FTIR peaks at 3200-3600 cm-1, 2920-2930 cm-1, 1645-1655 cm-1 and 1220-1240 cm-1. These main recorded bands on the FTIR spectral absorption plots were assigned to different functional groups. The broad bands at 3600–3200 cm–1, possibly owed to stretching vibration of hydrogen-bonded hydroxyl (OH) groups of alcohols, phenols and organic acids.

The peak at 2930–2920 cm–1 was due to the stretching vibration of C-H of alkyl groups. The broad bands at 1655–1630 cm–1 corresponded to aromatic C=C and C=O bonds in amides, conjugated ketones and quinones. Lastly, the weak bands at 1240–1220 cm–1 corresponded to aliphatic ketone's C-O stretching and carboxyl groups' O-H bending. The humification index indicated the proportion between C=O and O-H systems. Treatments ZT-ZT+R and PB-PB+R registered lower values of the humification index compared with CT-CT.

The accumulation of fresh organic matter under CA exceeded the capability of microbes to act on them for their humification or decomposition into CO_2. On the other hand, the aromaticity index indicates the proportion between aromatic and aliphatic systems. The CT rice treatments registered the highest value of aromaticity index. The polarity indices indicated either the proportion between aliphatic C=O, COO- and O-H systems or aliphatic C=O, COO- and alkyl C-H systems.

The values of polarity indices were lowest under CA, implying a low redox status of HAs under CA. Physical protection through soil aggregation was the major mechanism of C stabilization under CA instead of chemical recalcitrance. Therefore, there was an abundance of humic acids typically rich in aliphatic compounds with lower semiquinone-type free radical concentration and a lower percentage of aromatic C under CA, representing a less advanced stage of humification, promoting higher C lability.

Mineralization of soil organic carbon and nitrogen under different moisture and temperature regimes

The first-order two-compartment model of SOM mineralization recorded higher values of decay constants associated with labile pools of SOC mineralization, as compared with that related to recalcitrant pools, suggesting more significant decay of labile SOM. Higher temperature generally enhances SOM mineralization due to temperature-mediated increases in the physiological and biochemical reaction rate of microorganisms involved in the process. On the other hand, the field capacity moisture regime is the optimal condition for SOM mineralization. Poor supply of oxygen slowed down SOM decomposition under submergence. The cumulative C mineralization (Ct) was initially higher under FC25, owing to optimum moisture than 2.5 cm standing water in SM35. In later periods, however, the effect of higher temperature (35˚C) on microbial activity was possibly far greater than that of optimum moisture (field capacity), in turn registering higher Ct under SM35 compared with FC25. Higher values of decay constants were reported under SM35 than FC25.

The study conclusively proves the higher GHG emission potential of edaphic conditions prevalent during rice crop (SM35) compared to that during wheat crop (FC25). The ill effects of higher temperature on CO_2 emission surpass the reductive effects of submergence. There was the possibility of an excessive gaseous loss of N through denitrification and slower SOM decomposition owing to poor oxygen supply under submergence, which might have resulted in lower mineral N in SM35 than in FC25. Higher losses of N through volatilisation at elevated temperatures and higher microbial requirement of mineral N at higher temperatures due to increased microbial activity could be the other possible reasons.

Despite higher per se values of Ct, heavy residue retained CA treatments registered significantly lower decay rates of C mineralization compared with CT under FC25. Under CA, the SOM is more labile, as is evident from a lesser degree of humification and higher values of C lability. Greater physical protection of labile SOC in the form of POM-C resulted in lower rates of C loss from relatively more labile pools under CA compared with CT. A more significant physical barrier between SOC and metabolizing microbes under ZT-ZT+R slowed down C decay despite its' enhanced lability. These increment in labile C has great ramifications in sequestering and stabilizing C, as well as improving the nutrient-supplying capacity of soils.

CONCLUSION

The CA preserves the lability of SOM in a physically protected state, providing us with a win-win situation of C stabilization. The effects of submergence in stabilising SOM is rather inconsequential in the prevalent higher temperature range in the rice growing periods of eastern IGP. The comparative study of different edaphic scenarios also cautions us about incomplete adoptions of the CA package of practices regarding C emissions and suggests maintenance of the zero-till conditions throughout the year. The optimum crop residue cover is imperative towards a C-neutral farming system, both as an input source of soil C and as a barrier to C-mission from the crop field.

KEYWORDS

crop residue retention, decay constant, humic acid, labile carbon, zero tillage

CONSERVATION AGRICULTURE IN A SUBTROPICAL REGION OF BRAZIL: SOYBEAN YIELD AND SOIL HEALTH PARAMETERS AFTER 37 YEARS

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INTRODUCTION

For centuries in Brazil, agriculture was developed by soil management associated with conventional tillage (CT), which provoked soil degradation, nutrient depletion, biodiversity loss, and decreasing crop yield, leading to rural poverty. A regenerative conservation agriculture (CA), no-till system comprising cover crops and rotation, was needed to promote soil and plant improvement towards sustainability.

MATERIAL AND METHODS

An experiment was carried out over 37 years at the experimental station of the Agricultural Research Institute in Paraná State, Brazil, testing different mixed winter cover crops in a CT and CA system, rotated with soybean and maize in an Oxisol with high clay content (73%). During the study, ten applications of dolomitic limestone on the soil surface (19.5 Mg ha-1) and amounts of P and K exported by the soybean and maize grains were replenished with fertilizer applied in the sowing line.

The correction of potential acidity and the deficiencies of P and K after the last soil tillage and before establishing CA from degraded CT and control of reacidification, superficial lime, and replacement of nutrients exported by crops promoted acceptable crop yields.

RESULTS AND DISCUSSION

Maintaining no-till CA for thirty-seven years allowed the accumulation of soil organic carbon (SOC) of 40.8 g kg-1 in the surface layer of 0.5 m deep, compared to the 28.7 g kg-1 in CT soil that received 74 plough and 128 harrow events. The SOC content in the CA approached the undisturbed forest condition. All the biological, physical, and chemical soil parameters are suitable for life, including plants, promoting higher biodiversity. On average, soybean grain yield harvested in 2022/2023 was higher in CA (5310 kg ha-1) compared to the 4987 kg ha-1 in CT. However, in fallow, mix/wheat and mix/rye, the yield was higher in CT; in the mix/radish + rye + vetch and mix/hairy vetch treatments, the yield in CA and CT systems was similar. In contrast, when hairy vetch + black oat or simply wheat was used, CA yields were 30.7% and 20.7% higher than CT.

CONCLUSION

These results show the urgent need to eliminate soil disturbance (tillage), adjust nutrient status on soil profile, and include a diversity of cover crop species to enable CA (NT with quality, following the three principles), improving soil biodiversity. The long-term experiment in southern Brazil demonstrates the high viability of adopting dynamic CA in subtropical and tropical soils, like many African countries, after proper local adaptations.

KEYWORDS

No-till, crop rotation, cover crops, regenerative conservation agriculture, sustainability

SOIL HEALTH-FOOD HEALTH CONNECTION CONFIRMED IN CONSERVATION AGRICULTURE

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IINTRODUCTION

Although Conservation Agriculture has great benefits for soil health, it is not clear if soil health improvement also translates into healthier food. Ergothioneine (Ergo) may be the missing link between soil and food health. Ergo is a powerful antioxidant classified by medical authorities as a longevity vitamin that can fend off diseases of old age, such as Parkinson's, Alzheimer's, or cancer. Ergo neutralizes radicals in animal and human cells that affect the ability of the body to fight off diseases of old age, hence increasing lifespan.

Ergo cannot be produced by the human body or by animals or plants but only by non-yeast fungi and cyanobacteria, and mycobacteria. Nonetheless, it is also found in plant and animal products. There is increasing evidence that Ergo is predominantly passed on to plants by mycorrhizae that live in symbiosis with plant roots. Because mycorrhizal colonization of crop roots is affected by tillage, we evaluated mycorrhizal infection and Ergo content in grain crops in different tillage systems and also compared colonization and Ergo content in crops grown in sterilized or field soil inoculated with mycorrhizae.

MATERIALS AND METHODS

Grain and soil samples were taken from Penn State's Long-Term Tillage Trial in central Pennsylvania. This trial was started in 1978 and had plots where annual moldboard ploughing/disking/harrowing (MB), chisel ploughing/disking/harrowing (CD), and no-till (NT) have been practised continuously for more than 40 years. For the first twenty-five years, corn (Zea Mays, L.) for grain was grown without a cover crop. Since 2003, the field has been in a corn-soybean (Glycine max (L.) Merr.) - wheat (Triticum aestivum L.) /legume cover crop rotation. If the fall soybean harvest was delayed or the field was excessively wet, oat (Avena sativa L.) was planted in the spring instead of wheat in the previous fall. Grain samples were collected in 2018 (corn), 2019 (soybean), and 2020 (oat), and analyzed for Ergo content (see (Beelman et al., 2021) for more details).

To further investigate the link between mycorrhizal colonization and Ergo content, black beans (Phaseolus vulgaris L.) were grown in pots in a 2:2:1 mix of sterilized field soil:peat moss:turface or inoculated with seven different species of mycorrhizae and a natural community of mycorrhizae from organically managed field soil. Mycorrhizal colonization and the Ergo content of the black bean grain were measured. Wheat and oats were also grown in a temperature-controlled greenhouse in pots filled with 2:2:1 field soil:peat, moss and surface mix. The field soil came from organically managed soil and was either sterilized by autoclaving at 121 oC or not sterilized. The soil was inoculated with two different species of mycorrhizae (Scutellospora calospora or Claroideoglomus etunicatum) or left uninoculated. Mycorrhizal colonization was measured, and Ergo content of wheat and oat grain was determined (more details of the latter two trials can be found in Carrara et al. (2023)).

RESULTS AND DISCUSSION

Corn grain Ergo content was 1.68, 1.95, and 2.46 mg kg-1 in MB, CD and NT, respectively, representing a 46% increase in Ergo from MB to NT, with the CD being intermediate. These results encouraged us to test further tillage effects on soybean and oats, grown in 2019 and 2020, respectively. The average Ergo content was 1.61, 2.47, and 2.40 mg kg-1 in MB, CD and NT in soybeans and 6.14, 8.09 and 8.53 mg kg-1 in MB, CD and NT in oats, respectively, with only MB being significantly different from the other two tillage systems ($p<0.05$).

This research showed that Ergo content was 49% higher in NT soybeans than MB and 38% higher in NT oats, with CD not being different from NT. These results suggest a consistent increase in Ergo in reduced tillage systems compared with conventional moldboard ploughing. We hypothesized that Ergo was passed on to the plants through the more extensive and active mycorrhizal network in the reduced tillage soil because, in other studies, mycorrhizal colonization was reduced with intensive tillage.

The effect of mycorrhizal colonization of roots on grain Ergo content was confirmed in the pot studies. In the black bean study, the Ergo content was increased up to 72-fold in mycorrhizal black beans compared to non-mycorrhizal controls. Interestingly, colonization and the level of Ergo in the black beans varied by mycorrhizal species, while the best colonizers did not necessarily result in the highest Ergo levels.

In the wheat pot study in sterilized field soil, 42% of the roots inoculated with S. calospora were colonized, while 13% inoculated with C. etunicatum were colonized. When grown in non-sterilized soil, 33% of wheat roots were colonized, while 57% and 30% were colonized when inoculated with S. calospora and C. etunicatum, respectively. In oats grown in sterile soil, inoculation with S. calospora resulted in 42% colonization but only 5% with C. etunicatum. In non-sterilized field soil, colonization of oats was 10%, while inoculation with S. calospora resulted in 50% colonization, but no increase was noted with inoculation with C. etunicatum.

The pot studies with wheat and oats in field soil show that inoculation with mycorrhizae can increase root colonization, even in natural field soil, but the effect varies by species. The mycorrhizal inoculation with the effective species (S. corpora) resulted in a 4x increase in Ergo in wheat grown in sterile soil and a 2x increase in non-sterile field soil. In oats, S. corpora inoculation resulted in a 5x increase in Ergo in sterile soil and a 2x increase in non-sterile field soil. Inoculation with C. etunicatum did not increase Ergo content in either crop. The pot study with wheat and oats further confirmed that mycorrhizal colonization of roots leads to Ergo in the grain and that inoculation may increase colonization and Ergo content, depending on mycorrhizal species.

CONCLUSION

The studies provide evidence of a soil health-food health connection through soil management effects on mycorrhizal colonization of roots. The results suggest that mycorrhizae produce Ergo, which is then passed on to the plant through their symbiotic relationship with roots. Pot studies in sterile soil showed that grain Ergo content resulted when crops were inoculated with mycorrhizae. They also showed that, depending on species, mycorrhizal inoculation may increase root colonization and grain Ergo content even in natural field soil.

Intensive soil tillage has been shown to impact mycorrhizal colonization of roots negatively, and our research showed that Ergo content of grain grown with intensive tillage practices was also reduced compared with reduced tillage, probably because of lower mycorrhizal colonization. Our research indicates that CA can improve the nutritional quality of food because of its effect on mycorrhiza, resulting in grain increases in the longevity vitamin Ergo. Nonetheless, the effects of other practices such as rotation with non-mycorrhizal (cover) crops (e.g. brassica species), fertilizer application, and phytosanitary products such as fungicides on mycorrhizal colonization and Ergo must also be investigated.

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KEYWORDS

Ergothioneine, Mycorrhizae, Tillage, No-Tillage

MANAGEMENT OF FUSARIUM CROWN ROT OF WHEAT THROUGH CONSERVATION AGRICULTURE

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IINTRODUCTION

Fusarium crown rot (FCR) is an economically significant disease of wheat in semi-arid regions worldwide. FCR has inflicted losses of up to $79 AUS annually in Australia alone. FCR poses a major threat to wheat production in the Western Cape (WC) province of South Africa (SA), a dryland region where roughly 50% of South Africa's wheat is produced.

Fusarium pseudograminearum is the predominant causal agent of FCR globally. The fungus, a stubble-borne pathogen, can survive on infected cereal debris for up to three years. Infection occurs on the lower stem and subcrown internode, resulting in a characteristic honey-brown discolouration of infected tissue, resulting in dead culms and little to no wheat grain. Infection of the subcrown internode prevents moisture uptake via seminal roots, making the plant more dependent on water absorption from the shallower crown roots. This becomes increasingly difficult if drought conditions prevail later in the season, exacerbating FCR severity and negatively impacting plant productivity.

Crop rotation with broadleaf (non-host) crops can reduce FCR levels, and two years between planting cereals is recommended. Agronomical practices like deep ploughing and burning of stubble, which reduces the amount of stubble, can reduce FCR, while retention of stubble under reduced tillage can elevate FCR levels. In semi-arid regions, however, removal of stubble can have a detrimental effect on grain yield due to the resultant soil moisture loss. Management of FCR, therefore, relies on integrating agronomical practices like crop rotation with non-host crops, seed treatment and host tolerance.

The WC province of SA has two major wheat production areas: the Swartland and the Overberg / southern Cape. Wheat is grown here from May – November (late autumn – late spring) on dryland (rainfed) fields in rotation with broadleaf crops like canola, lupin and annual medic, but also host crops like barley and oats. Conservation agriculture (CA) has increased in popularity in the WC from the late 1990s onwards. However, the stubble-borne nature of FCR is a negative consequence of CA, given the build-up of stubble, which can increase FCR levels. Furthermore, the Mediterranean climate of the WC is expected to become hotter and drier in future, which, in turn, will favour the development of FCR. CA, which results in improved soil moisture conservation, can thus be a valuable tool in combatting FCR during drought conditions but may be detrimental due to increased stubble retention. Therefore, this study aimed to determine the effect of crop rotation in combination with different tillage practices on FCR disease incidence and severity of wheat in the WC and how these practices affect selected agronomic parameters of wheat.

MATERIALS AND METHODS

The effect of four crop rotation systems (main plot factor: wheat-canola-wheat-lupin; wheat-lupin-wheat-canola; wheat-medic-wheat-medic; wheat monoculture) combined with four tillage practices (subplot-factor: conventional-, minimum-, no- and zero tillage) on FCR disease and agronomical parameters was investigated from 2018 – 2022 in two identical long-term field trials, situated at Langgewens (Swartland) and Tygerhoek (Overberg) research farms in the Western Cape. Twenty-eight wheat plants were sampled each year during the soft dough stage (Feekes 11.2, Zadoks 85) in a W-transect (seven plants per transect) covering the width and length of each sub-plot factor, totalling 112 plants sampled per replicate of each main plot factor per location per year. Disease parameters measured included disease incidence (percentage infected plants), disease severity (no. of infected tillers per plant and average lesion-length on tillers), and direct quantification of F. pseudograminearum target DNA in crown tissue (ng µL-1) for 2018 and 2019 only. Agronomical parameters included yield (kg ha-1), hectolitre mass (kg hL-1), 1000-kernel weight (g) and biomass (kg ha-1), among others.

Analysis of variance (ANOVA) for the year, location, main factors (crop rotation), sub-factors (tillage treatments) effects and interactions were calculated using SAS software. Fishers protected the least significant differences (LSD), which were estimated at the 5% significance level to establish differences between treatment means. Pearson correlation coefficients (r) were calculated to confirm the relationship between disease and agronomical parameters. Principal component analysis (PCA) revealed the association between experimental factors (year, location, rotation system, and tillage practice), disease and agronomical parameters.

RESULTS AND DISCUSSION

Crop rotation with canola, lupin, and medic significantly reduced all disease parameters for most years at both locations, compared to the wheat monoculture. At Langgewens in 2019, for example, wheat after canola significantly ($P < 0.0001$) reduced the disease incidence (15.5%) compared to the wheat monoculture (58.9%).

During 2020, however, the disease incidence was 83.9% and 75.9%, respectively, for the same rotation systems. Similarly, at Tygerhoek in 2019, the disease incidence in wheat after medic was 49.4%, compared to 80.3% in the wheat monoculture ($P = 0.0002$). During 2020, however, the disease incidence was 90.2% and 95.8% for the same rotation systems. Interestingly, zero tillage consistently reduced all disease parameters for most years, compared to the remaining tillage practices at both locations. The disease incidence under conventional tillage at Langgewens ($P = 0.0020$) was 56.4% during 2018, compared to 21.1% under zero tillage. At Tygerhoek, zero tillage (61.0%) significantly ($P = 0.0096$) lowered the disease incidence compared to a minimum- (67.1%), conventional- (66.6%), and no-tillage (65.9%), over the duration of the study.

Each year at Langgewens, rotation with most broadleaf crops reduced the percentage of diseased tillers ($P < 0.0001$) compared to the wheat monoculture (for example, wheat after canola during 2019 = 7.1% vs 45.1% for the wheat monoculture). A similar response was achieved every year at Tygerhoek, where rotation with broadleaf crops consistently ($P = 0.0002$) recorded less diseased tillers, except during 2020, when none of the broadleaf crops significantly reduced diseased tillers compared to the wheat monoculture (86.9%) treatment. Less diseased tillers were recorded under zero tillage ($P = 0.0244$) compared to conventional tillage at Langgewens during 2018 (16.4% vs 46.6%), 2021 (36.7% vs 49.8%) and 2022 (30.4% vs 40.7%). Significantly fewer diseased tillers ($P < 0.0001$) were also recorded for zero tillage (46.9%) at Tygerhoek, irrespective of year, compared to conventional tillage (57.4%), no-tillage (57.3%) and minimum tillage (56.4%).

The target fungal DNA of F. pseudograminearum quantified from diseased crown tissue was significantly affected by the rotation system ($P = 0.0099$) and tillage practice ($P = 0.0051$) at Langgewens and differed only between years at Tygerhoek ($P < 0.0001$). Significantly less fungal DNA was quantified at Langgewens in wheat produced after medic (0.39 ng µL-1), canola (0.27 ng µL-1), and lupin (0.25 ng µL-1) compared to the wheat monoculture (1.10 ng µL-1). Conversely, significantly less fungal DNA was quantified at Langgewens under zero tillage (0.24 ng µL-1) compared to no- (0.51 ng µL-1), conventional- (0.55 ng µL-1) and minimum tillage (0.57 ng µL-1). Significantly more target fungal DNA was obtained during 2019 (2.30 ng µL-1) than in 2018 (0.49 ng µL-1) at Tygerhoek.

Numerous significant negative correlations between disease and agronomical parameters highlighted the negative effect of FCR on agronomical parameters. At Langgewens during 2021, for example, disease incidence, - severity, and average lesion length were all significantly ($P \leq 0.05$) negatively correlated with grain yield ($r = -0.512$, -0.437, and -0.455, respectively). Similarly, at Tygerhoek during 2021, disease incidence, - severity and average lesion length were significantly ($P \leq 0.05$) negatively correlated with hectolitre mass ($r = -0.549$, -0.375, and -0.548, respectively). This was further supported by the PCA conducted at each location for each season.

Crop rotation with broadleaf crops effectively reduced FCR at both locations tested. This can be explained by the disruption of the disease cycle and inoculum build-up during the non-host crop cycle. Minimal differences were found among the different broad-leaf crops within years, suggesting that any crops tested can be suitable for crop rotation, depending on regional suitability and economic considerations. Contrary to previous studies, an exciting and promising finding was that zero tillage frequently reduced FCR disease levels.

The stubble remaining on top of the soil following zero tillage means that infection of the subcrown-internode is less likely compared to more disruptive tillage practices. Therefore, water absorption from the deeper seminal roots can still occur in plants where the subcrown internode is not infected, as is the case for wheat under zero tillage. This can offset the damage inflicted by FCR, especially in drought conditions. The soil under zero tillage over time accumulates a higher soil organic matter content, improving the soil's water retention capabilities and thereby further alleviating the negative effects of FCR. Under drought conditions, FCR severity can thus be reduced by the higher soil moisture content of fields under zero tillage.

CONCLUSIONS

FCR levels is likely to increase in the Western Cape in future. Implementing conservation agriculture, which is more environmentally friendly and cost-effective, can significantly assist in reducing FCR levels, thereby improving agronomic performance.

KEYWORDS

Conservation agriculture, crop rotation, Fusarium crown rot, tillage, wheat

THE ROLE OF WATER SATURATION IN CONSERVATION AGRICULTURE

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IINTRODUCTION

Water is essential for all life, without which no organism can survive. Yet too much water can easily cause death by obstructing access to oxygen. Field experience and observation have shown that most irrigation farmers manage their soil's water content to the wetter end of the spectrum, thus increasing the risk of saturation.

This paper aims to highlight the relationship between soil water saturation and aeration, focussing on conservation agriculture where the organic matter and organism activities are increased.

MATERIALS AND METHODS

For one year, soil water content, bulk density, water pH, and redox potential were measured in triplicate for four wetland zones in the Florisbad wetland, 40 km northeast of Bloemfontein. These measurements were used to calculate the porosity, degree of water saturation, and redox potential.

RESULTS AND DISCUSSION

The average degree of soil saturation was 0.14 in the terrestrial zone, 0.45 in the temporary wet, 0.52 in the seasonally wet, and 0.73 in the permanently wet wetland zones. The concomitant redox statuses were 25.8, 21.0, 8.8, and 4.9. Interpolation of these data indicated that the change from oxidised to reduced occurred when 60% of pores were saturated with water.

Irrigation scheduling is typically done by measuring or calculating the drained upper limit and lower limit of plant available water and then calculating the plant available water. The refill point is generally taken as 50-60% of plant available water. No cognisance is taken of aeration in these determinations. Yet research (Greenwood, 1970; Vigil and Sparks, 2003) have shown that biological activity is seriously diminished when water saturation exceeds 60% of porosity.

This situation is exacerbated in more healthy soils where organic matter, microbial population, and thus biological oxygen demand are elevated.

CONCLUSIONS

Most farmers manage their soils wetter than optimally. This situation has been brought on by fears of limiting plant water and infrastructure failure. The risk of soil water saturation and the associated anaerobic risk has not received due recognition. It is, therefore, important that farmers also include oxygenation in their soil water management strategy.

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KEYWORDS

aeration, irrigation, microorganism, porosity, reduction

30 YEARS OF CONSERVATION AGRICULTURE AT THE AGRICULTURAL TEACHING AND TESTING INSTITUTE MERKLINGSEN, EFFECTS ON SOIL FUNCTIONS

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INTRODUCTION

The South Westphalia University of Applied Sciences presents Merklingsen crop production systems as experiments at the trial farm and offers a high level of practical training with demonstration examples to accompany lectures, exercises, and seminars.

Key elements are eight-part crop rotation, minimum soil disturbance, consistent soil cover and intercropping. Crop rotation consists of Canola, Wheat, Field beans, Wheat, Silage corn, Sugar beet, Oats and Barley. The general management of the farm is based on the "Soest crop production concept" according to CA-farming principles, starting in 1993:

1. Consistent avoidance of ploughing on all areas since 1993
2. Mulch sowing (max. 12 cm) → establishment of excellent soil structure
3. Consistent soil cover (mulch layer/cover crop)
4. No "black fallow", no straw export → earthworm feed, organic fertilizer from 2000 to 2007: dry chicken manure, compost use: since 2002, liquid manure fertilization: since 2010
5. Nutrient supply according to plant requirements with intensive use of soil reserves → balanced nutrient flows
6. Use of all potentials to minimize the use of pesticides: resistant varieties, "field hygiene" (straw rotting), and activity of soil organisms

MATERIAL AND METHODS

The content of organic matter is determined by the standard DIN EN 15936:2012-11. The 200 µm soil fraction is incinerated using the catalytic raw combustion process at 550 °C in the so-called total organic carbon (TOC) device. Organic carbon compounds change into the gaseous state of aggregation, while the inorganic carbon remains stable.

According to THIELEMANN (1986), the occurrence of soil life was determined using the "octet" method (electro-trapping). A spade is used to remove the top litter and herb layer of the test area. Eight electrodes are then inserted into the water-saturated soil. Merklingsen trial farm of the South Westphalia University of Applied Sciences, Department of Agriculture Soest, belongs to the Natural area "Soester Börde" in the "Westphalian Bay".

Climate parameters of approx. 750 mm average annual precipitation, average annual temperature of 10.5 °C at an altitude of 95 m above sea level. The soil texture consists of weak to medium clay silt (Ut2 to Ut3) from loess weathered loam with a silt content from 84 - 87%. German credit rating figures out 70 – 85 (of 100) "soil points", soil type is a Luvisol (Pseudogley-Parabrown soil according to German taxation).

The mineral treasure stores 400 liters of water available to plants up to 160 cm. Yields at the Merklingsen trial farm compared to the German federal average is double in terms of Silage corn, Canola and Oats.

RESULTS AND DISCUSSION

After more than 30 years of conservation tillage, various positive effects on soil parameters can be observed. The content of organic matter and soil life (measured by earthworms) play a significant role in the assessment.

This increased due to the reduced tillage: In 1993, when the farming system was converted to conservation tillage, the average organic matter from 0-20 cm depth was around 1.5 %. By 2020, the organic matter content had increased to 4 % in many areas. No sample contains less than 2 %, considered a parameter for healthy soils. A map of the arable areas of the trail farm Merklingsen, which shows the current organic matter of the arable soils, is shown in Figure 1.

There was also a significant increase in the number of earthworms to up to 300 earthworms per square metre, shown in Fig. 2. Even on the soil surface, the increase of life in the soil is almost visible. High earthworm frequency and vertical earthworm burrows provide rain permeability and root canals, which avoid backwater and increase the soil's load-bearing capacity. The crop yields also reflect these favourable developments, as shown in Figure 3. On average, yields (tonnes per hectare) are sometimes twice as high as the national average in Germany!

To improve soil health in Germany, soil biology still receives too little attention. The agricultural sector is determined by the machinery, fertilizer, and chemical industries. Farming with conservation/regenerative principles is under 1 % in total in Germany. The increase in soil health is due to more soil awareness. Carbon is the currency of the soil and brings back life in it. Storing carbon is crucial to farmers. The importance of cover crops arises from their influence on the liquid carbon pathway. Finally, soil health also means food security and sustainable land use.

CONCLUSIONS

Conservation tillage reduces the intensity of interventions in the soil structure, thus improving erosion control and water infiltration. This strengthens water protection by reducing surface runoff and loss of nutrients and active substances. Extended crop rotations facilitate the use of conservation tillage/direct sowing and reduce direct and labour costs. They save energy and labour and increase species diversity in the cultivation spectrum. It can, therefore, be said that the "soil treasure" produces top yields and prosperity under conservation tillage!

KEYWORDS

Conservation Agriculture, agricultural teaching and testing institute, soil evolution, soil health, soil management, soil protection

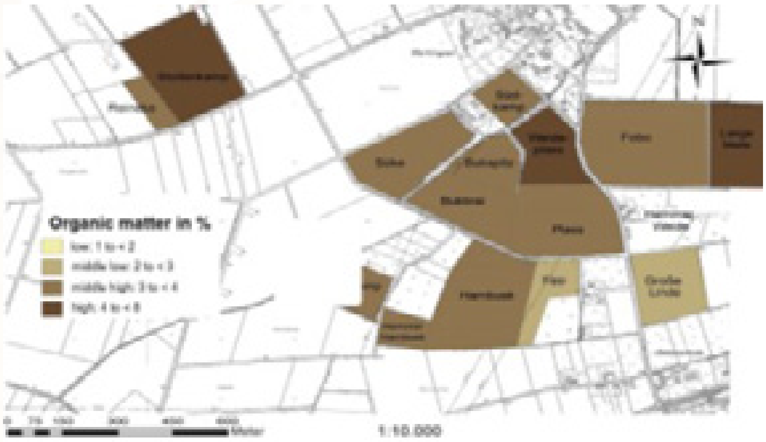

Figure 1. Map of the arable land on the Merklingsen trial farm: Increase of organic matter in soil

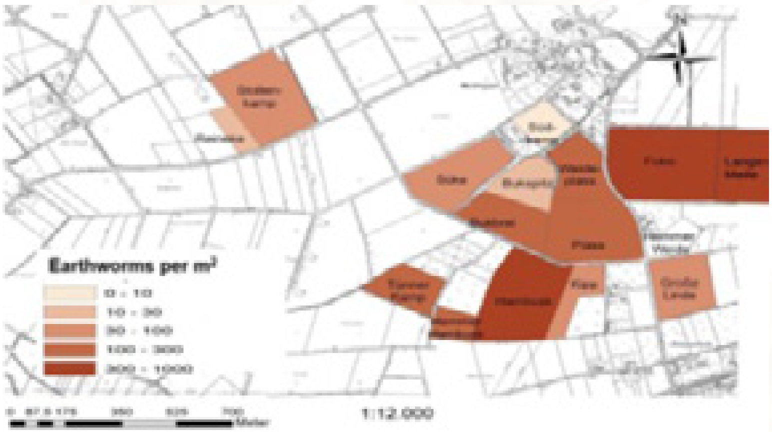

Figure 2. Map of the arable land on the Merklingsen trial farm: Increase of life in the soil

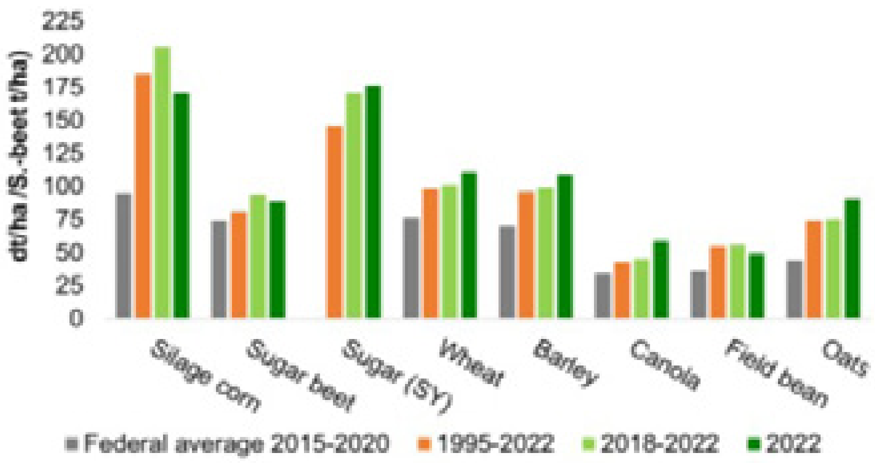

Figure 3. Yields at the Merklingsen trial farm compared to the German federal average

CAN “SMALL” MAIZE FIELDS SEQUESTER CARBON?

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INTRODUCTION

Crop yields at field edges are poorly understood. The literature has few studies either substantiating or discounting increased (or decreased) yields at field edges. A possible reason for this is that edge effects are likely a scale issue whereby plants on the extreme edge—the first row—may have plants that produce much better than plants deeper in the field. Soybeans can also have visual height differences along field boundaries, and corn can have stalks with up to 5 cobs per plant when 1-2 is typical, yet few papers are definitive on the causes of the phenomenon. Earlier works by Ghaffarzadeh et al. (1994) found yield increases and decreases when they evaluated strip cropping with alternating crop species in Iowa. Similarly, Francis et al. (1986) report that the results from several strip cropping experiments from the U.S. Corn Belt were inconclusive from a yield standpoint but did indicate a reduction in overall soil erodibility using predictions from the Universal Soil Loss Equation. While taller plants can benefit from additional sunlight on the edges of plantings, the overall effect on yield is unclear.

This current work builds on previous field observations in Lesotho, Zimbabwe, Ohio (USA) and two sites in Tennessee (USA) over the past 15 years using Bowen’s Ratio Energy Balance (BREB) and eddy covariance (EC) (O’Dell et al., 2020) methodologies. BREB is a method (Hicks et al., 2020) that measures carbon dioxide, temperature (T), and relative humidity at both the top of the canopy and 1.5-m above the canopy. BREB can be used to measure carbon capture by plants in real-time effectively. EC is a statistical method used to estimate the net production of vegetation. From these sites, we have found high nocturnal carbon dioxide (CO_2) concentrations, often greater than 700 ppm, values that we initially believed to be anomalous or outright outliers. While our original plan was to monitor daytime data to calculate real-time carbon capture, these high concentrations caused us to investigate the conditions whereby CO_2 pooling occurred on the landscape.

MATERIALS AND METHODS

To evaluate the overall productivity of various field research sites, we have measured CO_2 concentrations continuously at different research sites with differing field sizes and tillage treatments in Lesotho, Zimbabwe, Ohio, and Tennessee. In 2023 we measured canopy [CO_2] in the center of a maize field and again saw nocturnal pooling of CO_2. In 2024, we established our current study to elucidate the pooling effect on field edges further. We used a multiport profile system from four heights above the soil surface. The lowest height was fixed at 0.11m; the other three were raised as the maize grew in height (h) changed (0.5m*h, 1m+h, and 2m+h). A bare area 15 m wide and 20 m long was maintained in the direction of the prevailing wind to provide an area that lacked plant-capturing CO_2. The site was in Central Ohio and was planted to maize on May 18, 2024, at a population of 86,400 plants per hectare on a small commercial farm.

RESULTS AND DISCUSSION

A couple of generations ago—before the introduction of seeds resistant to herbicides—farmers often cultivated between rows during the growing season for maize and soybean. While the purpose of the cultivation was to reduce and eliminate weeds, a byproduct of the cultivation and subsequent tillage of the soil was the release of carbon dioxide due to short-term aeration of the soil and microbial processes.

Many farmers were convinced that their crops grew better following cultivation, and they could likely have due to the flush of CO_2 by the interrow cultivation. Carbon dioxide can be a limiting factor in photosynthesis, and the nighttime data shows that pooled CO_2 is quickly consumed following sunrise. During the nighttime, we recorded greater than 730 ppm of CO_2 concentration (Figure 1), which quickly dropped to 320 ppm within one hour of sunrise (ambient CO_2 concentration is 421 ppm). These results indicate that nighttime pooling of CO_2 occurs due to combined effects of atmospheric stratification, low wind speeds, soil microbial activities and plant respiration. Our results suggest that farmers using no-till (or potholes) can sequester substantial carbon (C) if adequate inputs are added for greater yields. While average yields in Lesotho are commonly low (< 1Mg/ha), yields of > 10 Mg/ha were achieved on research plots and small subsistence fields. With these higher yields, our results showed up to one ton of C/ha can be sequestered under low tillage conditions; this value could increase using winter cover crops.

In our work, we found nighttime peaks of CO_2 upwards of 700 ppm in maize fields on mountainous terrain in Lesotho (Figure 2). These high concentrations were consistent at the other research sites mentioned previously. We have documented CO_2 capture in several papers (Figures 2, 3, and 4), including Oetting et al. (2024) and a paper currently under review (Raza et al. 2025). A couple more papers are forthcoming from this work. If it is true that increasing [CO_2] will increase grain yield and that field centers have higher CO_2 concentrations, a pertinent question becomes how big a field must be to yield the best. Robinson et al. (2022) found substantial wheat yield increases once 50 m from the field boundary, based on combined yield monitor data from 252 field-years of data. Our research on nighttime pooling of CO_2 and subsequent CO_2 consumption after sunrise supports the hypothesis that field centers should produce up to 25% more than field edges. On the contrary, much of the world's food is produced by farmers on tiny plots, often much less than 1500 m2. These smaller-scale subsistence farmers have recently been pushed to intensify their production onto smaller and smaller fields sustainably; in contrast, in the past, they would farm more land area to increase food production. Unfortunately, the larger area meant more weeding and increased seed cost, which often resulted in less grain being harvested.

CONCLUSION

While these small acreage producers may have lower yields on a global basis, these farmers have a significant impact on local food security. Globally, higher yields are possible with solid agronomics and soil-conserving methods regardless of field size. However, smaller fields will have lower yields than larger fields due to less C pooling in smaller maize fields. How big should the smallest field be to benefit from carbon pooling?

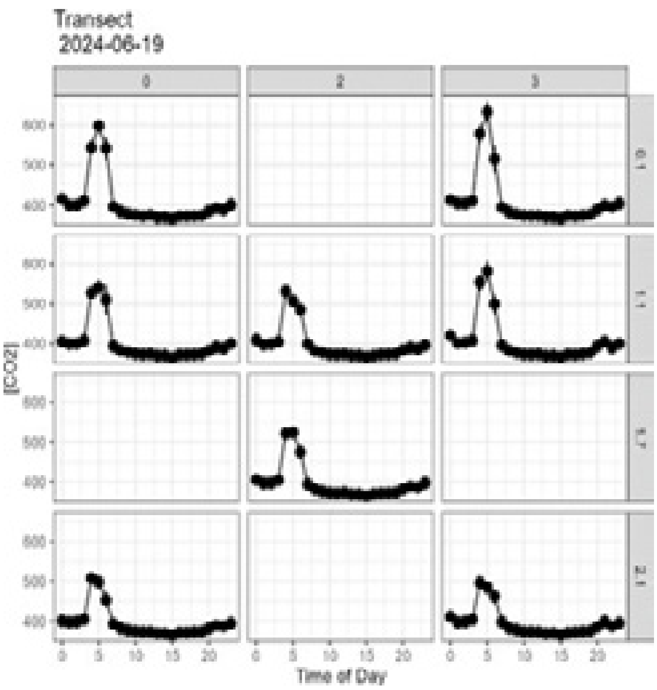

Figure 1. [CO_2] pooling in the canopy is quickly consumed by the plants at daybreak quickly resulting in less than ambient [CO_2].

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KEYWORDS

Soil carbon, carbon sequestration, conservation tillage, no-till, small acreage farmers

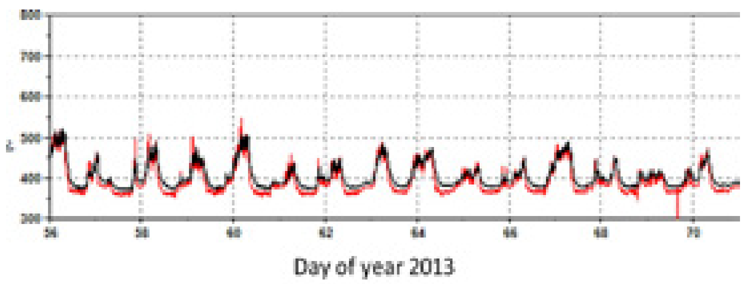

Figure 2. Data from Lesotho in 2012. Unusually high CO_2 concentrations were observed right before sunrise.

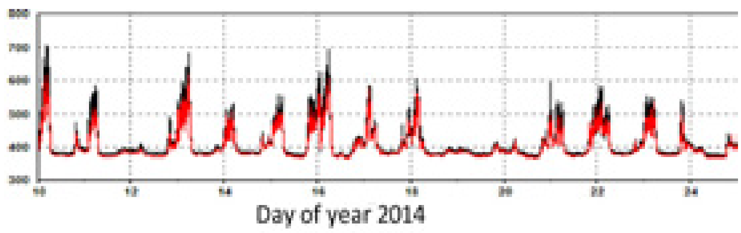

Figure 3. Data from Zimbabwe in 2014 over two fields cropped to maize. 160-m by 160-m plots were split to allow four different crops to be compared using BREB and EC; also added downward-looking infrared temperature sensors. Note that again we see high CO2 concentrations right before sunrise.

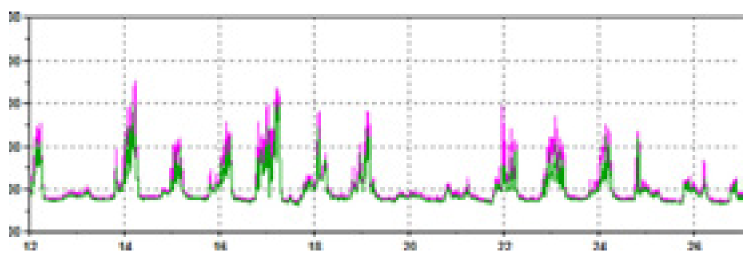

Figure 4. Nocturnal pooling over a blue lupin cover crop in Zimbabwe.

THE EFFECT OF CONSERVATION AGRICULTURE ON ORGANIC CARBON CONTENT IN ARID AND SEMI-ARID AREAS: A CASE STUDY OF RAINFED LANDS IN AQ-QALA CITY, NORTHERN IRAN

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INTRODUCTION

Conservation Agriculture (CA) is defined as a sustainable agriculture production system comprising a set of farming practices adapted to the requirements of crops and local conditions of each region, whose farming and soil management techniques protect the soil from erosion and degradation, improve its quality and biodiversity, and contribute to the preservation of the natural resources, soil, water and air while optimizing yields. Agronomic practices included in CA are based on three interlinked principles, which must be fulfilled concomitantly: 1-Minimum soil disturbance 2-Maintenance of permanent soil covers and 3-Cropping system diversity and crop rotations.

In addition, CA refers to a set of management practices in agriculture that can reduce greenhouse emissions, increase soil carbon sequestration, and improve soil conditions to enhance crop growth. On the other hand, conventional tillage (CT) has a negative impact on the quality of natural resources such as soil, water, biodiversity, and ecosystem services worldwide. Intensive tillage, burning of crop residues and excessive use of chemicals reduce soil carbon. According to the official statistics of Iran's Soil and Water Research Institute (SWRI), more than 61% of Iran's agricultural soils have soil organic carbon (SOC) levels of less than 1%. Since SOC is an important issue and challenge in the global environmental program, it is included in the United Nations program. Therefore, we need to reduce the loss of OC in the soil to achieve this goal.

MATERIALS AND METHODS

In climate-smart agriculture (CSA), organic matter (OM) is a vital indicator of soil fertility and ecosystem services, and it plays an important role in adapting to climate change. CA systems can increase organic content (OC) and improve soil quality index and soil health by fully implementing the three interlinked principles: minimum and without soil manipulation, permanent soil cover, and plant diversity and crop rotation, especially in rainfed lands. This study investigates the impact of CT and CA methods on the OM content in rainfed fields in northern Iran. Iranians are living in an arid and semi-arid belt of the world with limited access to water resources–in addition to their declining groundwater reservoirs. They receive just one-third of the average global rainfall.

The constraints of crop production differ widely across regions. The availability of water and good soils are major limiting factors. Significant losses in crop yields occur due to pests, diseases, and weed competition, which are also of concern. Current approaches to maximizing production within agricultural systems are unsustainable. Agricultural systems demand a diversity of approaches, specific to crops, localities, cultures and other circumstances.

Intervention on a regional and global scale is required from researchers, experts and end-users. Iran, being an agriculture-based economy, better agricultural practices would be key in achieving the Sustainable Development Goals (SDGs), thereby enhancing the peace and prosperity of its citizens. The research was conducted in the rainfed fields of AQ-Qala city, Golestan province, located in the north of Iran. The area has a dry and semi-dry climate with an average rainfall below 350 mm yearly. The site's research includes two regions, A and B, with distinct microclimates. These regions differ in rainfall, temperature ranges, annual evaporation rates, elevations and salinity levels.

Region A has a textured range of silty clay to silty clay loam, salinity levels ranging from 1.3 to 7.5 ds/m, and an average annual evaporation rate of 1800 millimetres. On the other hand, region B has a textured range of silty clay to silty clay loam, salinity levels ranging from 3.6 to 9.2 ds/m, and an average annual evaporation rate of 2400 millimetres.

Additionally, the minimum and maximum air temperature in Region A ranges from -5 to 39 degrees Celsius, while in Region B, it ranges from -12 to 49 degrees Celsius. The average rainfall in Region A is between 250 to 350 millimetres, whereas in Region B, it is between 130 to 210 millimetres. The study compared eight farms, each with an average area size of 10 hectares, representing a unique combination of CT and CA methods.

These fields included CTA, CTB, and various no-till (NT) scenarios with different crop rotation histories. The study included various treatments: CTA and CTB (conventional tillage from each region), NTRA3 (conservation field with crop rotation and a 3-year NT history from region A), NTRA2 (conservation field with crop rotation and 2-year NT history from region A), NTA2 (NT field with 2-year NT history and not crop rotated from region A), NTA1 (NT field with 1-year NT history and not crop rotated from region A), NTB2 (NT field with 2-year NT history and not crop rotated from region B), and NTB1 (NT field with 1-year NT history and not crop rotated from region B).

Soil samples were collected from four depths (0-5 cm, 5-10 cm, 10-20 cm, and 20-30 cm) during the (2022 and 2023) crop seasons and before cultivation. The laboratory measured SOM using the oxidation method (Walkley and Black). The soil analysis results were statistically analyzed using SAS software and the GLM method in a completely randomized basic design. Duncan's multi-domain test was used to compare the averages. The study aimed to evaluate organic carbon content as an indicator of soil quality and fertility. The study results indicated that NT farming, with the longest crop rotation history, positively and significantly affected organic matter content.

RESULTS AND DISCUSSION

The treatment of NTRA3 (a conservation field with crop rotation and 3 years) showed the most significant increase in organic carbon, with the highest OC content averaging 1.467%, 1.400%, 1.353%, and 1.313% in depths of 0-5 cm, 5-10 cm, 10-20 cm, and 20-30 cm, respectively, during the two years of the study. The microclimate of each region had a significant impact on organic matter content. Over the two-year study period, there was a notable increase in organic matter content in fields under no-till treatments, while the OC content in fields under CT decreased.

The findings indicate minimal soil disturbance, using NT methods, implementing crop rotation, and maintaining organic residues, which lead to increased OC content in farm soils in arid and semi-arid areas. Regions (A and B) face various climatic challenges such as water scarcity, extreme heat, limited access to water, high evaporation rates, uneven rainfall distribution, and climate changes. Therefore, adopting CA practices like NT and crop rotation will serve as an effective long-term strategy to enhance soil fertility and structure by increasing OC content in these areas. CA practices can potentially mitigate the adverse effects of climate change on agriculture. CA practices reduce pollution to a certain extent, which benefits the environmental and health perspective. Using newer technology and biological intervention in CA will enhance productivity.

Given the low land holding capacity of most of the farmers, regional needs can be taken care of with CA, which will help reduce inequality. Governmental commitment towards sustainable agriculture and food security and concerted and coordinated efforts of all stakeholders will help achieve the Sustainable Development Goals (SDGs) targets.

CONCLUSION

The knowledge that farmers gained about CA enabled them to understand why and how to practice CA, unlike other programs that required them to follow instructions. The farmers grasped the technical information about CA, thus contrasting with other findings suggesting that CA knowledge was too complicated a package for ordinary rural small-scale farmers to understand.

The demand for more CA training, extension services, equipment, and machinery provides a timely opportunity for institutional support through appropriate partnerships to enable the purchase of capital assets that can be shared within the communities. This will allow smallholder farmers to take advantage of the technology and eventually scale up. CA may become more attractive if future research quantifies annual yield increases, reduced input/labour costs, and increased financial returns. Further research also needs to consider factors such as social networks in this postwar area, gender issues, land issues, machinery-sharing options, and viable markets that could absorb CA produce.

KEYWORDS

biodiversity, crop rotation, dry region, and no-tillage.

55 YEARS OF NO-TILLAGE AND CROP RESIDUE RETENTION ON A VERTISOL IN NORTH-EASTERN AUSTRALIA

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INTRODUCTION

The study addresses a notable gap in our understanding of the long-term impacts of no-tillage (NT) and crop residue management (CRM) on productivity, soil health, and the environment.

MATERIALS AND METHODS

Launched in 1968 at Hermitage Research Station in Queensland, Australia, this experiment is the second-longest continuously maintained no-till research project globally.

RESULTS AND DISCUSSION

Over 55 years and 48 cereal crops, the findings reveal that grain yield was significantly higher under NT compared to conventional tillage (CT), with stubble retention (SR) and stubble burning (SB) showing no significant differences. However, SB exhibited a significantly higher grain protein content than SR, irrespective of tillage practices.

The application of nitrogen fertilizer (NF) significantly increased both grain yield and protein content. Notably, NT with SR demonstrated enhanced water storage efficiency during the fallow period and retained more water in the soil profile at sowing. Pre-sowing soil nitrate-N levels were generally lower under SR and NT than under SB and CT.

Soil organic carbon (SOC) and total nitrogen (STN) concentrations and stocks were significantly higher under NT, SR, and NF than under CT, SB, and N0. However, over time, SOC and STN stocks indicated a decrease across the experiment, particularly in the top 0.1 m under SB and CT, compared to SR and NT.

While topsoil aggregate stability was generally higher under NT and SR, water-stable aggregates were usually unaffected by tillage and CRM. NT typically had no significant effect on biotic factors. SR had significantly higher microbial activity, C-acquiring, and N-acquiring enzyme activities (β-glucosidase, cellobiohydrolase, N-acetyl-β-D-glucosaminidase), easily extractable and total glomalin-related proteins, microbial biomass C, large- (>2 mm) and medium aggregates.

Annual N_2O emissions were significantly higher in NF compared to N0 and lower under NT compared to CT and SR compared to SB. No significant differences in CH4 emissions were observed for any treatment. Leveraging data from the experiment, the APSIM crop simulation model successfully simulated grain yield, soil water, and SOC.

CONCLUSION

This comprehensive study provides valuable insights into the long-term impacts of tillage, crop residue management, and nitrogen application on crop production, soil biology, and environmental dynamics in a sub-tropical environment.

SMARTAGRI: CONSERVATION AGRICULTURE AS A PILLAR IN SUB-NATIONAL CLIMATE SMART AGRICULTURE STRATEGY AND IMPLEMENTATION IN THE WESTERN CAPE OF SOUTH AFRICA

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IINTRODUCTION

In South Africa, the Western Cape Department of Agriculture (WC-DoA) and the Department of Environmental Affairs & Development Planning (WC-DEA&DP) have identified climate change as a significant threat to agriculture and supporting ecosystems. There is strong observational evidence that the climate of the Western Cape is shifting.

Temperatures have increased significantly across all agro-climatic zones, with more hot days and fewer cold days. Reductions in rainfall have occurred primarily in autumn (March-May), including in the two primary rainfed winter grain production regions, the Swartland and the Overberg. Climate change contributes to increasingly frequent and intense drought, but exceptionally wet conditions are also becoming a greater risk.

These trends will continue according to multiple climate change scenarios and models. Projections suggest changes in the quantity, intensity and distribution patterns of rainfall – for example, failure of sufficient autumn rain and more frequent heavy rainfall and flooding. The resulting heat and water stress will hurt crop yield and quality. Due to increased temperatures and changing rainfall patterns, it is also expected that the prevalence and damage caused by pests and diseases will increase.

While the Western Cape Province has had a Climate Change Response Strategy since 2008 (under the overall climate change mandate within WC-DEA&DP), there was a clear need for a sectoral strategy for agriculture to drive effective adaptation and mitigation and to build resilience to the impacts of changing climatic conditions. A climate change response framework and implementation plan for agriculture (SmartAgri plan) was developed with stakeholders starting in 2014, with implementation starting in 2016. Since conservation agriculture (CA) was already proving its value as an approach that can provide on-farm resilience and adaptation to climate risks, especially in rainfed cropping systems, CA became an important part of the SmartAgri plan. Thus, CA, amongst other effective approaches, was incorporated to provide structure and institutional support for further scaling out and up.

MATERIALS AND METHODS

The SmartAgri plan emerged from a 20-month intensive knowledge-gathering and stakeholder engagement process across the province in 2014-2016. Participants represented farmers, extension, organised agriculture, agri-business, financial/insurance institutions, provincial and local government, and water and conservation sector practitioners.

At the start, a "Status Quo Review of Climate Change and the Agriculture Sector of the Western Cape Province" was produced to provide a scientific and contextual basis (Midgley et al., 2016a). During participatory workshops, climate risks, impacts, and possible adaptation and mitigation responses were identified. These were analysed and prioritised using Multi-Criteria Analysis. The Framework and Implementation Plan was then developed (Midgley et al., 2016b).

A systems approach was taken, integrating on-farm production systems; agricultural resources such as soil, water, ecosystem services and energy; human resources; value chain and market factors; monitoring, research and knowledge management; climate extremes and disaster risk reduction and response; and joint planning and action.

Climate change adaptation and mitigation were not assessed separately, and opportunities for co-benefits were identified. Spatially, the assessments were conducted for 23 agro-climatic zones, based on 88 Relatively Homogeneous Farming Areas, a detailed agricultural land use survey, dryland production potential, elevation, and vegetation types (bioregions).

RESULTS AND DISCUSSION

The overall objective of the SmartAgri plan is to provide a roadmap to ensure a low-carbon, climate-resilient agricultural sector in the Western Cape. The SmartAgri plan has four Strategic Focus Areas, including SFA1: "Promote a climate-resilient low-carbon agricultural sector that is productive, competitive, equitable and ecologically sustainable across the value chain".

The first objective is to "Promote climate-smart soil and land use management practices", with the first action to "Increase Conservation Agriculture (CA) adoption rate across all commodities and farming systems". The action is described as "Develop partnerships between Western Cape Government: Agriculture and commodity organisations to drive the further adoption of CA, conduct long-term research and training on CA, and promote financial incentives for the uptake of CA". Owing to the very high prioritization of this action, it is also the first of six Priority Projects and the topic of one of six Case Studies.

Long-term resilient food production under conditions of climate change depends on restoring agricultural soils in terms of their structure, fertility and organic carbon content, water retention, and biotic diversity. CA has proven benefits, leading to stable production even in climatically tricky seasons. CA in the SmartAgri plan aims to build on existing programmes to transition from conventional production systems to CA across the Western Cape. A high proportion of stakeholders prioritised the scaling up of existing CA activities as an essential climate change response measure.

In addition, CA practices were also prioritised by the WC-DoA and WC-DEA&DP because they provided resilience to the significant drought experienced in 2015-2017. Furthermore, reduced tillage, one of the principles of CA, was identified by the provincial government as an important climate change mitigation practice which will contribute towards the provincial emissions reduction goals. Reducing greenhouse gas (GHG) emissions is linked to reduced diesel usage, possible reductions in fertiliser and pesticide usage, and opportunities for carbon sequestration. The Multi-Criteria Analysis (MCA) results of response options showed that CA was one of only four options that appeared in the top 10 of four or more of the rankings.

CA in the Western Cape has historically been researched and implemented in winter grain cropping systems (wheat, medic, lupin, and canola rotations). Still, the principles of sound integrated management can be applied to other commodities and farming systems with context-specific adjustments. During the development of the SmartAgri plan, the opportunity to expand the CA approach to perennial crops (e.g. indigenous rooibos tea, vineyards and fruit orchards), underground crops (potatoes), and livestock systems was highlighted. Mixed crop-livestock systems and managed pastures for dairy production show potential opportunities for the expansion of CA in the Western Cape. The SmartAgri plan provided scientific and policy support for the proposed broadened research and development scope, with good progress made since 2016.

The CA Priority Project focused on creating conditions that catalyse and encourage the adoption of CA principles across the province. Economically, the adoption of CA principles generally leads to a substantial reduction in diesel costs as well as a reduction in the amount spent on fertiliser. However, significant upfront investment is needed to purchase specialised CA machinery, which initially inhibited adoption. The private sector has partially addressed this hurdle and responded by developing local manufacturing capacity, thus contributing to increased adoption of CA. The implementation of the plan is through its institutionalisation within government programmes (including the WC-DoA programme for Research and Technology Development Services and the Extension Services within the programme Agricultural Producer Support and Development), combined with actions taken by non-governmental researchers, farmers and private sector (agri-businesses). In the case of CA, collaboration and partnerships (as envisaged in the fourth Strategic Focus Area: "Ensure good co-operative governance and joint planning for effective climate change response implementation for agriculture") have played a large role in uptake and scaling out. Specifically, the work of the Western Cape CA Association (CAWC) in sharing knowledge and encouraging cooperation to strengthen the advancement of CA practices has been invaluable.

Three years after its initiation, the WC-DOA commissioned an independent diagnostic, design and implementation evaluation of the SmartAgri plan. The purpose was to assess the plan's relevance and design, climate change resilience outcome achievement and how the plan and its implementation can be strengthened going forward. Seven high-level recommendations were made, which are currently being implemented to strengthen its impact. These include the re-engagement and strengthening of uptake by industry organisations and role players and the adoption of mechanisms to identify, promote, and share farm-level innovation, learning, and change towards greater adaptation and mitigation of climate change impacts.

CONCLUSION

Implementing the SmartAgri Plan has contributed to the increased uptake of CA in the Western Cape. The policy continues to underpin research advancement and technology transfer to farmers in support of the up-and-out-scaling of CA in a structured manner. The SmartAgri Plan will be updated to reflect the more recent development of CA towards regenerative and agroecological production practices. Implementing the evaluation recommendations will strengthen existing public-private collaboration and innovation for greater climate-responsive benefits for CA.

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KEYWORDS

Adaptation, climate change, conservation agriculture, mitigation, sub-national policy, uptake

CARBON FARMING TO OVERRIDE THE YIELD-EMISSION TRADE-OFF IN PUNJAB, INDIA

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IINTRODUCTION

The increasing carbon footprint of agriculture and the Voluntary Carbon Markets has catalyzed the expansion of carbon farming. Higher productivity often coincides with increased greenhouse gas (GHG) emissions, complicating the balance between yield maximization and environmental sustainability in agriculture. While Conservation agriculture (CA) practices are gaining prominence in this context due to their ability to sequester carbon and reduce GHG emissions, there are questions on whether these practices pose a yield penalty for which farmers should be compensated in addition to the payments for ecosystem services. This paper aims to identify CA practices that minimize the global warming potential (GWP) without compromising yield in carbon farming projects and estimate a minimum price for carbon credits generated from such adoption.

MATERIALS AND METHODS

To address the abovementioned objective, we collected panel datasets (2018 and 2021) surveying 1021 farm households in Punjab, India. Details of inputs and outputs from wheat farming were gathered. The GWP values were estimated using the Mitigations Options Tool of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS-MOT). We use a trade-off analysis of wheat yield and GWP and a hyperbolic distance function approach to compute the shadow price of GWP in relation to adopting CA practices like zero tillage, mulching, not burning crop residues, and not overusing nitrogen (N) fertilizers.

RESULTS AND DISCUSSION

We find that the most effective practices for enhancing wheat yield relative to GWP (GWP-scaled wheat yield) are avoiding crop residue burning (30% increase), zero tillage (20% increase), and reducing N fertilizer overuse (17% increase). A distributional analysis of the GWP-scaled wheat yield shows a statistically significant improvement in CA adopters. Also, CA practices improve the technical efficiency of the farms. Our preliminary estimate of the GWP shadow price to compensate for the value of a ton of wheat yield (not accounting for any cost increases, labour changes or residue management) is about USD 8 per ton of GWP.

CONCLUSIONS

CA practices like zero-tillage, not burning residue, and not overusing N fertilizers have the potential to produce more wheat per GWP. Given the relative importance of the different CA practices at maximizing yield at minimal GWP, we recommend relatively higher compensatory payments for those not burning residues followed by zero tillage and not overusing N fertilizers.

KEYWORDS

Conservation agriculture, GHG, GWP, Carbon credits, Wheat, Residue burning.

IMPACT OF CONSERVATION AGRICULTURE ON RESIDUE BURNING AND AIR QUALITY IN PUNJAB, INDIA

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INTRODUCTION

Widespread crop residue burning (CRB) in the northwestern Indo-Gangetic Plains has garnered considerable media, policy, and academic attention. A significant share of the 2.5 million farmers in this region burns around 23 million metric tons of rice stubble annually during October-November, leading to heavy release of air pollutants. This study focuses on the impact of conservation agriculture (CA) and shallow tillage technologies on CRB in Punjab, India. Being declared illegal by the governments, CRB is under-reported in household surveys, a gap this study aims to bridge with remote sensing data.

MATERIALS AND METHODS

The study combines Sentinel-2 high-resolution data with a multi-index threshold to detect burned areas from 2019-2022. Virtual sample collection and a two-step change detection process enhanced accuracy in identifying different tillage practices. The smileRandomForest algorithm classified tillage types, complemented by ground truthing on 262 geo-referenced plots from four districts of Punjab. Different village-level Fixed-Effects-Instrumental-Variable (FE-IV) models analyzed the impact of CA on residue burning over three years.

RESULTS AND DISCUSSION

A 50% increase in CRB was observed from 2011-2022 in India. CA and shallow tillage showed a strong negative correlation with burned areas, affirming their efficacy in reducing CRB. However, complexities in detecting tillage adoption, especially the interplay between zero tillage and shallow tillage, affect the estimation of the impact of these technologies on CRB incidents. The measurement error was minimized using FE-IV models, which confirmed the significant causal effect of CA in reducing residue burning. A one per cent increase in CA adoption results in a 0.4%-0.6% reduction in CRB, highlighting the need for better dissemination and adoption policies.

CONCLUSIONS

The study emphasises the critical need for widespread adoption of CA technologies to combat India's increasing trend of residue burning. Despite their proven effectiveness, the declining adoption rates of these technologies call for enhanced support and dissemination policies to ensure environmental sustainability and boost agricultural productivity.

KEYWORDS

Conservation Agriculture, Crop Residue Burning, Externality, Remote Sensing, Technology Adoption

DECODING THE SMOKE: SOCIOECONOMIC DRIVERS AND REGULATORY STRATEGIES FOR CROP RESIDUE BURNING IN INDIA

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IINTRODUCTION

Crop Residue Burning (CRB) presents a quick and labour-saving but environmentally detrimental solution for clearing fields before subsequent cropping seasons (Haider, 2013). India practices intensive agriculture and resorts to CRB despite national policies attempting to curb it, like the National Policy for Managing Crop Residue (NPMCR) 2014 and the ban on CRB imposed by the National Green Tribunal in the Indo-Gangetic Plains (IGP) covering Punjab, Haryana, Rajasthan and Uttar Pradesh (Press Information Bureau, 2019).

The sub-optimally adopted Conservation Agriculture (CA), like zero-tillage (ZT) and mulching, can be incentivized using agricultural carbon credits. The alternative uses of crop residue as cattle feed and input for bioenergy production can be promoted. This calls for a robust measurement, reporting, and verification (MRV) system and a cost-effective approach to monitor CRB (Jayachandran, 2023). Thus, we must incentivize sustainable crop residue management (CRM) instead of burning it to lay the groundwork for an effective regulatory and reward mechanism. Our novel study investigates: Who practices CRB and why? What policy measures can discourage CRB and promote CA?

MATERIALS AND METHODS

The study scrutinizes farmer household data and remote sensing data from Punjab (which bans CRB) and Madhya Pradesh (which does not ban CRB). Employing multi-stage random sampling, the International Maize and Wheat Improvement Center (CIMMYT) obtained data regarding CRM practices from 1122 wheat-growing households (2021-2023). Corresponding to this, remote sensing data of burned agricultural residue areas was collected using Sentinel-2 satellite imagery by the Indian Institute of Science Education and Research, Bhopal (IISER-B). A correlation is drawn between the farmers' responses and remote sensing data to identify possible measurement errors like undetected burning, i.e., burning reported by farmers but not detected by the satellite, or unacknowledged burning, i.e., burning not reported by the farmers but detected by the satellite. Moreover, we integrate the satellite and household survey data to reveal the socio-economic and institutional/policy factors influencing the farmers' decision-making regarding CRB. For the same, in Punjab, we study the scenario of CRB after the Kharif season (June to September) of 2021. While in Madhya Pradesh, we examine the CRB after the Rabi season (October to April) of 2021 and 2023 and the Kharif season of 2022.

RESULTS AND DISCUSSION

We found that if other factors remain unchanged, then compared to Kharif crop residue, Rabi crop residue is less likely to be burnt, similar to the findings of existing studies (Kaushal, 2022). For instance, 43% of farmers in Punjab and 22% in Madhya Pradesh reported Kharif CRB in 2021 and 2022, respectively, also detected by the satellite. These can be classified under 'matched reporting and detecting residue burning'. Meanwhile, studying the prevalence of CRB in Madhya Pradesh, it was found that only 10% of farmers in 2021 and 2% of farmers in 2023 reported Rabi CRB, which was also detected by the satellite. This is because Rabi crop residue can be used as cattle feedstock or for biogas production, unlike Kharif crop residue (Venkatramanan et al., 2021).

Furthermore, Punjab shows a higher propensity for CRB despite its ban on the practice, unlike Madhya Pradesh. This could be due to the lack of precision in real-time satellite detection of open CRB hotspots. Additionally, the high cost of field visits limits the supervision of farmers' on-site behaviour (Cao & Ma, 2023) regarding their adherence to the ban. Thus, an alternative approach that discourages CRB while promoting alternative uses of crop residues accompanied by an effective MRV system is required. An agricultural carbon credit framework, modelled on the Payment for Ecosystem Services mechanism, can be a potential alternative. The recent advances in remote sensing technology to detect smallholder farmers' CRB using Sentinel-2 data can viably facilitate rigorous MRV for an efficient carbon market (Deshpande et al., 2022). Such an initiative could financially incentivize farmers to practice sustainable CRM and pave the way for regenerative agriculture and carbon farming. To effectively roll out the initiative, the reported and detected CRB determinants should be identified for targeted policymaking.

The econometric models find that the farmer's gender (female), religion (non-Hindu), caste (marginalized), soil type (non-clayey), reliance on rainfall for irrigation, mulching, and early sowing of Rabi crops in September-October inversely influence their likelihood of CRB. Meanwhile, the farmer's age, area under wheat cultivation, reliance on tubewells for irrigation, and zero tillage directly impact the farmers' likelihood of CRB. The total landholding of farmers and share of area under cultivation has a mixed effect on CRB. These align with previous studies (Gailhard & Bojnec, 2021; Gupta et al., 2007; Gupta et al., 2021; Bajracharya et al., 2021).

In some cases, the satellite may detect CRB, but the farmers may not report it, resulting in unacknowledged burning. This may be due to neglect of social costs for private benefits or fear of social disapproval of alternative practices (Lopes et al., 2023). As per our study, females, especially the Sikh, or educated farmers of scheduled castes or other backward classes, having a larger share of land under cultivation with non-clayey soil and solely dependent on rainfall for irrigation, are less likely to resort to unacknowledged burning. Older farmers or those dependent on tube wells for irrigation are likelier to practice unacknowledged burning.

CONCLUSION

Our novel study on the current scenario of CRB in Indian agriculture and its influencing factors follows a two-step approach to ascertain prospective regulatory strategies for CRB. Firstly, it studies a sample of farmers in two agricultural states of India, Punjab and Madhya Pradesh, and confirms a preference for CRB over CRM. A nationwide agricultural carbon credits policy could incentivize CRM under a robust MRV system. Secondly, the study identifies multiple socio-economic and institutional drivers for farmers that are associated with the possibility of CRB.

They can be targeted for specific policy formulation to discourage CRB. For instance, as education appears to positively influence the farmer's decision regarding CRB, awareness and training programs could be initiated to educate the farmers about the ill effects of CRB and promote sustainable agricultural technologies. These policies should essentially focus on involving more vulnerable classes of farmers like females, aged, small, and marginal farmers, or those belonging to marginalized castes.

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KEYWORDS

Carbon markets, Carbon sequestration, Conservation Agriculture, In-situ stubble burning, Payment for environmental services, Satellite mapping.

CONSERVATION AGRICULTURE: THE UNIVERSAL PARADIGM OF SUSTAINABLE AGRICULTURE

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IINTRODUCTION

It has now been more than half a century since the practical concept of no-till farming came into being in response to the global need to control soil erosion on agricultural lands managed under tillage farming in various countries around the world, including the devastating wind erosion events in the mid-west of the United States. No-till farming offered protection against erosion when combined with biomass soil mulch cover, including stubble mulch, which held the untilled soil together and protected it from erosive forces.

The modern forms of no-till mulch-based diversified cropping systems are sustainable, productive and profitable and are referred to as Conservation Agriculture (CA). In 2018/19, CA was being practised by small and large farmers on more than 205 million hectares in more than 100 countries under rainfed and irrigated conditions, and involving all land-based production systems, organic and non-organic, comprising annual and perennial crop systems, in mixed systems with or without animals, orchards and plantations, permanent pastures and grazing lands in all agroecologies in the tropics, sub-tropics and temperate climatic zones.

The annual rate of spread since 2008/09 has been about 10 million hectares of yearly cropland (Figure 1). In addition, there are significant areas of CA systems with perennial crops in regions with semi-arid, sub-humid and humid climates. The global uptake curve of CA represents an ongoing successful revolution in which farmers are moving away from degrading tillage-based agriculture.

Due to soil erosion problems and the need for production intensification, the search for sustainable farming systems began, leading to Green Revolution (GR) agriculture and Organic Agriculture (OA) and its political version of Agroecology. These systems have not been successful since they are all managed with intensive tillage and use sub-optimally high levels of synthetic agrochemicals (in GR systems), organic agrochemicals (in OA systems), and fossil fuel energy.

Regenerative Agriculture (RA) has recently attracted attention even among the promoters of tillage-based GR and OA systems. However, the origin of RA defines it with the three principles of CA as the foundation for its regenerative nature, adding the integration of animals and continuous root growth as further necessary components. Both are beneficial for regeneration and, as such, are not excluded in CA, but they are not universally applicable. Thus, no-till RA systems are essentially CA systems and not alternatives.

This paper elaborates on the reasons why CA works successfully universally for all land-based annual and perennial crop production systems in all agro-ecologies in all climatic zones, from the tropics to the subtropics to temperate zones. Understanding why CA principles and systems are the foundation for sustainable agriculture production for economic, environmental, and social development is important.

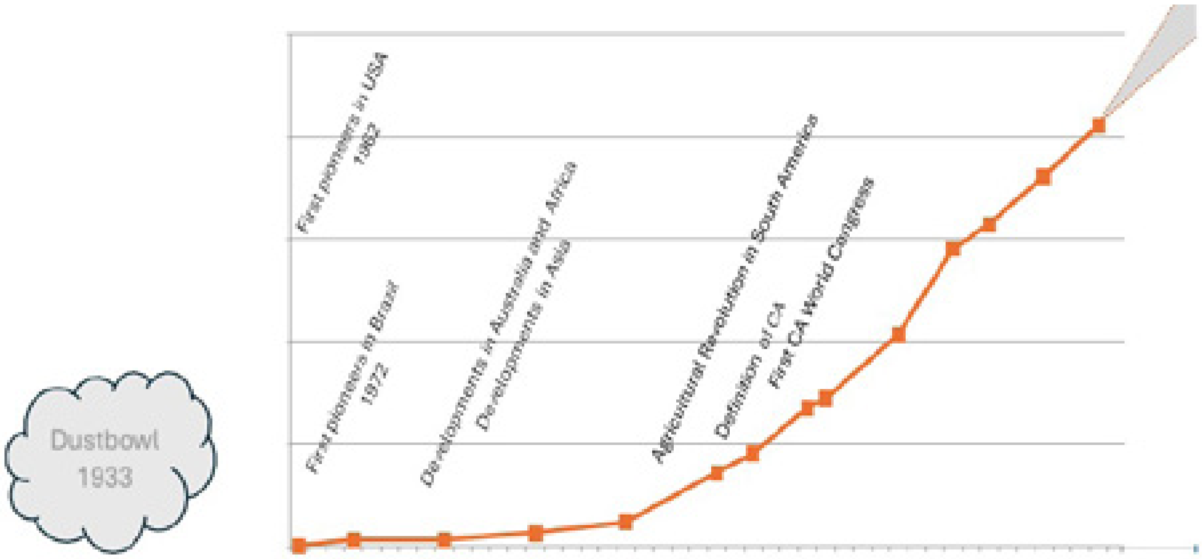

Figure 1. Historical uptake of CA cropland at the global level

HISTORICAL DEVELOPMENT

By the seventies, reduced tillage systems, including no-till systems, gained interest for erosion control and cost-saving reasons. In this process, these systems were better understood, noticing improvements in soil bio-physio-chemo-hydro quality and functions normally degraded under tillage management and input efficiency while delivering the desired production and environmental services sustainably and profitably. In the seventies, knowledge about no-till soil and weed management had spread from the USA to South America, Europe, Africa, and into Canada and Australia.

No-till farming management revealed that the resulting improvements in soil quality and functions not only improved production efficiency but also environmental performance in terms of minimizing runoff and erosion, improving soil-plant-water relations, water cycling and quality, nutrient cycling, and carbon capture in the soil, as well as enhancing biodiversity and food quality. These benefits aligned well with the increasing need for sustainable agriculture development as part of sustainable development. At the international and regional levels, FAO was a key institution that actively promoted what came to be known by 1997 as CA as the basis for sustainable production intensification. It has encouraged and supported farmers in field projects in all developing regions to adopt CA in collaboration with local and international research and extension colleagues and supported national no-till associations that had been established.

WHAT MAKES CA SYSTEMS GLOBALLY SUCCESSFUL

For a production system in any land-based agroecosystem to be able to operate sustainably and optimally at the farm and landscape level, including the need to intensify the desired biological and environmental outputs, it would need to be able to enhance and conserve or sustain agroecosystem health and functions of all its components. More specifically, it would need to:

- Offer best output performance in terms of biological products for a given unit of production inputs enabling best factor productivities.
- Allow the multiple-level agroecosystem processes underpinning environmental services to function at their best at the field, farm, landscape, and watershed levels, including the efficient management of carbon, nutrients, water, pests, energy, labour, and capital.
- Conserve all agroecosystem resources and ecological processes in the crop-soil-water-atmosphere system and regenerate degraded ecological processes and stocks of organic matter, nutrients, water, and biodiversity related to soil and landscape health and function.
- Contribute to multiple outcome objectives at the farm, community, landscape and national scales – multifunctional agriculture.
- Regenerate land productivity and ecosystem services in degraded and abandoned lands.

To achieve the above main biological output and environmental service performance objectives universally requires that the following four dimensions underpin the production system and landscape management:

1. An ecosystems approach to production and land use, to be holistic in design and practice, optimize not just production but all other multifunctional processes of the ecosystem and have the ability to address ecosystem issues by harnessing the rehabilitation, regeneration, and other life-giving processes of nature.
2. An ecological base for production systems for sustainable and optimum general performance, based on interlinked ecological principles and practices of no or minimum soil disturbance, permanent soil cover, and crop diversification to deliver biological products and ecosystem services regeneratively.
3. A minimised use of external production inputs, including agrochemicals, seeds, animal manure, water, energy, time, and machinery, supported by natural regulation processes and optimized input efficiency.
4. Agroecosystem resilience by sustaining crop health and productivity, soil and landscape health and functions, and offering the best climate change adaptability and mitigation.

The above conditions are met in any land-based production system when the three interlinked principles of CA are applied, along with complementary integrated crop, soil, nutrient, water, pest and energy management practices. Figure 2 illustrates the dynamics of enhancement and regeneration established in all CA systems. Figure 3 illustrates how a comprehensive CA system can be viewed regarding its potential to accommodate components adapted to local biophysical and socioeconomic contexts.

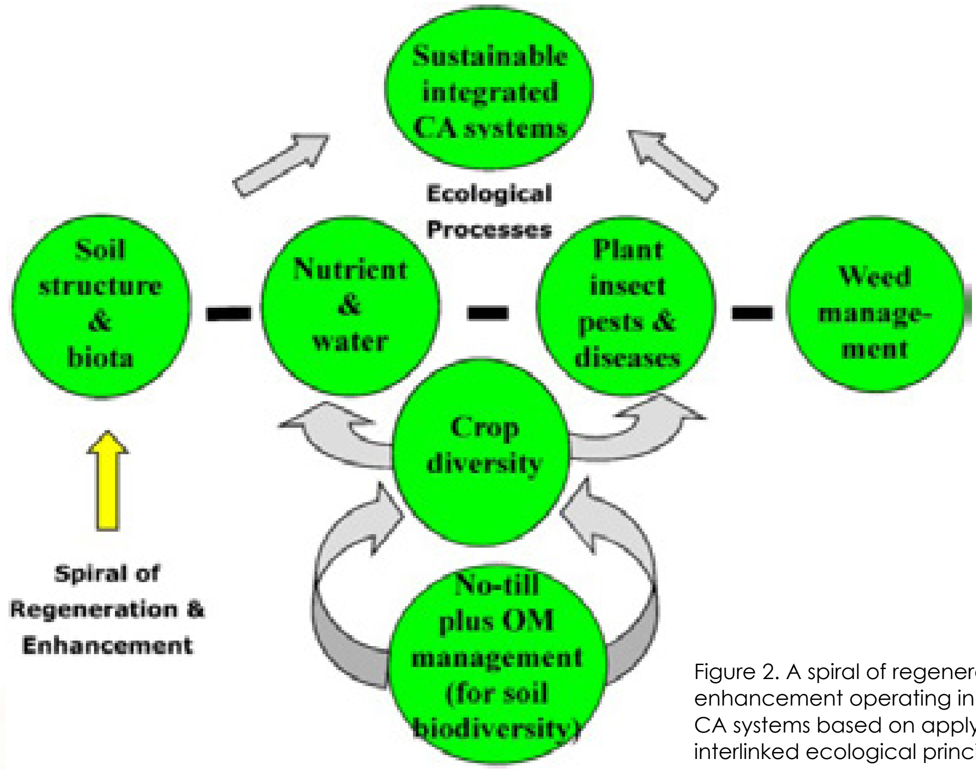

Figure 2. A spiral of regeneration and enhancement operating in integrated CA systems based on applying the three interlinked ecological principles.

In sum, CA systems perform optimally and are universally successful because they:

- Have ecological and biological foundations for sustainability.
- Generate enhanced soil health status, biology, and functions.
- Enhance biodiversity and, therefore, natural control mechanisms and feedback cycles.
- Have diverse plant root systems that enhance soil systems.
- Enhance environmental and ecosystem functions and deliver benefits to farmers and society.
- Develop maximum efficiency and resilience.
- Can regenerate and rehabilitate degraded agricultural lands.

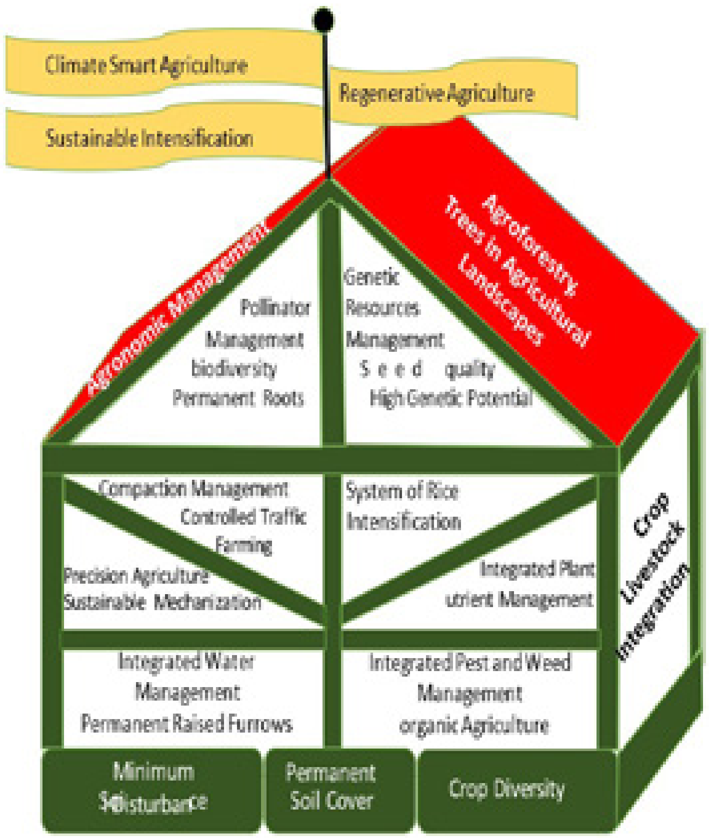

Figure 3: The three interlinked CA principles constitute the ecological foundation for sustainable agriculture with complementary good agricultural practices.

CONCLUSION

The CA principles are universally applicable to organic and non-organic production systems in rainfed and irrigated conditions, with annual and perennial crops, and constitute the best forms of sustainable production and land use systems for small and larger farms with any form of farm power. CA is a valid universally applicable paradigm for sustainable agriculture and land use which can contribute to the achievement of several of the Sustainable Development Goals.

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ENHANCING AGRICULTURE RESILIENCE WITH LONG-TERM CROP ROTATION TRIALS UNDER CONSERVATION AGRICULTURE

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INTRODUCTION

Enhancing wheat production under dryland conditions in a Mediterranean climate with hot and dry summers, degraded soils, and depleted soil carbon stocks is a challenge. Monoculture, tillage and overgrazing played a role in the degradation. However, conservation agriculture can improve soil quality and food production. The lack of knowledge on the biological and economic sustainability of crop and mixed crop/pasture rotation systems under conservation agriculture has been a barrier for local producers. Long-term crop rotation trials have the potential to help identify the ideal crop rotation system for a given environment and production area. The ideal crop rotation system could significantly reduce production costs, increase crop quality, create financial stability and create economically sustainable land use. This paper evaluated the performance of eight Conservation Agriculture systems over 20 years (under full CA practices).

MATERIALS AND METHODS

The trial was conducted under rain-fed conditions in the Western Cape South Africa's Swartland region. Eight cropping systems under Conservation Agriculture (1996 to 2021) practices were assessed. The eight cropping systems were as follows: A) Wheat monoculture, B) Wheat-Wheat-Wheat-Canola, C) Wheat-Canola-Wheat-Lupine, D) Wheat-Wheat-Lupine-Canola, E) Wheat-Medic pasture, F) Wheat-Medic and Clover pasture, G) Wheat-Medic pasture-Canola-Medic pasture, H) Wheat-Medic pasture with additional perennial old man saltbush (Atriplex nummularia) grazing. Four systems (A to D) contained only cash crops, while the remaining 4 four (E to H) combined cash crops and pastures. The four mixed pasture/crop systems and two cash crop systems (C and D) contain legumes. All eight systems were four-year rotations, and the trial contained all crops present in each system in the field every year.

The experimental design was a randomised block with two replications. The two replicates are laid out regarding soil, with one replicate on higher production potential soil and one on lower production potential soil. The data was analysed over 20 years because of the low number of replicates. The interaction was investigated using the Additive main effects multiplicative interaction (AMMI) analysis and the Genotype plus Genotype by Environment (GGE) biplots - GenStat software. The inputs of each system are managed according to the requirements of the specific system. Each plot's inputs and harvest data were recorded, and soil samples were collected annually.

RESULTS AND DISCUSSION

Soil disturbance was gradually reduced from minimum to zero-till as the soil improved and machinery became accessible. Minimum tillage was used until 2001 when the first no-till tine seeder was obtained. Tine seeders were used until 2016 when a zero-till double disc Piket seeder was introduced. Eight years after the trial started in 2003, a drought caused all the cash crops to fail except for wheat in the mixed crop/pasture systems.

The soils improved on the trial with increased soil carbon across all the systems. This indicates that reduced tillage and residue retention positively influenced all systems despite varying diversity levels and livestock presence in some systems. This was highlighted in 2015 and 2017, when all cash crops were harvested despite the lower rainfall than in 2003. The average wheat yield over all the systems was 500kg, 2100kg and 2500kg in 2003, 2015 and 2017, respectively, although 2017 was the driest year with 171 mm of precipitation in the season. The improved water use efficiencies are especially beneficial under varying climatic conditions with dry spells.

Wheat in systems containing legumes received lower amounts of nitrogen fertilisers. Wheat yield and quality improved and stabilised in the more diverse systems containing legumes. Wheat in a mixed pasture cropping system had the highest production and quality. System G and H received 54 kg/ha of nitrogen fertilisers compared to 81 kg/ha of nitrogen fertilisers in system B. However, despite this, systems G and H had the highest wheat yield and protein content compared to all the other systems, with a more stable yield over the years. The dependence of cash crops on nitrogen fertilisers was reduced, especially in systems containing legumes. The amount of nitrogen fertiliser applied decreased in all the systems as the efficiency of soil and nitrogen use improved.

The dependence on artificial inputs was reduced throughout the trial. Constant infield monitoring is used to identify when and if chemical inputs are required. Chemical inputs were only used when it would improve profits. The use of insecticides was phased out over time, and since 2019, no insecticides have been applied in any of the systems. In 2021, wheat plots in all the mixed pasture cropping systems achieved 5.8 tons to 6.2 tons of wheat yields. These plots received 35 kg/ha of nitrogen fertiliser and no insecticides. Weed pressure increased in the cash crop systems and influenced yields despite the use of herbicides. In 2021, some of the systems changed to further improve Conservation Agriculture in the area and address weed problems. These new systems improved diversity and incorporated cover crops.

CONCLUSION

Conservation agriculture alleviated problems in conventional agriculture. It improved sustainability with lower inputs and improved production over 25 years. Despite various systems, Conservation Agriculture can improve sustainability, but weeds can become problematic. This paper offers practical solutions for strengthening agriculture resilience and sustainability in dryland conditions. One main limiting factor in these conservation agriculture systems was trusting the system. Nitrogen fertiliser applications were drastically reduced 20 years after the trial started, and insecticide was phased out 23 years after the trial began. These actions could have been taken earlier. In short, management needs to adapt as systems improve. Risks must be taken to establish if systems can perform with fewer artificial inputs.

KEYWORDS

Carbon, input reduction, long-term research, rain-fed

THE IMPORTANCE OF UNDERSTANDING MESOSCALE WEATHER FEATURES TO ASSIST CONSERVATION AGRICULTURE PRACTISES IN SOUTH AFRICA: A CASE STUDY

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INTRODUCTION

South Africa is situated at the southern tip of Africa (22-35°S and 16-33°E), bordered by the Indian Ocean along the east and south-east coastline and the Atlantic Ocean along the western coast. South Africa has a subtropical and temperate climate (RSA, 2018). Subtropical regions are usually arid or semi-arid due to the dominance of subsidence (Tyson et al., 2000). The western parts are mainly influenced by the subsidence (descending air associated with the Hadley cell) and are consequently drier compared to the eastern parts (Mahlobo et al., 2018). This is also supported by the Köppen-Geiger climate classification, as modified by Engelbrecht and Engelbrecht (2016) (fig 1).

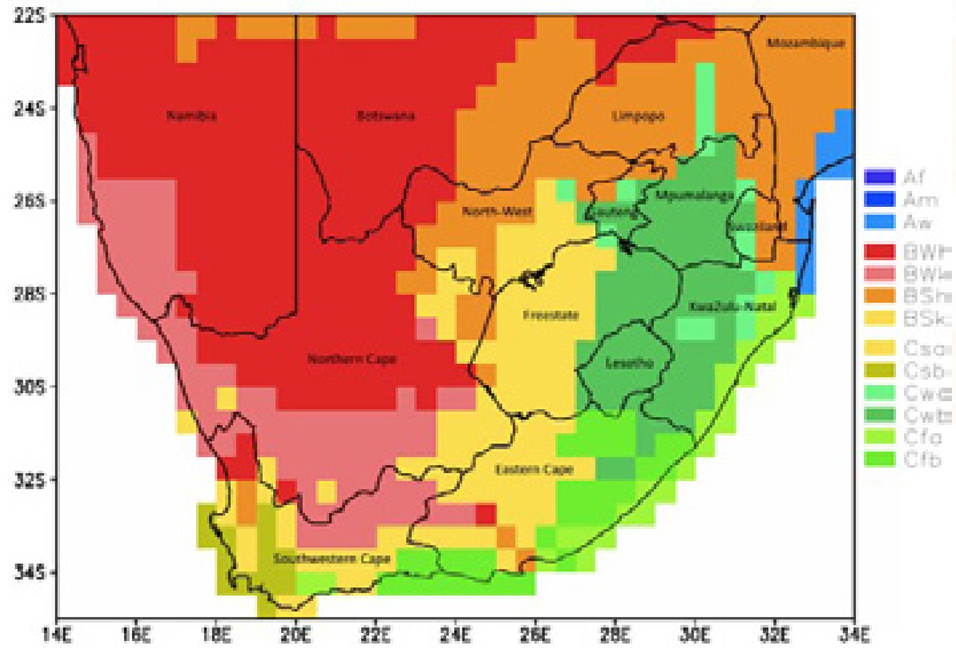

Figure 1. The Köppen-Geiger climate classification for Southern Africa (Engelbrecht and Engelbrecht, 2016).

South Africa's rainfall seasonality differs significantly from the east (mainly during the summer) to the west (mainly during the winter) (Fig 2). The eastern parts of the summer rainfall region generally receive precipitation during early to mid-summer, and the western parts late to very late summer. The precipitation source is primarily due to convective systems (such as squall lines, supercell thunderstorms, etc.). (Liesker, 2021, Gijben, 2011), either as heat-induced thunderstorms or due to synoptic systems such as Africánes (Viljoen et al., 2022) or Tropical Temperate Troughs (TTTs) (Hart et al., 2010).

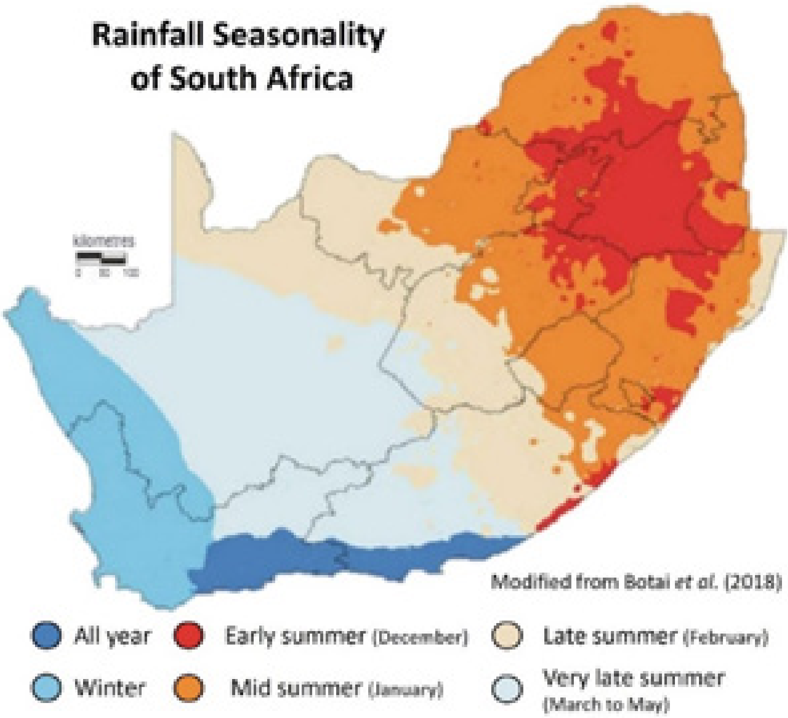

Figure 2. The rainfall seasonality of South Africa (Botai et al., 2018).

In meteorology, we can define three distinct horizontal scales of motion (fig 3). These are: 1) the synoptic scale, which comprises atmospheric phenomena that exceed 2000 km in horizontal scale; 2) the mesoscale for phenomena that range between 20 and 2000 km; and 3) the convective scale for phenomena between 0.2 and 20 km (Houze, 2014). Squall lines (SLs) are mesoscale systems that can produce damaging straight-line winds, large amounts of small hail, large hail, heavy downpours leading to flash flooding and even tornadoes or the occasional dust storm (Ashley et al., 2019, Basara, 2008, Bhalotra, 1957, Przybylinski, 2004, Takemi, 1999, Wiston and Mphale, 2019). According to the Glossary of Meteorology , a Mesoscale Convective System (MCS) is "a cloud system that occurs in connection with an ensemble of thunderstorms which produces a contiguous precipitation area on the order of 100 km or more in horizontal scale in at least one direction". Houze (2014) also suggested that MCSs have a length scale of 100 km and a timescale of approximately three hours. MCSs are divided into two groups, Mesoscale Convective Complexes (MCCs) and SLs.

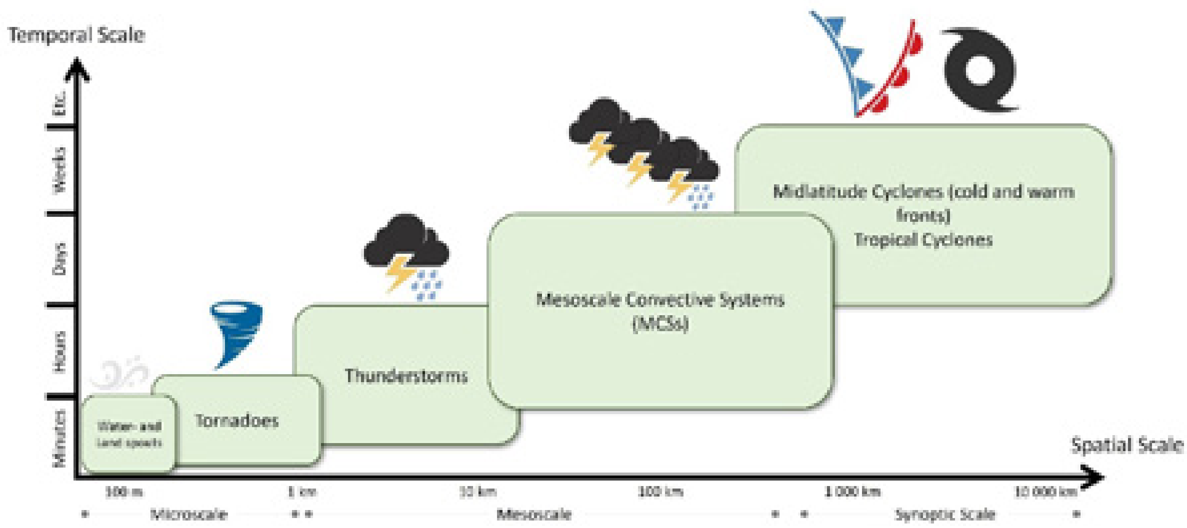

Figure 3. The scales of atmospheric air motion in relation to time and space. Modified from Brisch and Kantz (2019).

MCSs have a positive impact on the agricultural sector due to the distribution of essential rainwater over a large spatial extent (Blamey and Reason, 2012)However, this study's objective was to highlight the possible negative impacts associated with MCSs and their impact on the agricultural sector.

Data and Methodology

This study used geostationary infrared (IR 10.8µm) satellite imagery from EUMETSAT. IR satellite imagery assists in determining the intensity of convective systems by displaying the cloud top temperatures (CTTs). The colder the CTT, the more intense the convective cell. Maddox (1980) used IR satellite imagery and CTTs to define an MCC. Anderson and Arritt (1998), modified this criterion and added a shape criterion to identify SLs (table 1). Both methods were used in this study. MCCs and SLs share the same physical characteristics on IR satellite imagery; however, the shape of the convective system at its maximum extent differentiates the two types. To identify MCCs and SLs on IR satellite imagery, a continuous cloud shield with temperatures less or equal to -52°C with an area greater and equal to 50 000 km2 should be identified. The convective system should last for at least six hours, and when its maximum extent is reached, it should have an eccentricity greater or equal to 0.7 or less or equal to 0.2, respectively. However, the duration of South African squall lines typically does not exceed six hours (Held, 1977, Edwards, 1994), unlike squall lines in other regions (Parker and Johnson, 2000, Fernandez, 1982). Nevertheless, when using the radar identification method, they are classified as SLs (Heyneke et al., 2023), emphasizing the need for a specific definition of squall lines for southern Africa. Additionally, Houze (2014) mentioned that the minimum duration for an MCS is three hours. Therefore, South African convective systems can be classified as MCSs when they meet the size and shape criteria, lasting only between three and six hours.

Table 1. IR satellite imagery criteria for MCCs and SLs (Maddox, 1980, Anderson and Arritt, 1998)

	Physical characteristics	
MCS type	MCC	Squall line
Size	Continuous cloud shield: IR temperature ≤ -52°C and area ≥ 50 000 km²	
Initiation	When size definition is first met	
Duration	Size definition met for ≥ 6 hours	
Maximum extent	When cloud shield reaches maximum extent	
Shape	Eccentricity (minor/major axis) ≥ 0.7 when maximum extent is reached	Eccentricity (minor/major axis) ≤ 0.2 when maximum extent is reached
Termination	When size definition no longer met	

RESULTS AND DISCUSSION

Case study 1: Squall line

The first MCS occurred on 31 January 2018. This system developed over the western parts of the Free State (fig 4 at 20:30 UTC), intensified, and moved to the central Free State where the Beatrix gold mine is situated (fig 4 at 21:30 UTC). At this stage, it was classified as a squall line (Heyneke et al., 2023) with a length of 261 km and a width of 43 km. Further intensification of the squall line occurred on the western flank of the system (Fig 4 at 22:30 UTC). The impacts made global headlines after nearly 900 miners were trapped underground due to power lines being blown over by damaging straight-line winds (Batchelor, 2018; Guardian, 2018; Westcott, 2018).

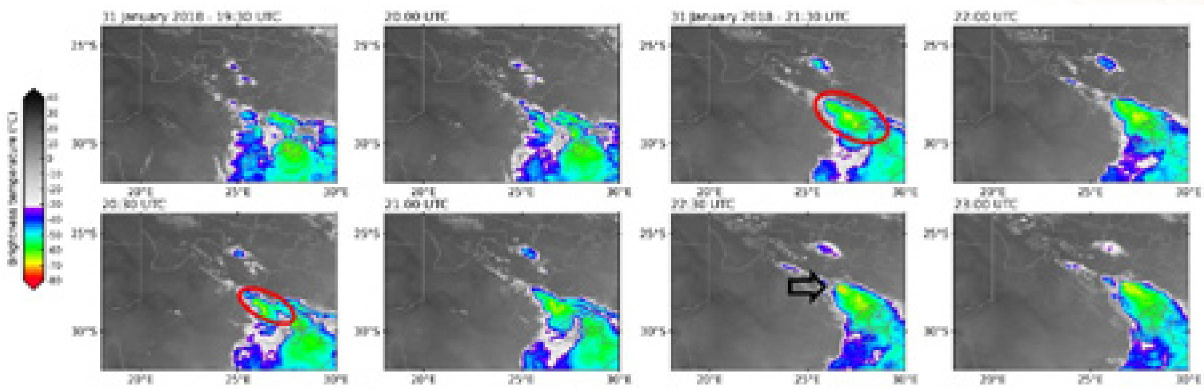

Figure 4. The CTT (brightness temperatures in °C) associated with the 31 January 2018 SL. The red ovals highlight the area of the SL, while the black arrow indicates the most intense part of the system.

Case Study 2: Mesoscale Convective System

During the first week of February 2024, unseasonal severe thunderstorms were observed over the western interior of the Western Cape. On 2 February, a hailstorm Near Citrusdal, agricultural netting was torn due to the weight of the hail. On 3 February, a rare MCS with estimated wind gusts up to 100 km/h blew over several Eskom power lines near Laingsburg, resulting in electricity disruptions for large parts of the region (Payne, 2024). Before the event, an overshooting top (fig 5a at 17:00 UTC) indicated strong updrafts and a possible severe thunderstorm, was observed north-west of the damage location. This MCS was classified as a rare event (Heyneke et al., 2024), since these systems typically occur over the eastern parts of South Africa, where moisture from the southwestern Indian Ocean is abundant (Blamey and Reason, 2012).

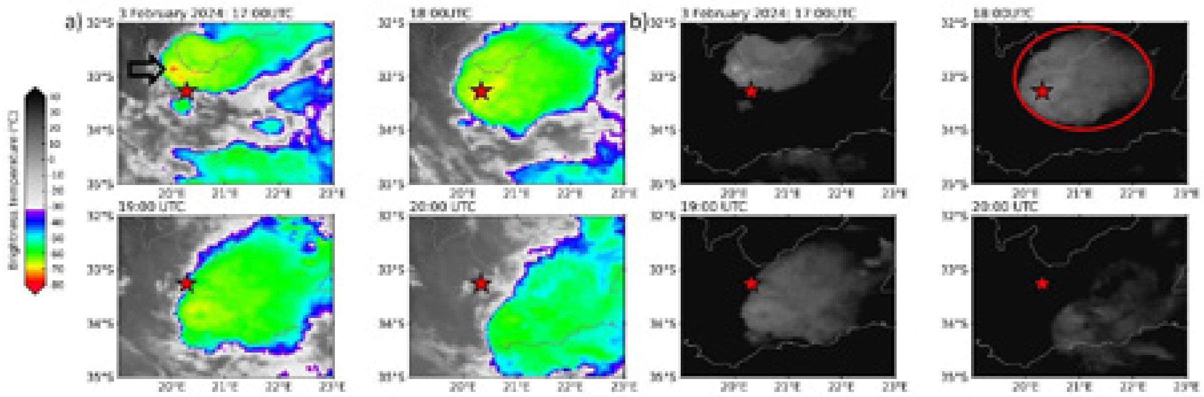

Figure 5. a) The CTT (brightness temperatures in °C) associated with the 3 February 2024 MCS, and b) the cloud shield (CTT ≤ -52°C) for the same case. The red oval highlights the area of the MCS when the maximum extent was reached, while the black arrow indicates the overshooting top. The red star marks the damage location.

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- *[1]https://glossary.ametsoc.org/wiki/Mesoscale_convective_system*
- *[2]https://www.facebook.com/Platteland/videos/hael/1454888445063271/*

KEYWORDS

Impact-based Forecasting; Severe weather events; Squall lines; Mesoscale Convective Systems

HERBICIDE RESISTANCE IN LOLIUM SPP.

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INTRODUCTION

Conservation Agriculture (CA) systems are based on three principles: minimal soil disturbance, permanent soil cover, and crop diversification (FAO, 2024). Herbicides such as paraquat (1,1'dimethyl-4,4'-bipyridynium dichloride) and glyphosate (N-(phosphonomethyl)glycine) have been used for decades to control unwanted plants, i.e., ryegrass (Lolium spp.).

Belonging to the same taxonomic family (Poaceae) as wheat, ryegrass is a problem in the predominately CA grain-cropping systems of the Western Cape South Africa (Pieterse, 2010; Popay, 2013; Modisella et al., 2015). The CA principles limit weed control options, increasing reliance on herbicides during a herbicide-resistant epidemic (Cobb, 2022). Paraquat-resistant ryegrass was first observed in South Africa in 2004 (Yu et al., 2004).

The same ryegrass population was later determined to be the first reported case of glyphosate and paraquat multiple herbicide-resistant ryegrass globally (Yu et al., 2006). The herbicide practices on the herbicide-resistant population have not been amended in the last twenty years. Additionally, this population is suspected of being resistant to glufosinate-ammonium (2-amino-4-(hydroxymethylphosphinyl) butanoic acid) used in trials.

The site conditions provide an opportunity to observe the development of multiple herbicide resistance. Ryegrass plants from a CA site were suspected to being herbicide-resistant and having adapted to herbicide application by selecting for longer germination periods. Germination and dose-response experiments were conducted on ryegrass from the known resistant site and the CA site to analyse the effects of a CA system on paraquat resistance in terms of life-cycle adaptations and lethal effective dose (LD50) in South Africa.

MATERIALS AND METHODS

Ryegrass seeds were collected from Welgevallen Experimental Farm (WS) in Stellenbosch (33◦56'33.86" S, 18◦51'54.11" E), having been consistently sprayed with glyphosate and paraquat for 40 years to clear the field for herbicide trials. Seeds were collected from the perimeter (paraquat and glyphosate regime - WP). Additionally, seeds from Langgewens Research Farm (LS - 33◦16'36.588" S, 18◦42'11.416" E) were sprayed sporadically with paraquat and followed a diverse herbicide regime and a wheat-wheat-wheat canola crop rotation. Commercially available ryegrass (Lolium multiflorum) for pasture production (BC) was used as a control. Germination experiments were conducted following the International Rules for Seed Testing (ISTA), determining mean germination time (mgt), mean germination percentage (mpg) and thousand-seed weight (TSW) calculated using Data Count S 25+. Two dose-response experiments took place.

First, under stressful glasshouse conditions, i.e., heat stress (35◦C Day/ 4◦C night), plants were subjected to a dose-response experiment using a randomised block design with four replications per treatment. The varying number of treatments were increasing doses of Gramoxone® 360 (paraquat) starting from 0.25X to 33X, where X is the recommended dose at 0.6 kg active ingredient (a.i.) ha−1. Second, the glyphosate-paraquat-resistant WP and WS populations were tested for multiple-herbicide resistance combination with glufosinate-ammonium, with ryegrass grown in a glasshouse (23◦C Day / 8◦C night).

Glygran® 710 SG (glyphosate at X = 1.08 kg a.i. ha−1), Skoffel® 200 Super (paraquat at X = 0.6 kg a.i. ha−1) and Lifeline® (glufosinate-ammonium at X = 1.5 kg a.i. ha−1) were applied from 0X to 8000X. Surviving plants, i.e., had living tissue, were recorded, and the above-ground biomass was collected and dried at 60◦C for 72 hours.

Data was analysed using R. A 4-parameter logistic function was applied to determine the lethal effective-dose LD50, defined as the dose (dosej) that results in 50% mortality of a population: f[dosej , θ = (C,D,B,E)] = D + (C − D) 1 + eB×(log10(dosej)−E). C is the upper limit, D is the lower limit, B is the slope of the curve, and E is the (LD50).

RESULTS AND DISCUSSION

Significant results ($p<0.05$) were seen across germination experiments and between sites with BC (2.7 g TSW) reaching a mgp of 96% and mgt of 3.1 days; LS (3.4 g TSW) the longest mgt at 10.1 days. Similar TSW between WS (1.6 g TSW) and WP (1.5 g TSW), yet significant differences in mgp (WP = 41.75%, WS = 61.50%) and mgt (WP = 6.56 days, WS = 4.29 days). These differences in germination characteristics reflect the findings of Gundel et al. (2008) concerning the biological adaptations of ryegrass to farming practices, i.e., tillage.

Extreme adaptations were reported by Chauhan and Walsh (2022), where ryegrass began emerging in the Australian summer, making ryegrass a year-round phenomenon. The first paraquat dose-response results showed tolerance in LS (LD50 = 0.48X) and resistance in the WP (LD50 = 21.73X) and WS (LD50 = 11.78X) plants. Significant differences ($p<0.05$) between the LS and Welgevallen (WP and WS) plants can be explained by the contrast in the herbicide regimes.

The infrequent application of paraquat, combined with the diverse herbicide regime and incorporation of at least one different crop, delayed herbicide resistance in the LS population. The difference between the paraquat WP LD50 and the WS LD50 was not statistically significant. The WS field has been exposed to various crops and herbicides, yet it still has the annual spray of glyphosate and paraquat. The WP LD50 was larger than the WS LD50. These sites were close in proximity, yet WP had no crops planted and was exposed to only two herbicides. This result reaffirms the statements of many weed scientists about the need to diversify to delay the onset of herbicide resistance (Gressel, 1991; Pieterse, 2010).

A strong negative association (-0.80) between TSW, mgp and paraquat LD50 was identified in the tested populations. The second dose-response experiment found that both WP and WS ryegrass had multiple herbicide resistance to glyphosate (WP LD50 = 2.54X, WS LD50 = 9.96X), paraquat (WP LD50 = 1138.93X, WS LD50 = 949.73X) and glufosinate-ammonium (WP LD50 = 0.88X, WS LD50 = 0.89X). This is the first case of glyphosate, paraquat and glufosinate-ammonium multiple herbicide resistance in a ryegrass population globally.

A significant difference ($p<0.05$) was seen between the paraquat WP LD50 and WS LD50 in the second dose-response experiment due to the high dose treatments allowing for a more precise dose-response model compared to the first dose-response experiment where the treatments were not high enough to completely control the population. Above-ground dry matter showed increasing biomass for increasing doses of glyphosate in the Welgevallen population (WP R^2 = 0.35 and WS R^2 = 0.44). This increase aligns with the literature regarding glyphosate as a stimulant for CO_2 assimilation at sub-lethal doses (Nascentes et al., 2018). The extreme differences between the first and second dose-response paraquat results can be attributed to the different temperature regimes; paraquat is more effective at higher temperatures (Purba et al., 1995).

CONCLUSION

There is a trade-off in CA practices between delayed germination and herbicide resistance. Herbicide resistance can be delayed, as seen in the difference between the LS and Welgevallen plants, yet the LS plants have adapted to avoid pre-emergent herbicide applications. Adopting CA practices prevents the misuse of herbicides, which can remain extreme, as seen in the case of the Welgevallen ryegrass plants.

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KEYWORDS

Conservation Agriculture, herbicide, paraquat, glyphosate, glufosinate-ammonium, resistance, ryegrass

MODELING SOIL-PLANT BEHAVIOR IN A WHEAT-CANOLA ROTATION IN THE SOUTH OF SPAIN: A NEW APPROACH FROM DIGITIZATION AND CONSERVATION AGRICULTURE

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INTRODUCTION

Soil conservation is an essential factor in ensuring the ecological transition of agriculture. Among its functions, soil is a carbon (C), water and nutrient reservoir for plants and micro-organisms. However, its capacity to provide ecosystem services has been reduced due to the intensification of agriculture in response to population growth.

Moreover, these consequences are more significant in Mediterranean soils because of climate change effects in semi-arid areas. Besides, these soils' low soil organic matter (SOM) content results in a substantial C and biodiversity loss (Gonzalez-Sanchez et al., 2015). Theoretically, healthy soils allow sustainable crop production without degrading or affecting the environment. Nevertheless, 60% of European Union (EU) agricultural soils are unhealthy. In response, the EU approved the European Green Deal and the EU Mission, 'A Soil Deal for Europe', aiming to lead the transition towards healthy soils by 2030 (European Commission, 2024).

To implement this paradigm, it is necessary to apply environmentally friendly agricultural practices, facilitating a link between production and conservation. Agricultural practices of interest could be direct sowing, no-tillage, crop rotations, cover crops, crop residues and organic matter application to the soil. These practices help improve soil health and reduce the impact of agriculture on the environment (Rose et al., 2021) by increasing SOM content and reducing nutrient losses and greenhouse gas emissions (Sánchez-Rodríguez et al., 2021). However, the effects of these practices depend on soil properties. Because of that, soil health is a function of agricultural practices and soil properties, affecting crop production and quality.

Despite that, technology plays a fundamental role in facilitating the digital transition of agriculture. Specifically, remote sensing using satellite images helps predict the nutritional condition of plants and crop yields. This may result in more accurate decisions that can maximize crop production and refine the application of inputs to agroecosystems.

The aim of this work is to develop a soil-plant model fed with chemical, physical, and biological soil properties, plant variables, and satellite images to find correlations between them and predict crop responses in a wheat-canola crop rotation under different soil management strategies (conventional tillage and no-tillage), facilitating the digital and ecological transformation of agriculture.

MATERIALS AND METHODS

A field experiment was developed in southern Spain using different agricultural management strategies in rainfed conditions (Figure 1). The experiment, located at the Experimental Farm of Rabanales (University of Córdoba), has two blocks, each split into two plots of 5 ha. Wheat (Triticum durum L.) and canola (Brassica napus L.) were grown following a crop rotation in each block.

Regarding soil management, one block has been managed by no-tillage (NT) for 13 years, and the other by conventional tillage (CT). Moreover, a 50-point grid was defined in each plot to perform soil samplings. Concretely, soil samples were collected to determine physical and chemical properties.

Derived from this analysis and earlier studies, it is known that there are two different soils in the experiment area: a Stagnic Luvisol (west part) and a Vertic Cambisol (rest of the field). These two soils present differences in physical-chemical properties like texture, water holding capacity, presence of rock fragments, soil pH, calcium carbonate content and nutrient availability, which can lead to different crop responses. In addition, 25 plant samples from 1m2 per sampling point were collected to determine crop production and nutrient concentrations per crop and soil management. Also, PlanetScope satellite images were used to determine the NDVI during the crop season and to feed the proposed model, that later can help better understand soil-plant behavior.

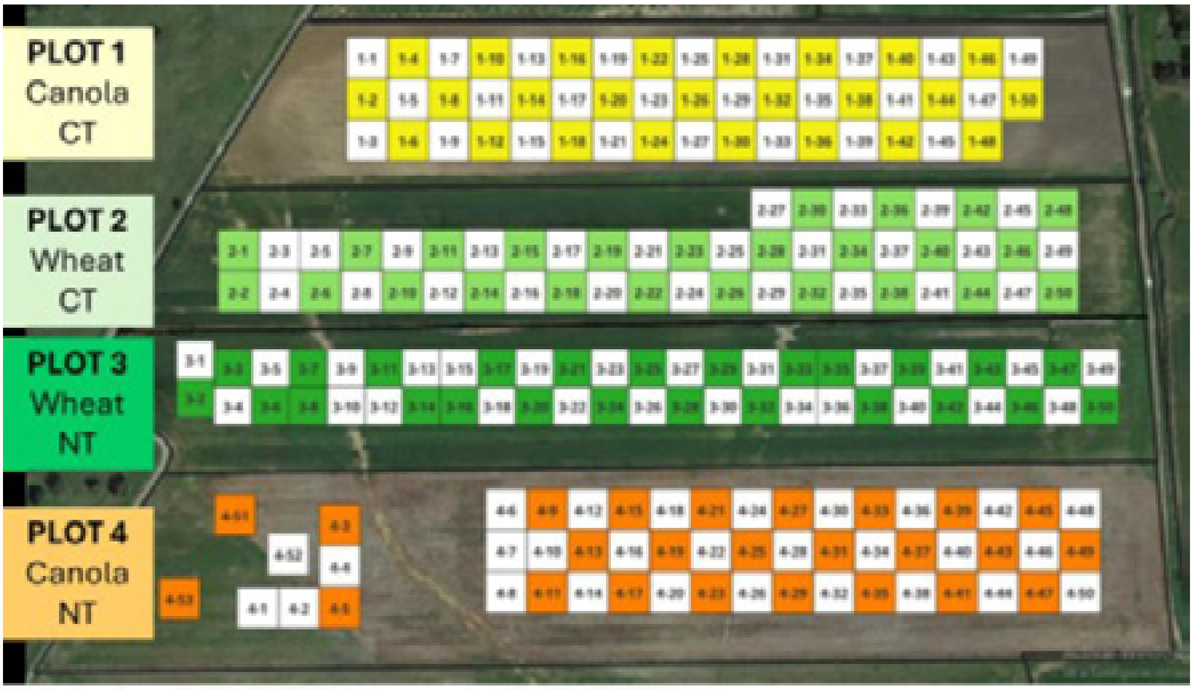

Figure 1. Experimental design for a wheat-canola crop rotation under different soil management strategies: Conventional Tillage (CT) and No Tillage (NT) in an experimental field with two different soils: Stagnic Luvisol (west part) and Vertic Cambisol (east part).

RESULTS AND DISCUSSION

It is necessary to remark on the importance of soil management in modifying SOM content. Figure 2 shows the SOM content as a function of the crop and soil management, showing an increase up to 3.5% due to NT over the last 13 years (from 2.3% under CT). These results align with similar studies in northern Italy (Valkama et al., 2020).

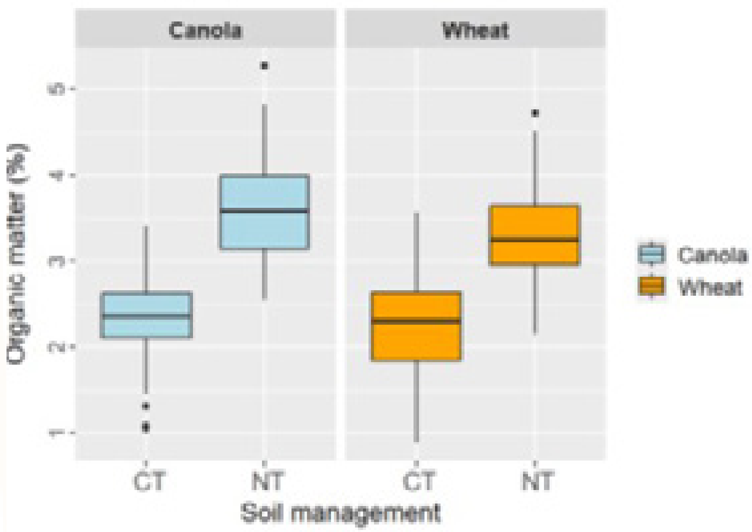

Figure 2. Box and whisker plot of SOM content (%) as a function of crop and soil management (CT: conventional tillage, NT: no-tillage).

A Principal Component Analysis (PCA) was done for each crop-soil management combination (Figure 3) to find relationships between soil, plant variables and satellite images and their importance in developing a model to predict soil-plant behaviour. For wheat, NDVI, pH and EC (Electrical Conductivity) were strongly correlated with crop yield. However, in the opposite sense, we found soil sand content, available P (P Olsen) (Sánchez-Rodríguez et al., 2021b) and grain protein content (Proteins).

Despite that, for canola, the analyzed variables did not behave in the same way for the two soil management systems, finding correlations between canola yield and different variables as a function of soil management. This can be partially explained by the fact that canola suffered more weed competition under NT, resulting in irregular crop development. It is also important to appreciate that SOM was more correlated with yield under CT, but in NT, where the SOM content was higher and more uniform along the plot, there was not a clear correlation between SOM and yield variables.

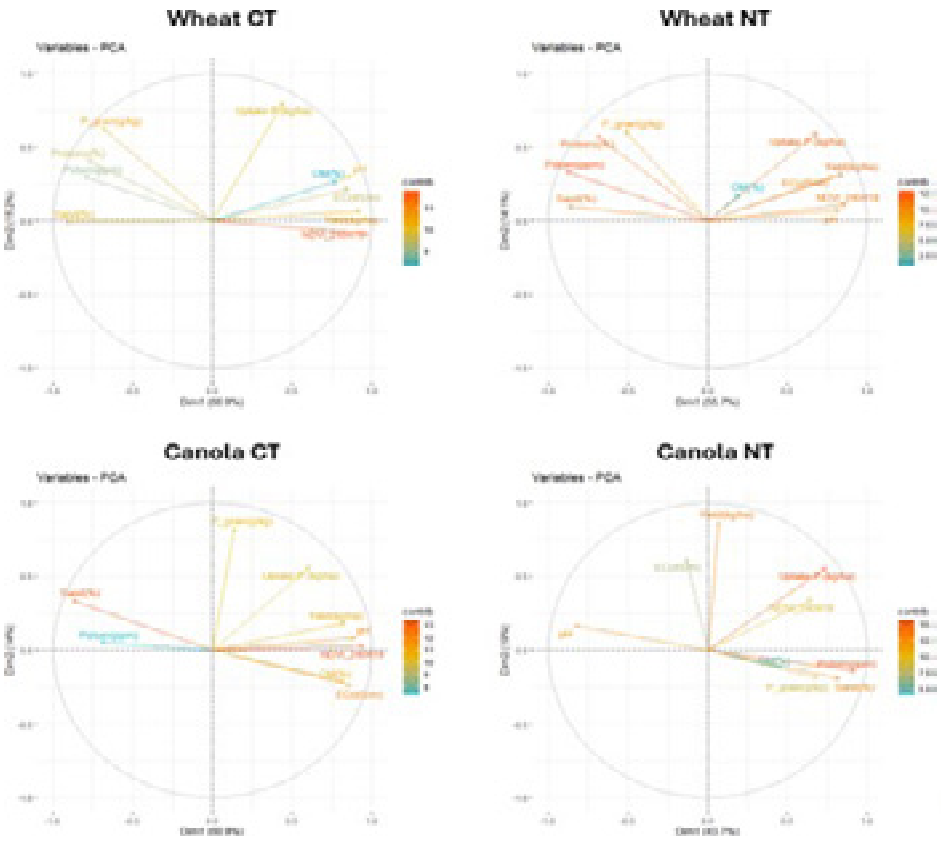

Figure 3. Principal Component Analysis (PCA) per crop and soil management (CT: conventional tillage, NT: no tillage).

CONCLUSION

The results obtained establish that a large period of NT (>10 years) increments SOM content, and so it mitigates climate change effects and enriches poor organic matter soils. Moreover, the exploratory data analysis that has been done through PCAs, have allowed us to make an approximation to better-know soil plant behavior as a function of soil type and soil management strategy, establishing solid basis to implement a more complex model that helps predict crop yields and soil health indexes variations as a function of soil management and soil properties. Also, it is especially important to remark on the importance of NDVI and its correlation with crop yields, which opens a work horizon leading to Smart Farming in a Conservation Agriculture paradigm.

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KEYWORDS

soil health, crop rotation, semiarid areas, soil-plant model

DOES SOIL NATIVE NUTRIENT SUPPLY DEPENDS ON ALL THE THREE PRINCIPLES OF CONSERVATION AGRICULTURE?

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IINTRODUCTION

The significant increase in food demand due to the increased human population has necessitated intensive cropping of lands. In intensification systems, resources need to be used sustainably. Most soils are inherently poor in fertility and prone to degradation, especially in intensive production systems (Sileshi et al., 2010). Therefore, agriculture needs to be conducted in a more sustainable way.

Conservation Agriculture (CA), based on minimum soil disturbance, crop residue retention, and crop diversification, is a system that aims to promote sustainability while enhancing productivity and preserving natural resources (Thierfelder et al., 2024). Among several benefits, long-term implementation of CA has been reported to significantly increase soil health by improving soil aggregate stability, moisture retention, micro-organisms and organic matter population, and crop yield (Mhlanga et al., 2022).

One of the indicators of soil health is its ability to supply nutrients to crops. Native soil nutrient supply is the maximum nutrients plants can uptake from unfertilized soil (Janssen et al., 1990). Many reports indicate a relative advantage of CA over conventional soil nutrient availability practices. However, understanding which components of CA affect native soil nutrient supply has so far been neglected. Therefore, this study aims to disaggregate the effect of each CA component on the native soil supply of N and P in soils with clay and sandy textures after 6 years of practising CA. We hypothesize that CA results in a higher native soil supply of N and P under both soil textures than Conventional Tillage (CT).

MATERIALS AND METHODS

The experiment was established in the 2013-14 season at the Domboshawa Training Center (DTC) and the University of Zimbabwe (UZ). The data presented here were collected in the 2018-19 growing season after 6 years of trial implementation. The soil at DTC had sand, silt and clay contents of 730 g kg-1, 50 g kg-1 and 220 g kg-1, respectively; and organic carbon (C) content of 7.3 g kg-1 and is classified as Arenosol. The soil at UZ had 390 g kg-1 sand, 210 g kg-1 silt, 400 g kg-1 clay, and a C content of 16.8 g kg-1, classified as Rhodic Lixisol.

During the sampling season, the total rainfall received was 603 mm at DTC and only 383 mm at UZ. The mean seasonal maximum air temperatures were 29.0 □C and 27.5 □C at DTC and UZ, respectively, while the mean air minimum temperatures were 15.1 □C at both sites.

The treatments were based on combinations of CA components under no-tillage (NT) or under CT. Four treatments were under CT, the other four under NT, one without mulching (M) and rotation (R), and the other three with either mulching and rotation or both. The treatments were randomized and established in complete blocks in plots measuring 12 m × 6 m, which were replicated four times at each site. Maize was sown at an interrow spacing of 90 cm, an intra-row spacing of 25 cm, cowpea at an interrow spacing of 45 cm, and an intra-row spacing of 25 cm. The mulched plots received crop residues at the rate of 2.5-3.0 t ha-1.

Four soil samples were collected from each plot, prepared, and analysed for soil organic carbon (SOC) using the Walkley-Black wet combustion method, total N using the macro Kjeldahl digestion procedure, available phosphorus using the Olsen method, and pH using the potentiometric method.

The native soil supply of N and P was estimated using the QUEFTS model (Janssen et al., 1990). This was developed using a multiple regression between soil organic carbon, total N, pH, available P and K. The model was parameterized with the soil analysis results described above (SOC, total N, P, and pH).

RESULTS AND DISCUSSION

The native soil supply of N varied significantly only at DTC. The CT+M and CT+M+R had the highest N, almost 50% higher than NT+R, CT and NT, which were statistically similar. Native soil supply of P varied across the treatments at both DTC and UZ. The highest P supply was observed at DTC under the CT+M+R (41.6 kg ha-1) and NT+M (39.6 kg ha-1). Except for NT+M+R, the remaining treatments had similar lower P supply, which ranged from 16.9-19.2 kg ha 1. At UZ, the highest P supply (39.5 kg ha-1) was observed under CT, and the lowest was observed under CT+R (12.5 kg ha-1) and NT+M+R (11.9 kg ha-1).

Dissecting the effects of each CA component of the treatments showed that tillage significantly affected the native soil supply of N only at DTC. Residue retention affected supplies at DTC. Higher native soil supply of N was observed under CT treatments (mean = 40.9 kg ha-1) compared with NT treatments which had a mean of 35.4 kg ha-1. Residue retention increased the average N supply from 34.4 kg ha-1 (for the no-residue treatments) to 41.9 kg ha-1. Similarly, retaining the residues doubled the native soil supply of P (from 16.0 to 31.5 kg ha-1).

At UZ, the effects of the CA components of the treatments were not significant except for rotation on native soil supply of P, where rotation had a lower mean (20.6 kg ha-1) compared with continued maize, which had 33.3 kg ha-1.
Generally, the results indicate that residue retention is the most crucial pillar of CA for enhancing the supply of nutrients. This could probably be attributed to increased biological activities when residues are retained. However, that differed based on other soil properties.

The pH was higher at DTC, and that could have increased the rate of mineralization and subsequent supply of nutrients. Native soil supply of N has been observed to have a positive correlation with pH, which enhances the rate of mineralization (Janssen et al., 1990). At UZ, retaining residue, irrespective of tillage or rotation, resulted in a lower native soil supply of P. The UZ farm is a low pH clay environment, thus P availability is expected to be critical for crops due to potential P-fixation. Therefore, it is expected that the legume during the rotation phase utilizes the scarcely available P in the soil, leading to further depletion of P.

CONCLUSION

The findings of this study reveal that CA significantly affects the native supply of N and P in both sand and clay soils. Residue retention was the most crucial component of CA that enhanced nutrient availability.

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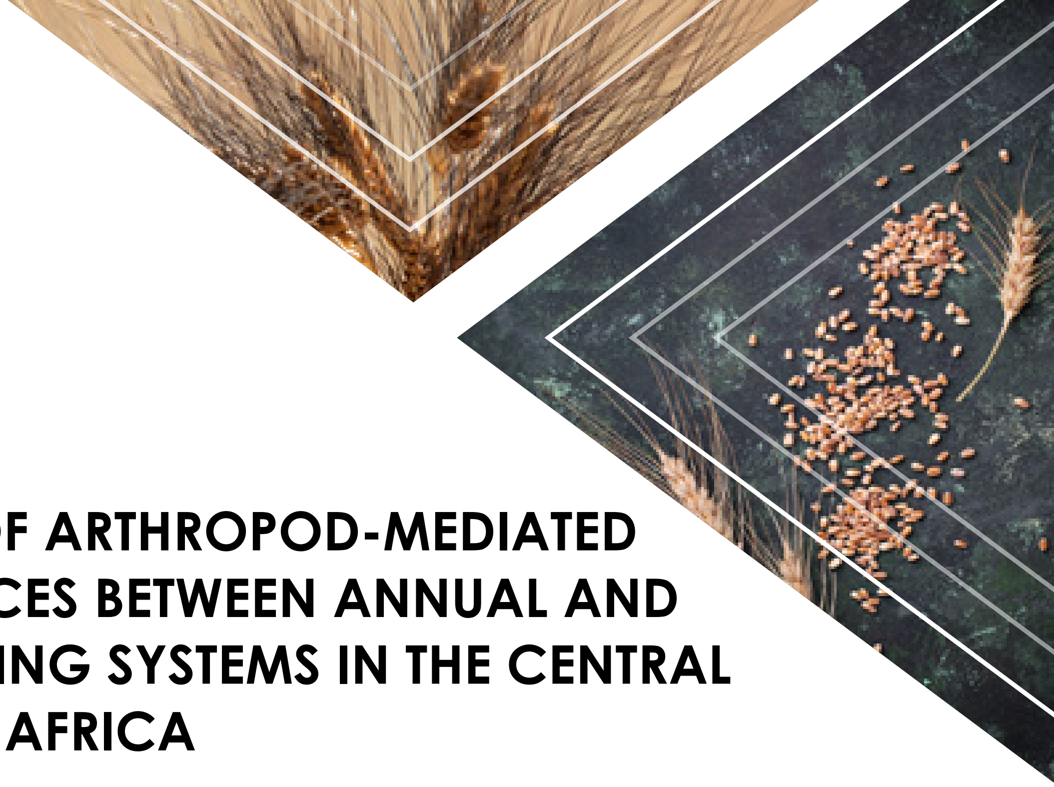
KEYWORDS

Conservation agriculture, crop rotation, nutrient supply, residue retention tillage

POSTERS



A COMPARISON OF ARTHROPOD-MEDIATED ECOSYSTEM SERVICES BETWEEN ANNUAL AND PERENNIAL CROPPING SYSTEMS IN THE CENTRAL FREE STATE, SOUTH AFRICA

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INTRODUCTION

Agro-ecosystems host many organisms that can contribute to weed pest control through seed consumption and field predations. Beneficial arthropods, like predatory beetles and insects, play a crucial role in agroecosystems' post-dispersal weed-seed removal. Different cropping systems can influence it. Employing natural predators like larvae can contribute to integrated pest management. This study compared arthropod-mediated ecosystem services between two cropping systems (perennial and annual) on the post-dispersal weed seed and prey removal in agro-ecosystems.

MATERIALS AND METHODS

Crops that were used are potatoes and onions (annual crops), and prickly pears and pecan nuts (perennial crops) in the 2023 trial. Four weed species were selected for post-dispersal weed-seed removal, and the weed species used included two types of grass, saw-tooth love (Eragrostis superba) and blue buffalo (Cenchrus cilliaris); two broad-leaf weeds, namely smooth pigweed (Amaranthis hybridus) and Russian tumbleweed (Salsola tragus). These were attached to petri dishes in enclosed wire cages. Black Soldier fly (Hermetia illucens) and mealworm (Tenebrio molitor) were used to determine the effects of the different cropping systems on predator activity, both nocturnal and diurnal. Predator larvae were pinned onto triangular clay bases with #1 insect pins.

RESULTS AND DISCUSSION

In the weed predation experiment, more weed seeds were consumed in the perennial treatment. In perennial cropping, significantly more broad-leaf seeds were consumed than grassy seeds. Carabidae beetles were recorded mostly during collections, showing their role in seed predation. Field predation experiments showed more prey consumption in the perennial cropping system during nocturnal hours and least during diurnal hours. Mealworm was greatly consumed in both systems. The abundance of Formicidae as a predator family was recorded during the observation of field predation. This research demonstrated seed and pest predation by beneficial arthropods is an essential component of the agro-ecosystem. A perennial cropping system enhances biodiversity, fostering a balanced ecosystem that supports pest and weed control. The system also provides shelter for beneficial arthropods, promoting sustainable and resilient agro-ecosystems. In conclusion, this set out independence for emerging farmers to identify certain pests affecting their crops and remove invasive weeds and their impact.

CONCLUSION

Integrated pest and weed management with conservation agriculture entails implementing practices that minimize the overuse of chemicals and minimal soil disturbance while enhancing the soil health and biodiversity of beneficial arthropods. Further, biological control through pest predation and weed seed removal is practised.

KEYWORDS

Agro-ecosystem, Field predation, post-dispersal weed seed removal

ADOPTION OF SELF-REGULATING, LOW-ENERGY, CLAY-BASED IRRIGATION (SLECI) SYSTEMS TO SAVE WATER AND IMPROVE CROP PERFORMANCE BY SMALLHOLDER FARMERS

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INTRODUCTION

Crop failures are quite common under rain-fed farming in Sub-Saharan Africa. Low and highly variable yields often characterize smallholder farming (SHF) in South Africa. Water scarcity is considered a limiting factor in the development of the agricultural sector, given that the country is one of the driest countries in Africa and globally (Adetoro et al.,2022). Because of the often inadequate and uneven rainfall distribution in South Africa, more inventive efforts are necessary to assist farmers in maximizing food production. Water-saving irrigation technologies can contribute significantly to limiting crop failures, especially within SHF enterprises with limited access to irrigation water.

MATERIAL AND METHODS

The SLECI technology was compared with subsurface and standard drip irrigation to determine their effects on Moringa's performance when intercropped with Cowpea. The trial was conducted in the open field during a summer growing season (October 2022-March 2023) at the Agricultural Research Council (ARC-VIMP), Pretoria, South Africa. The experimental design was a Randomized Complete Block Design (RCBD) with nine treatments replicated four times. Data on water usage, crop growth, yield and physiological parameters was collected and subjected to ANOVA using GenSTAT. Crop yields and water use were compared for the different irrigation methods.

RESULTS AND DISCUSSION

Moringa and Cowpea crop yields reacted differently to the irrigation system types used. Moringa performed best with SLECI (880g fresh mass per tree) versus 200g fresh mass with standard drip, while Cowpeas performed best under standard drip irrigation (500g fresh mass) versus SLECI (200g fresh mass). The irrigation system also affected the water use of the two crops. On average, standard drip irrigation used significantly more water (164.895 m3) compared to subsurface (85.214 m3) and SLECI (66.363 m3) during the growth season.

CONCLUSIONS

The SLECI irrigation system seems more suitable for Moringa (perennial crop), while Cowpea (seasonal crop) performed best with standard drip irrigation. SLECI showed significant potential to minimize water loss by evaporation, runoff, and percolation and can be considered a promising new irrigation technology that can increase water use efficiency, especially for perennial crops.

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KEYWORDS

Drip irrigation, SLECI, subsurface irrigation, water use efficiency.

ADVISORY FOR STAKEHOLDERS: ADOPTION OF CONSERVATION AGRICULTURE WITH THE RIGHT COMBINATIONS OF TECHNIQUES AND NICHES

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INTRODUCTION

The adoption of Conservation Agriculture (CA) by farmers globally has been gradual despite its enormous benefits in addressing the issues of food security and agricultural sustainability.

MATERIALS AND METHODS

A meta-analysis of 750 peer-reviewed studies, with 5493 pairs of data points, has been conducted to identify a unique niche for better success and adoption of CA.

RESULTS AND DISCUSSION

Globally, CA had yields comparable to conventional tillage when all three principles were followed. However, yields decreased by 5.5% when CA was practised partially (when three principles of CA were not observed). In arid climates, yields increased by 3.0% in full CA (when all three principles of CA followed) or 1.7% in partial CA, making it a viable option. In an arid region with sandy soil, adopting partial CA resulted in a yield loss of 7.5%, but this was minimized by increasing the duration or practising full CA even with a shorter duration.

In temperate climates, legumes may have comparable yields in sandy and loamy soils and higher yields in clay soils only when partial CA is practised for more than five years. With more than five years in continental climates, partial CA can prevent yield loss. In tropical climates, full CA ensured a 7.1% higher yield. Partial CA resulted in a 13.7% loss, especially with short duration. The full CA increased yield by 2.4% in clay soils, comparable in loamy soils, and a 7.5% loss in sandy soils. Cereal crops responded well to full CA (-0.3%; NS) compared to the partial CA (-7%). Yields of legumes were similar in both full and partial CA. Sorghum yield increased by 10.3% in full CA, while rice and wheat responded with full CA, but the yields of maize remained poor. Yield gaps improved substantially in soybeans with full CA (-1.0%; NS) from 3.4% yield loss in partial CA. Other beans and peas showed a positive or marginal response. Shallow-rooted crops have marginal yield differences with CT under full and partial CA. The yield gaps decreased steadily as the duration of CA increased.

CONCLUSION

A minimum of fifteen years of CA has a positive impact, although a five-year period might be sufficient to close the yield gaps when all three principles are followed. The study identified the niche areas (climate, soil texture, and problem soils) for potential CA adoption and the techniques (CA principles, crop management, and duration) to minimize the yield gaps with conventional tillage.

KEYWORDS

Conservation Agriculture, Yield gap, Potential condition, Advisory

DETERMINANTS OF CONSERVATION AGRICULTURE ADOPTION AND FARMERS PERCEPTIONS OF EFFECTS OF ITS ADOPTION ON MAIZE AND BEANS YIELD IN LESOTHO

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INTRODUCTION

A significant proportion of Lesotho's population depends on agriculture as the primary source of livelihood, hence the undisputed importance of this sector (BOS, 2022). Even though agriculture is essential to the livelihoods of many Basotho, it is a sector vulnerable to climate change's effects. Adopting improved agricultural technologies is fundamental to transforming sustainable farming systems and a driving force for increasing agricultural productivity.

Conservation Agriculture (CA) is argued to have the potential to counteract the climate change-related challenges that threaten to affect crop production. However, a large proportion of farmers have not adopted this technology. Therefore, this study aims to determine the factors that lead to the adoption of CA by maize and bean farmers in Lesotho and to assess the farmers' perceptions of the effects of CA on yield.

MATERIALS AND METHODS

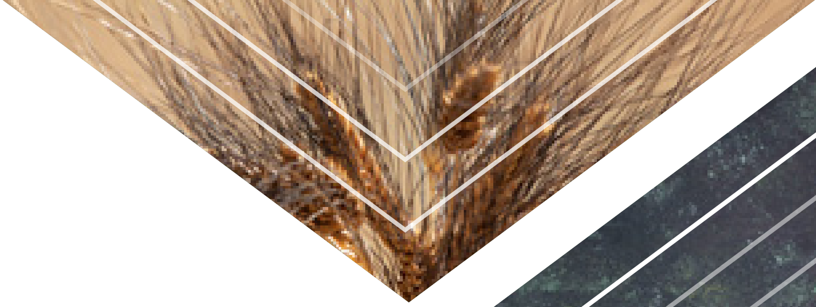
Data were collected through a structured questionnaire administered to 807 maize and bean farmers, selected through a multi-stage sampling process. In the first stage, 7 Districts were purposively selected. In the second stage, a stratified random sampling technique was used to select villages with the assistance of the District Agricultural Offices. A multinomial logit regression model was used to determine the factors affecting CA adoption and those affecting farmers' maize and bean yield perceptions after CA adoption.

RESULTS AND DISCUSSION

The study revealed that most farmers were non-adopters of CA, with few being partial CA adopters and fewer full CA adopters. This implies that CA adoption in Lesotho is still low. Gender, field size, household income, farming experience and training influenced the decision to adopt CA. Most CA farmers perceived their yields to have increased after CA adoption. Farmers' perceptions of maize and beans yield after CA adoption were influenced by age, soil fertility perception, and years since CA adoption.

CONCLUSIONS

High-income farmers were found to be more likely to adopt CA than low-income farmers. Farmers who have more years of practising CA are more likely to see their crop yields increase after CA adoption than farmers who are just starting to practice CA. Among other recommendations, the study encourages owners of machinery rental businesses to buy and rent out CA machinery to increase their availability and accessibility to farmers in Lesotho.



BEST MANAGEMENT PRACTICES IMPLEMENTED IN ANNUAL CROPS MITIGATE CLIMATE CHANGE

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INTRODUCTION

Agrifood systems and markets must ensure food and supply for the exponentially growing world's population in a socially, economically, and environmentally sustainable way. The production of annual crops is the basis of human and livestock diets, especially cereals, which are sources of energy, vitamins, and minerals. In Europe, cereal production reached 276 million tonnes in 2022, mainly wheat, maize, barley, and oats. LIFE Innocereal EU project works to solve different issues in the cereal value chain, working with the entire sector, from farmers to distribution. The objective is to improve economic and environmental sustainability through the implementation of a series of Best Management Practices (BMP) in different Mediterranean agroclimatic regions.

MATERIALS AND METHODS

Based on Sustainable and Digital Agriculture principles, the project elaborated the "Manual of Best Practices for cereal production", in which 11 BMP were described. During the first season of the project (2022/2023), all of them were implemented on a durum wheat field plot in the pilot farm "Rabanales" belonging to the University of Cordoba (Spain) and compared to a plot under conventional management.

These same BMPs are being progressively implemented on demonstration farms at national and European scales in countries such as Greece, Portugal and Italy. The quantification of greenhouse gas emissions (carbon footprint) in the agronomic process, production and economic balance are being studied during the project.

RESULTS AND DISCUSSION

Preliminary results show that the BMP plot decreased emissions by 27% due to a reduction in the number of field operations, which resulted in a 55% lower fuel consumption. Durum wheat production increased 17% in the BMP plot, and the economic benefits were 47% higher than in the conventional one.

CONCLUSIONS

This first year reflects the path forward to completing the project, reducing crop costs and improving productivity, final product quality, and soil health. Likewise, connecting the whole cereal value chain in Europe leads to creating a global low-emission cereal certification system, demonstrating farmers' competitiveness and facilitating integration and entry into national and international markets.

KEYWORDS

Cereal, emissions, Sustainable and digital agriculture, global low-emission cereal certification system

ACKNOWLEDGEMENTS

The authors thank the European Commission's LIFE (Financial Instrument for the Environment and Climate Action) for co-financing the LIFE Innocereal EU project (Connecting the cereal value chain and creating sustainable certification for carbon neutral production in Europe–LIFE21-CCM-ES-101074009). The results exposed are part of the projects.

CANOLA (BRASSICA NAPUS L.) CULTIVAR, PLANT DENSITY AND HERBICIDE USE EFFECT ON WEED SUPPRESSION

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INTRODUCTION

Removing tillage practices in CA systems has dramatically increased reliance on herbicides to manage weeds in cropping systems. The high dependence on herbicides increases the risk of herbicide-resistant weeds. The presence of herbicide-resistant weeds poses a significant threat to conservation agriculture, as denser weed populations impede sustainable cropping intensification, which is necessary to meet increasing food demands. Due to this, more sustainable weed-management practices are needed whilst decreasing the dependence on herbicides. This study investigated the weed suppression ability of different canola cultivars at various planting densities in the presence and absence of herbicides.

MATERIAL AND METHODS

Trials were conducted at the Langgewens Research farm near Moorreesburg. Plots were planted in early May 2023 at two locations on the farm, SKOG and CAMP. Data collection occurred over one growing season. The trial was laid out as a split-plot design with four replications. Triazine-tolerant canola (TT) and Imidazolinone-tolerant canola (Clearfield) cultivars were used as the main plot factor. Half the plot received herbicide application according to best practices (cultivar-specific), while the other received no application (sub-plot factor). Four canola seed rates 1, 2, 3 and 4 kg/ha were randomly allocated to each sub-plot, resulting in Individual plot sizes of 2m by 6m. At 30 and 60 days after emergence (DAE), canola and weed plant counts were done randomly with a one-meter stick and within 0.0225 m2 quadrant. At 60, 90 and 140 DAE, canola and weed biomass within 0.25m2 were measured.

RESULTS AND DISCUSSION

From early season weed densities (30 and 60 DAE), the site, cultivar, and planting densities had significant interaction ($p<0.05$). CAMP and SKOG had different weed density patterns between the two cultivars. TT at CAMP showed better suppression than TT at SKOG. At 3kg/ha, TT had the lowest suppression in SKOG, whilst in CAMP, the lowest suppression from TT was at 1kg/ha and 4kg/ha.

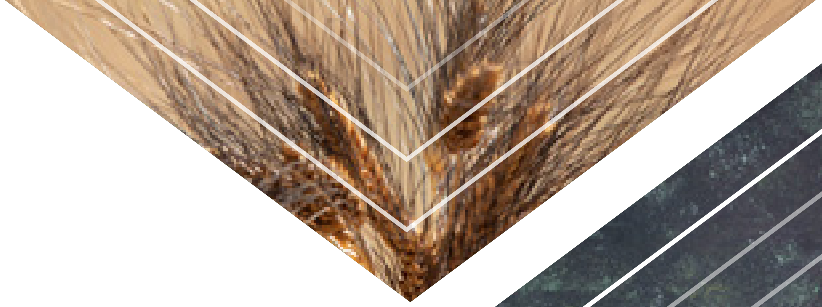
Clearfield canola, however, had similar suppression across all four planting densities and similar suppression between the two sites. Biomass later in the season showed a significant interaction between cultivar, herbicide use and planting density ($p<0.05$). The pattern across all four planting densities was not similar between the two cultivars when herbicides were removed.

CONCLUSION

The results show that integrating agronomic factors can influence canola crop weed suppression and yield. These practices could also potentially lower the dependency on herbicides and thereby reduce the frequency of herbicide application, resulting in the postponement of herbicide resistance occurrence.

KEYWORDS

Integrated weed management, Weed suppression



CLIMATE CHANGE IMPACTS ON CANOLA GROWTH AND YIELD CHARACTERISTICS: CHALLENGES AND OPPORTUNITIES

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INTRODUCTION

Climate change, caused by the increase in atmospheric greenhouse gases, has led to rising temperatures, which have altered rainfall amounts and distribution patterns, which will affect canola growth and yield characteristics. A systematic literature review investigated the influence of changing climatic factors on canola growth during its vegetative stage and canola yield development through its reproductive stage.

MATERIAL AND METHODS

Twenty-two peer-reviewed papers were selected after screening 2055 papers according to the climatic factor's effects on canola growth and yield characteristics. All aspects were compared to the control within the study and expressed in a percentage.

RESULTS AND DISCUSSION

During its vegetative growth stage, canola growth responded positively to an increase in CO_2 by improving the carbon assimilation rate by, on average, 40%, which resulted in plants producing 58% more biomass. If temperatures were closer to the optimum (20-25 °C), biomass production improved, with colder temperatures (5 °C) having a more significant impact on the biomass (34% reduction) than extreme hot conditions (34 °C) (9% reduction).

Moderate soil moisture stress caused an average decrease in leaf area of 41%, a 44% reduction in stomatal conductance, and a decrease of 17% in evapotranspiration. Climatic factors mainly affected canola seed yield during its reproductive growth stage. Elevated CO_2 improved the seed yield by, on average, 38%. Daytime temperatures above 28 °C (heat stress) caused canola flower abortion and resulted in a 16% reduction in pollen viability, ultimately leading to an 87% decrease in seed yield. Heat stress also reduced the oil extraction by 50%. Soil moisture stress during the flowering stage resulted in a 43% reduction in seed yield, on average, and an oil extraction reduction of 36%. Soil moisture stress during the seed fill stage had the same effect, but to a lesser extent; a 22% reduction in seed yield and an oil extraction reduction of 27% were observed.

CONCLUSIONS

This literature-based study illustrates that rising atmospheric CO2 concentration has a fertilising effect on canola growth and production, the impact of heat and drought stress during the reproductive stage is detrimental to canola production, and elevated atmospheric CO_2 concentration may offset the yield-limiting effects of heat and drought stress. Conducting research on alternative strategies, like conservation agriculture, in conjunction with the impact of climate change is necessary to identify potential solutions for mitigating canola production deficits.

KEYWORDS

heat stress, drought stress, CO_2 fertilisation


CLIMATE CHANGE PERCEPTIONS AND ADAPTATION STRATEGIES AMONG WHEAT FARMERS IN THE WESTERN CAPE PROVINCE, SOUTH AFRICA: INSIGHTS FROM THE 2015–2018 DROUGHT

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INTRODUCTION

Between 2015 and 2018, the Western Cape Province of South Africa experienced a multi-year severe drought that negatively impacted the urban and agricultural sectors. Future climate projections show that the Western Cape will likely experience hotter and drier conditions, with more frequent droughts.

Without appropriate adaptation, climate change is likely to constrain agricultural activities in the province increasingly. Conservation agriculture (CA) has been identified as a vital tool for mitigating the effects of climate change on rainfed agriculture.

Yet, it requires early adoption by farmers who may not immediately realize the associated benefits. Commercial wheat farmers represent a considerable population of decision-makers fundamental to climate change adaptation in the Western Cape. Thus, understanding farmers' perceptions is essential to develop effective policies, support structures, and communications. This study aimed to understand wheat farmers' perceptions of climate change and adaptation in the Western Cape, South Africa, and establish whether the recent drought offered lessons for adaptation.

MATERIALS AND METHODS

Study methods included an online Likert questionnaire and several in-depth interviews with farmers. The machine learning algorithm random forests was used to analyze the interview data statistically.

RESULTS AND DISCUSSION

Results showed that most farmers agree that climate change is real and is caused by human activities, and in response, most farmers are actively (or intend to start) preparing for climate change (69%). CA was identified as a critical adaptation strategy by wheat farmers. Many farmers further agreed that they had learnt from the past 2015–2018 drought and cited adopting CA as a key strategy for mitigating the effects of the drought.

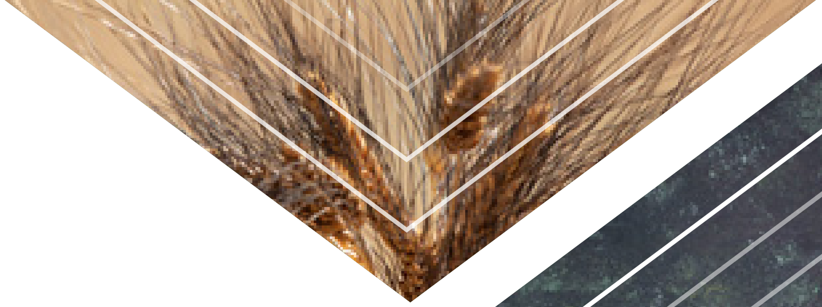
Furthermore, results showed that farmers who rely greatly on weather forecasts were likelier to feel that their farm's response was effective. The importance of farmer networks in driving decision-making also emerged from the study. Policymakers and extension services must understand how to drive the adoption of practices such as CA in farming communities.

CONCLUSION

It is recommended that investments in climate change adaptation focus on research and development, particularly cultivar development, crop management (such as CA), tailored weather forecasting, and localized risk assessments. The policy should prioritize the more vulnerable farmers while focusing on integrated risk reduction measures that account for multiple stressors.

KEYWORDS

adaptation, climate change, conservation agriculture, drought




CO-DESIGNING INNOVATIONS IN ZIMBABWE: A COMPREHENSIVE STRATEGY TOWARD AGROECOLOGY TRANSITION

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INTRODUCTION

The Agroecology Initiative (AE-I) is leading the transformation of agroecology across food, land, and water systems in Zimbabwe. Various environmental, socio-economic, and climatic challenges have greatly affected the country's food systems. In the districts of Mbire and Murewa, the AE-I has implemented a comprehensive strategy that prioritizes farmers' opinions in addressing challenges such as pest outbreaks, inadequate grazing lands, drought, and limited access to quality seeds and livestock breeds.

MATERIALS AND METHODS

The strategy involves active participation from local communities, agricultural extension services, researchers, and service providers in co-designing agroecological solutions that are relevant and easily adopted. The co-design process begins with identifying value chain challenges and opportunities. The AE-I team conducted focus group discussions with Agroecology Living Landscapes (ALL) members to determine the innovations required to support the agroecology transition.

An inventory of existing technologies, including conservation agriculture, intercropping, crop rotation, and organic inputs, was conducted through baseline surveys and dialogues with ALL members. The AE-I ensured these practices were optimized while considering scientific validation, ecological considerations, biodiversity preservation, cultural insights, and local suitability. The identified and validated technologies underwent iterative researcher and farmer-managed field trials throughout the 2022/23 and 2023/24 seasons.

RESULTS AND DISCUSSION

Feedback on yield, pest management, and disease assessments from the first season was disseminated to farmers through field days, ALL meetings, and seed and livestock fairs, which informed changes and improvements in the second season. Demonstration plots were set up to compare treatments, such as conservation agriculture, push-pull systems, and biochar. Continuous monitoring and participatory evaluation are carried out to ensure that the co-designing process remains aligned with the community's evolving needs.

CONCLUSION

Adaptive testing and iterative feedback loops are key to developing context-specific solutions and promoting adopting agroecological practices. It empowers local communities, enhances agricultural sustainability, and sets a precedent for the agroecology transition in Zimbabwe.

COMPARING THE FINANCIAL BENEFITS OF DIFFERENT GRAIN FARMING SYSTEMS IN SOUTH AFRICA

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INTRODUCTION

There is an urgent need for sustainable crop production systems that can tackle environmental, social, and economic challenges and safeguard financial return. Here, we analysed and compared the financial viability and sustainability of three maize-based crop production systems in South Africa: conventional tillage (CT), no-tillage (NT), and conservation and regenerative agriculture (CA/RA).

MATERIAL AND METHODS

The analysis used primary data from six entirely statistical on-farm trials, local farmers, cooperatives (i.e. VKB and NWK) and Grain South Africa (GSA) in the Mpumalanga Highveld, North West, and Maluti Eastern Free State regions for the three production systems (CA/RA, NT, and CT). Certain assumptions were included in the model configuration for farm size, inflation, crops (selling prices, rotation system and yield), livestock integration, dry matter, agrochemical input efficiency, and capital replacement period. These were used to calculate net operating cash flows, free cash flows (FCFs)), and average cash flow per hectare in absolute terms (ACFs) for all three systems. Optimistic and conservative scenarios were modelled for each trial to manage sensitivities.

RESULTS AND DISCUSSION

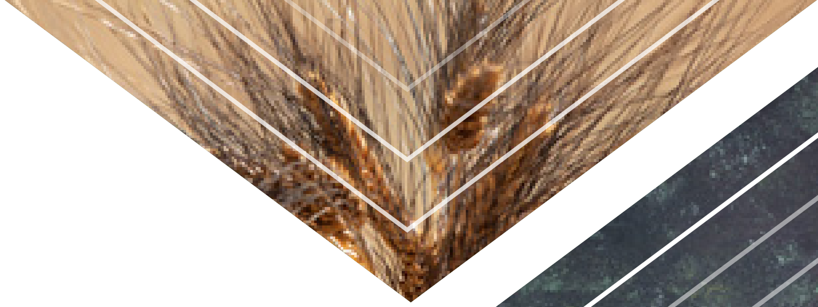
Over the 20 years analysed in the future, the average cumulative free cash flow (CFCF) is considerably higher under the CA/RA system than the alternative systems (CT and NT) in the three production areas and scenarios. In the Mpumalanga region, the CFCF for the CA/RA system at year 20 is estimated to be R86 million compared to -R51 million for CT and about R4 million for NT. In the North West region, the CFCF for the CA/RA system is estimated at R35 million, compared to R9 million for CT and R21 million for NT. For the Maluti region, the CFCF for the CA/RA system is estimated at R26 million compared to -R66 million for CT and -R19 million for NT. These produce an estimated net difference of R137 million (compared to CT) and R82 million (compared to NT) in Mpumalanga and significantly more in the other two regions.

CONCLUSION

This study shows that CA/RA is not only an environmentally friendly solution but also a financially viable one. It offers the best financial returns and presents a significantly high financial opportunity cost of not converting to CA/RA systems, as indicated by the net differences in the CFCF to CT and NT.

KEYWORDS

conservation and regenerative agriculture, financial analysis, Crop production systems, investment J-curve



CONSERVATION AGRICULTURE ENHANCED BY BETTER TARGETING OF RESOURCES DRIVEN BY POLICY IN ZIMBABWE

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INTRODUCTION

Precision agriculture is a transformative farming approach that uses advanced technologies to optimize farming practices and improve crop productivity. This study aimed to assess the benefits of precision farming, particularly conservation agriculture and conventional agriculture, in enhancing crop production for smallholder farmers in the Murehwa communal area.

MATERIAL AND METHODS

Maize yields were monitored and recorded for two consecutive growing seasons, 2020-2021 and 2021-2022, on a plot closest to the homestead and identified by the farmers as the most fertile field. Forty-seven farmers were studied, practising either conservation or conventional tillage on the plot. Thirty-three farmers practised conservation agriculture, while the rest practised conventional farming.

RESULTS AND DISCUSSION

In the first season, maize yields were 4.2 t vs 3.7 t, whereas, in the second season, yields were 3.3 t/ha vs 3.0 t/ha for conventional and conservation farming, respectively.

CONCLUSION

The results from this study highlight the importance of promoting and supporting the adoption of precision farming techniques, such as conservation agriculture, to improve crop productivity in the area.

CONSERVATION AGRICULTURE FOR REGENERATING SOIL HEALTH AND CLIMATE VARIABILITY IN SMALLHOLDER SYSTEMS OF ZIMBABWE

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INTRODUCTION

The last ten years have seen a significant shift in terrestrial ecosystems and populations, with agricultural activities playing a substantial role in Earth's temporal and spatial changes. Many soil health concerns, including nutrient imbalances, soil erosion and compaction, loss of organic matter, pesticide contamination, and soil salinization, are caused by agricultural practices. To solve these problems, sustainable farming methods and soil-saving techniques like crop rotation, zero tillage, cover crops, and biopesticides must be used.

Conservation agriculture practices help to prevent soil erosion, which is particularly important during extreme weather events such as heavy rain or wind. Maintaining soil cover and structure minimizes erosion risk, preserving valuable topsoil. Conservation agriculture can also contribute to climate change mitigation by sequestering carbon in the soil, promoting organic matter accumulation, and reducing soil disturbance, thereby helping offset greenhouse gas emissions. Soil testing, field observations and change detection analysis are methods and materials used to collect data.

My research findings indicate the four main principles that need to be adopted are crop rotation, use of biopesticides, cover crops and zero tillage. These methods seek to increase soil health and biodiversity by reducing soil disturbance, increasing soil organic matter, and lowering dependency on chemical inputs and long-term productivity. Less soil disturbance allows microbial communities and organisms to be preserved, eventually improving soil fertility and health. Precision farming techniques and agroecological approaches can help mitigate the negative impacts of agricultural activities on soil health.

RESULTS AND DISCUSSION

As a result, this approach to managing agroecosystems aims to achieve sustainable and profitable production. By researching the relationship between soil health regeneration and climate variability, it becomes evident that Conservation Agriculture plays a significant role in improving yields and income, food security, Biodiversity and livelihoods.

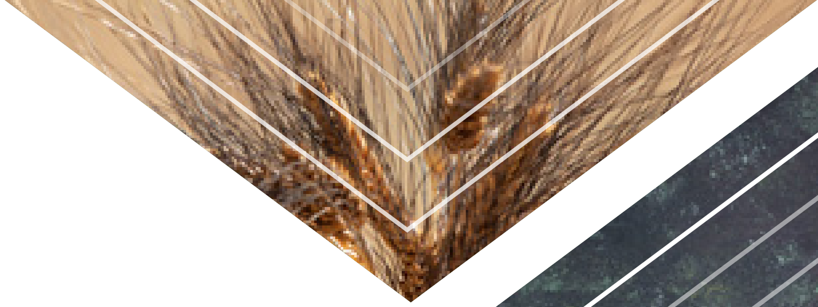
This is how conservation agriculture can help achieve these objectives. Regeneration of Soil Health: Minimal soil disturbance, maintenance of soil structure, decrease of erosion, and preservation of soil organic matter. Conservation agriculture advocates limited tillage or no-till methods.

CONCLUSION

Overall, conservation agriculture offers a promising approach for regenerating soil health and enhancing the resilience of agricultural systems to climate variability, thereby contributing to more sustainable and productive farming practices. Therefore, this research is an analysis of CA for regenerating soil health and climate variability in smallholder farmers in Zimbabwe.

KEYWORDS

biodiversity, conservation agriculture, climate variability, crop rotation, organic matter, soil health.



CONTROLLING GULLY EROSION IN THE FREE STATE PROVINCE USING LOW-COST SOIL CONSERVATION TECHNIQUE

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INTRODUCTION

Conservation agricultural practices are about farming methods that enhance carbon sequestration, thereby mitigating climate change impacts. Land degradation in the form of soil erosion is a worldwide phenomenon. Research indicates that soil erosion has affected over 70% of South Africa's landscape (Le Roux., et al., 2010). Gully erosion increases surface runoff with a substantial negative impact on soil erosion, nutrient losses and soil productivity, while the measures to control it are usually expensive.

Soils in semi-arid rangelands develop low vegetation cover under unsustainable grazing practices and have low soil erosion and gully formation tolerance. Sannaspos farm, threatened by gully erosion, was selected as a demonstration site for controlling gully erosion using low-cost control measures. At the same time, a sustainable rangeland management system was also implemented.

MATERIALS AND METHODS

The study site lies 28 km east of Bloemfontein. The gully where the conservation technique had been implemented was 240 m long. The method entailed placing old tyres and bags filled with soil inside the gully. Filled tyres were spaced 10 m apart, with two bags spaced approximately 3 m apart in between the tyres. The function of the soil-filled tyres and bags was to decrease runoff velocity in the gully and ensure siltation. Three reference points were selected along the gully. The three points represented deep, medium and shallow gully depths, respectively. Gully depths were then measured and monitored for forty-two months.

RESULTS AND DISCUSSION

After 17 months, gully depth decreased from 70 to 34 cm, 45 to 20 cm, and 35 to 19 cm at the three reference points. After 24 months, gully depth decreased from 34 to 27 cm, 20 to 14 cm, and 19 to 10 cm for the three points. Thirty months later, the gully was sealed at all reference points. Forty-two months after the trial's initiation, the entire gully was sealed and covered with vegetation.

CONCLUSION

This low-cost method successfully secured the gully and stopped further soil loss. Vegetation also regrew on the bare areas surrounding the gully. This technique, therefore, contributed successfully to the conservation of agriculture and the improvement of ecosystem functioning.

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KEYWORDS

Erosion control, gully erosion, low-cost soil conservation.

COPING STRATEGIES FOR LOWER RAINFALL SCENARIOS ON WINTER CEREAL PRODUCTION SYSTEMS IN THE SWARTLAND, WESTERN CAPE

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INTRODUCTION

The northern parts of the Swartland Area in the Western Cape province of South Africa are expected to be more severely influenced by anticipated climate change than the southern parts. The Swartland is one of the most essential wheat-producing areas of South Africa and falls within a typical Mediterranean climate zone, with winter rainfall and warm, dry summers. Because of the impact of climate change on farm profitability, producers need to develop negating or mitigating strategies.

MATERIALS AND METHODS

In this study, a combination of expert group discussions and whole-farm multi-period budgets were used to assess its expected impact on profitability.

RESULTS AND DISCUSSION

Both methods allow for incorporating systems methods and integrating knowledge that may already exist but may have become fragmented due to scientific specialisation. This was done for three homogenous production areas within the Swartland. A typical farm was identified for each location, which served as the basis of the modelling exercise. The expectation was that the areas would be influenced differently by climate change.

CONCLUSION

Several strategies could be employed to negate some of the adverse effects. Soil- moisture-saving production practices and a shift to livestock production buffer the impact of the harsher growing conditions on farm profitability.

DECODING BEHAVIOURAL DRIVERS IMPACTING THE ADOPTION OF CONSERVATION AGRICULTURE BY THE FARMERS IN INDO-GANGETIC PLAINS

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INTRODUCTION

Rising income, population, urbanization, and climate change have transformed Indian agriculture post-green revolution, impacting farming sustainability. Intensive crop cultivation contributes to GHG emissions. As an alternative, Conservation Agriculture (CA) offers eco-friendly climate change mitigation. Although CA has multi-faceted benefits, its progress has been sluggish. Existing research mainly focuses on adoption, with limited insights into the behavioural aspect. The present study aims to assess farmers' CA knowledge and analyse the impact of behavioural drivers on adoption.

MATERIALS AND METHODS

The research was conducted in Punjab and Haryana, covering six villages from purposefully selected districts of each state. Ten CA adopters and ten CA non-adopters were chosen using stratified random sampling from each village, making a total sample size of 240. Ex-post facto and analytical research designs were applied. A standardized knowledge test was developed for assessing knowledge. An integrated and modified model of TPB and TAM was used to analyse the impact of behavioural drivers. SEM was used for model measurement.

RESULT AND DISCUSSIONS

The study's findings reflected that CA adopters differed significantly from CA non-adopters regarding socio-economic and psychological attributes. For CA adopters, an overall Mean Knowledge Score (MKS) was 16.26 with an SD of 1.68. For CA non-adopters, the overall MKS was 12.25, with an SD of 2.05. Low SD reflects that there was not much variation in the responses of both adopter and non-adopter farmers. The CA Knowledge Index (CAKI) for adopters and non-adopters was 81.29 percent and 61.29 percent respectively. Surprisingly, adopter farmers still lacked understanding regarding nutrient scheduling and management practices under zero-tilled conditions.

Having a positive attitude (β=0.463), PU (β= 0.433) of CA and comprehending the relative advantage (β= 0.460) of CA over tillage-based cultivation mainly influenced the intention and behaviour of CA adopters. For non-adopters, apart from attitude, perceived usefulness, and relative advantage of CA, subjective norms also play a significant role in shaping the intention to adopt. Thus, the research has explored the behavioural aspects of CA adopters and non-adopters through a K-A-P (Knowledge-Attitude-Practice) study.

CONCLUSION

Worldwide CA adoption is crucial for carbon-neutral agriculture. Socio-economic factors alone can't drive adoption. Viewing sustainable agri-tech like CA through a behavioural lens is essential. Establishing village-level knowledge hubs and mapping behavioural drivers can effectively target CA technologies, aiding the formulation of tailored government roadmaps for scaling up CA adoption.

KEYWORDS

Behavioural drivers, Conservation agriculture, Knowledge.

STRIP CROPPING SYSTEMS IMPROVE SOIL FERTILITY, PRODUCTIVITY, AND NUTRITIONAL YIELD OF SMALL-SCALE MAIZE FARMERS IN ZIMBABWE

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INTRODUCTION

The food and nutrition security of a growing population in Zimbabwe is constrained by diverse biotic (weeds, pests, and diseases) and abiotic stresses (decline in soil fertility, lack of moisture, increased temperature). Therefore, developing innovative adaptive approaches is crucial to strengthening farmers` overall resilience. Strip cropping of maize with legumes can be one option to reduce variation in yields across cropping seasons. We evaluate the effects of different strip cropping options involving legumes on maize grain and nutrient productivity.

MATERIAL AND METHODS

The experiment was conducted in Murehwa district, a communal rural area in Zimbabwe, for four consecutive cropping seasons with the presence/absence of a Brachiaria hybrid variety (cv.) Mulato II (CIAT36087) grass border and maize strip cropped with either pigeon pea (Cajanus cajan (L.) Millsp), cowpea (Vigna unguiculata (L.) Walp.), lablab (Dolichos lablab L.), velvet bean (Mucuna pruriens (L.) DC.), or groundnut (Arachis hypogaea L.) and sole maize (Zea Mays L.) (control).

RESULTS AND DISCUSSION

Results showed that strip cropping systems, especially with cowpea, improved soil K by 65% and soil pH by 1.5%. However, no significant effects of strip cropping systems were found on soil organic carbon (SOC), and it decreased over the cropping seasons. A Brachiaria grass border significantly increased maize grain yield by 15%. Although sole maize had higher yields, the overall strip cropping system increased maize yield by 4-16% (1.7 t/ha to 2 t/ha). We also observed significant effects of strip cropping on legume grain yields, with pigeon peas having the highest grain yields (1 t/ha) compared to other legume species. Further, strip cropping had a significant effect ($p < 0.05$) on total system protein and starch content. The maize + pigeon pea strip cropping system yielded a higher protein yield of 0.3 compared to other strip cropping systems, while the maize + cowpea strip cropping system yielded a higher starch yield of 2.4 compared to other strip cropping systems.

CONCLUSION

The novel strip cropping strategy can potentially enhance crop productivity, soil fertility, and human nutrition in smallholder farming systems. However, choosing and adopting specific legume species in strip cropping combinations depends on the farmer's objectives and available resources.

KEYWORDS

Brachiaria, diversification, ecological benefits, legumes, nutrition, strip cropping

EFFECTS OF NO-TILLAGE ON SOIL NEMATODE POPULATIONS IN CEREAL CROPS IN SPAIN

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INTRODUCTION

A great diversity of microorganisms (fungi, bacteria and algae), microfauna (protozoa) and mesofauna (arthropods and nematodes) exist in crop soils. A great diversity of microorganisms (fungi, bacteria and algae), microfauna (protozoa) and mesofauna (arthropods and nematodes) exist in crop soils. Studying changes in nematode populations is of special interest. They have relatively short life cycles, occur in all soil types and are easily detectable under the microscope. In addition, their populations are easily changed by differential soil management. Populations are, therefore, expected to be more abundant in poorly disturbed soil than in tilled soil.

MATERIALS AND METHODS

The study was carried out on seven farms in different locations in Spain. In each farm, two plots were created, one managed with conventional tillage (CT) and the other with no-tillage (NT). After an agricultural campaign, four soil sampling points were taken from each plot at 0 to 20 cm depth. Subsequently, the nematodes in 200 grams of soil were extracted from each soil sample. They were counted using a 400x stereo microscope with reticulated plates. ANOVA statistically analysed the recorded data to observe significant differences between CT and NT.

RESULTS AND DISCUSSION

The results show that, in general, DS has led to an increase in the number of nematodes compared to LC. Even in one of the farms, the increase in nematodes was statistically significant, with a doubling of the populations. On average, nematode populations in NT were 18% higher than in CT. The detailed data show increases of nematodes in NT on four farms. In two farms, the population of these living creatures is reduced. And finally, there is one farm where no effect has been observed with respect to TC. The increased NT has followed the main pattern observed in the scientific literature, which reports an increase in nematode populations when soil tillage actions are eliminated.

CONCLUSIONS

After one year of testing, a boosting effect of nematode populations has been observed in NT compared to CT.

KEYWORDS

Biodiversity, cereal crops, nematodes, no-tillage, soil fauna.

ENHANCING USE OF SUSTAINABLE TILLAGE SYSTEMS UNDER CONSERVATION AGRICULTURE IN MALAWI

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INTRODUCTION

It is vital to mitigate the negative effects of climate change by practising sustainable tillage systems for crop production. A study was conducted from 2021-2023 in Malawi's varying agroecology to test the impact of different tillage systems on maize production.

MATERIALS AND METHODS

The sites were Bvumbwe (high altitude), Bolero, Chitala (low altitude) and Chitedze (mid-altitude). Four CA and four CT treatments were laid out in RCBD in a 4 x 2 factorial arrangement. Tillage and cropping systems were the factors. Tillage included conventional tillage without box ridges (CT), conventional tillage with box ridges (CT-B), Pit planting under CA (PT-CA) and permanent raised beds under CA (PRB-CA). Cropping systems included sole maize (SMZ) and maize legume intercrop (MZ-L).

Maize variety (SC719) and cowpea variety (Sudan) were used at Bolero, Chitala and Chitedze, while bean variety (NU45) was used at Bvumbwe. The data recorded included maize grain yield, legume grain yield and soil moisture (TDR) for the top 15cm soil layer. Statistical analysis was performed using THE lmer package of R version 4.3.2.

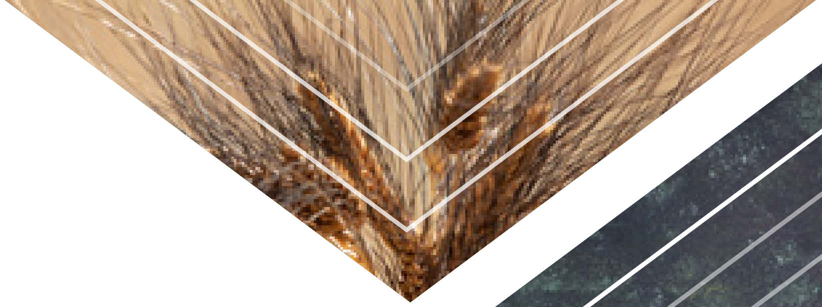
RESULTS AND DISCUSSION

Results: Maize grain yields were significant (p-0.05) at Bvumbwe, Bolero and Chitala. There were no significant differences at Chitedze. PRB-CA significantly (p-0.05) increased maize grain yield compared with PT-CA at all three sites and significantly higher compared with PT-CA and CT at Bvumbwe. At Bvumbwe, Bolero and Chitala, PRB-CA recorded 8997,7677 and 10918 kg ha-1, respectively. PT-CA SMZ and PT-CA MZ-L recorded 5056 & 3752kg ha-1 (Bvumbwe), 3752 & 4089kg ha-1 (Bolero) and 3910 & 7389kg ha-1 (Chitala), respectively. PRB-CA recorded significantly (p-0.05) higher yields for legume grain yield compared with CT at Bvumbwe, Chitala and Chitedze. There was missing legume data due to theft at Bolero. At Bvumbwe, Chitala and Chitedze, PRB-CA recorded 1586, 1417 and 1778kg ha-1 compared with 1099, 1153 and 840kg ha-1, respectively. Soil moisture was significantly (p-0.05) different at Bvumbwe, Bolero and Chitala.

There were no significant (p-0.05) differences at Chitedze. CT recorded significantly lowest soil moisture (29.11%) at Bolero compared with all tillage and cropping systems. At Bvumbwe, PRB-CA recorded significantly (p-0.05) higher soil moisture (59%) compared with the rest of the tillage systems. At Chitala, CT recorded significantly the lowest soil moisture (47%) while PRB-CA recorded significantly the highest soil moisture (58%) compared with all other tillage systems. There were no significant (p-0.05) differences between PT-CA and CT-B. However, these recorded significantly higher (52% each) soil moisture than CT.

CONCLUSION

Promoting sustainable tillage systems in farmer fields could improve crop yields in Malawi.



ENZYME ACTIVITY UNDER DIFFERENT TILLAGE TECHNIQUES AND N FERTILIZER MANAGEMENT IN DRY LAND AGRICULTURE

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INTRODUCTION

Soil enzymes play an important role in ecosystem function because they contribute to cycling key nutrients such as carbon (C) and nitrogen (N). Management practices such as tillage and fertilizer application can also alter soil enzymes' spatial and profile distribution. Proper choice of tillage technique and fertilizer application not only assists in improving crop productivity but also plays a salient role in sustaining microbial activity, subsequently enhancing carbon sequestration.

Poorly resourced farmers mostly practice monoculture, which tremendously degrades soil quality and consequently attenuates microbial activity. This study aimed to assay the activities of urease, invertase and acid phosphatase enzymes, under different tillage and fertilizer management.

MATERIALS AND METHODS

The 0.08M aqueous urea solution was used to assay urease activity, 0.17 M modified universal buffer (MUB) was used to assay invertase activity, and phosphatase activity was assayed using 0.025M nitrophenyl phosphate solution.

RESULTS AND DISCUSSION

Urease activity at 0-10 cm soil depth was higher ($p<0.05$) under NT compared to conventional tillage after the 5th season (CT-Y5) and conventional tillage CT-ANNUAL. A CT-Y5 had higher ($p <0.05$) phosphatase activity than CT-ANNUAL in the 20-30 cm depth with the control at 57 %, 60 kg N ha-1 at 72 %, and 120 kg N ha-1 at 45 %, whereas 240 kg N ha-1 had 58 % higher CT-ANNUAL compared to CT-Y5.

All these enzymes assayed NT have a distinct influence on the topsoil, especially under urease and phosphatase enzymes. Increased urease activity under conservation tillage systems may also be related to increased functional diversity of soils. The higher phosphatase activity under CT-ANNUAL systems at lower soil depths may be attributed to the mixing of fertilizer substrate, making it more available to microbes. Enzymatic responses to tillage and N fertilization influence ecosystem function and nutrient dynamics.

CONCLUSION

Among the three enzymes assayed, urease and phosphatase were more positively responsive to tillage and fertilizer application than invertase and can be useful indicators of soil quality. Higher fertiliser applications, such as 240 kg N ha-1, may be considered wasteful. Further investigation is needed on appropriate fertilizer expenditure costs with various tillage techniques to sustain soil quality. Following enzyme activity, NT at 120 kg N ha-1 is recommended for use in dry land agriculture, especially under N fertilization application.

KEYWORDS

Conventional tillage; Microbial activity; No-till; Urea fertilizer

EVALUATING THE EFFECT OF KNOWLEDGE TRANSFER ON THE ADOPTION OF CONSERVATION AGRICULTURE IN OR TAMBO DISTRICT

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INTRODUCTION

There is about degradation of land resources which maintain natural ecosystems, especially soils, which are the basis of agricultural systems (DAFF, 2011; Branca et al.,2013). Conservation agriculture is one of several land management practices with massive potential to reverse land degradation, increase crop yields and improve food security, given the real threats posed by climate. The adoption of CA in the Eastern Cape appears to be minimal, even though the province is one of the worst affected by soil erosion and degradation.

MATERIALS AND METHODS

The study was conducted in the OR Tambo District in two local municipalities, Ludaka, Nyandeni, and iNkozo, where 3 CA projects were implemented. The lands were used for maize production under conventional tillage for over 20 years. CA demonstration projects were implemented in these lands in 2019 and 2017, respectively. Awareness campaigns and skills transfer training were held in each project area.

Awareness campaigns were followed up with field days, during which project members shared their experiences with community members and farmers from other municipalities. Three projects that are practising CA in two local municipalities were selected. A semi-structured questionnaire was used as the primary data collection tool. A total of 90 farmers were interviewed. Data from completed questionnaires was analyzed using the Statistical Package for the Social Sciences (SPSS).

RESULTS AND DISCUSSION

93% of the farmers agree that they knew about CA after attending awareness campaigns, training, field days and hearing from other farmers, and 6.7 % of the farmers claim not to know about CA. 79% of the farmers practice CA (no-till and rotation), while 21% do not practice it due to fear of yield loss. Farmers practice CA for different reasons: the new knowledge gained (63%) and because it is less expensive (11%).

CONCLUSIONS

Awareness campaign has been one of the tools that has assisted in transferring knowledge and has influenced the adoption

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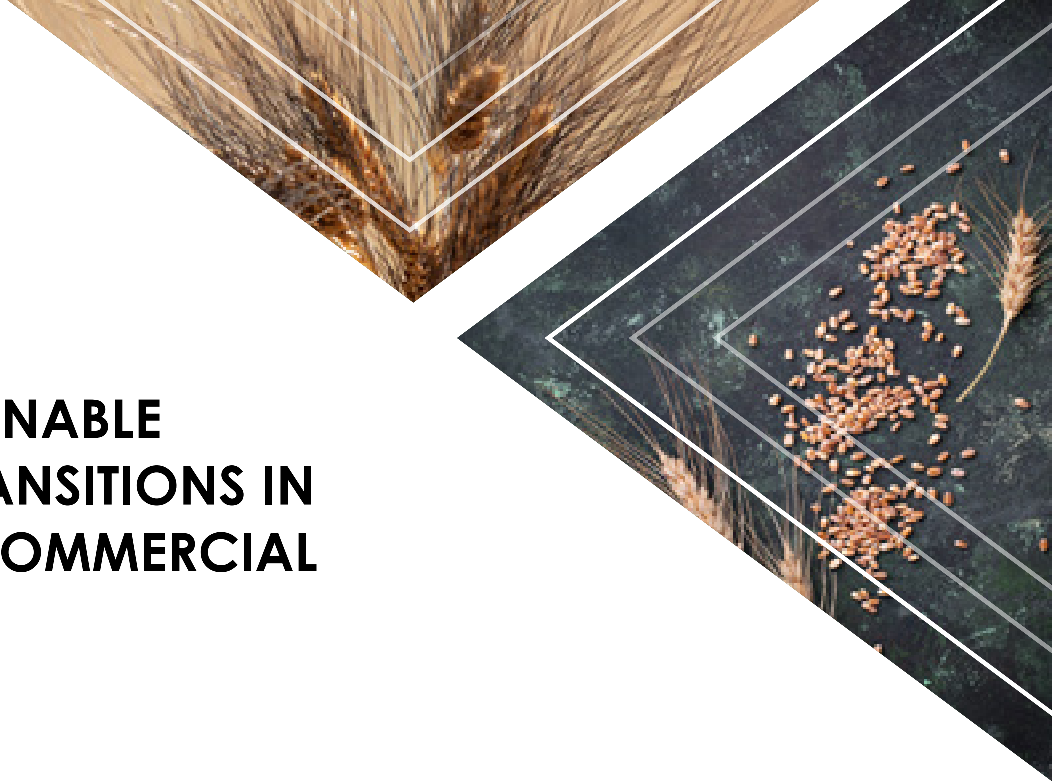
KEYWORDS

Conservation Agriculture, conventional tillage, knowledge Sustainable,



EXPLORING SUSTAINABLE AGRICULTURAL TRANSITIONS IN SOUTH AFRICA'S COMMERCIAL GRAIN SECTOR

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INTRODUCTION

Food insecurity and climate change are pressing challenges of our time. The global food system needs to be resilient and produce food sustainably for an increasing population. There is a general consensus that conventional commercial agriculture is no longer sustainable: high input costs, reduced profit margins, and environmental degradation have placed a strain on conventional practices.

A change is needed. Conservation agriculture (CA) has emerged as a viable alternative to conventional agriculture. It has been promoted as a transformative system that can sustainably intensify production and increase profits while reducing land degradation and mitigating climate change. However, CA adoption estimates are often disputed, and many farmers face challenges with its implementation. The question then arises: how do farmers change their farming practices, and how can we facilitate sustainable transitions on commercial farms?

MATERIAL AND METHODS

The presentation is based on ongoing PhD research at the University of Cape Town. The research aim is to explore the complexities of sustainable agricultural transitions on commercial grain farms in South Africa and determine the constraints to sector transformation. Over the last two years, I have interviewed farmers and relevant stakeholders (n = 43) in the wheat and maize industries and attended farmer days and agricultural exhibitions. In the semi-structured interviews, I spoke with farmers who were practising CA or were transitioning to CA. I asked about their experiences and challenges when changing their farming practices.

Data from the interviews were analysed using qualitative data analysis software, and a thematic content analysis was performed.

RESULTS AND DISCUSSION

The research's results have illustrated the complexities of the agricultural sector and the diverse factors that influence farmer decision-making. Further, the research has mapped agricultural transition trajectories and tracked how farmers experiment and begin to shift their practices.

The presentation will explain how grain farmers in South Africa moved away from the plough and began to implement CA. However, CA in SA is being practised in two distinct ways: rudimentary CA and ambitious CA.

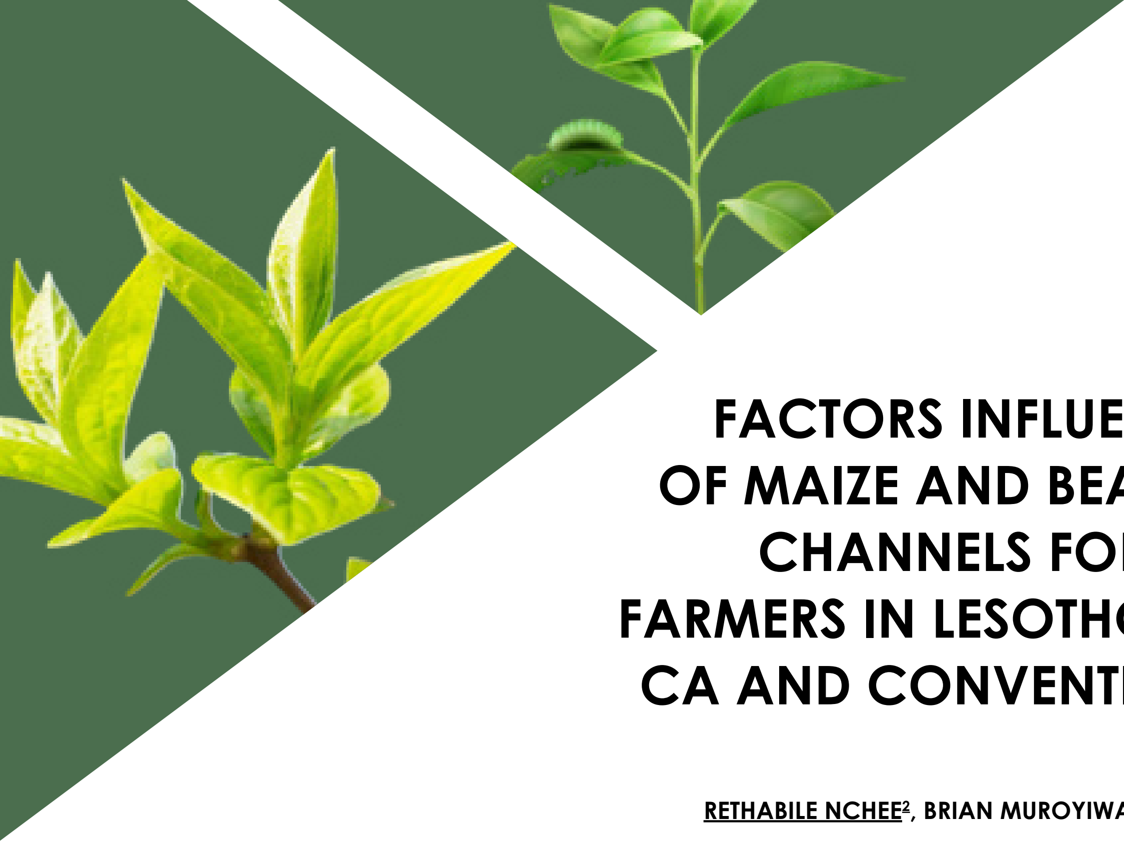
A key finding of the research is the lock-in mechanisms that prevent change and affect sustainability transitions. Four lock-in mechanisms are present in SA: 1. socio-cultural, 2. technological, 3. ecological, and 4. regulatory.

CONCLUSION

Recommendations to promote sustainable transitions and the uptake of CA in a sustainable and regenerative way. E.g., farmer-led innovation.

KEYWORDS

Sustainable transitions, lock-in, farmer decision-making, wheat, maize



FACTORS INFLUENCING CHOICE OF MAIZE AND BEANS MARKETING CHANNELS FOR SMALLHOLDER FARMERS IN LESOTHO: THE CASE OF CA AND CONVENTIONAL FARMERS

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INTRODUCTION

Although most smallholder farmers produce for subsistence purposes and household nutrition, a growing number of farmers are seeking markets for their surplus produce. In response to farmers' desire to sell their produce in formal markets, some aggregators are assisting farmers in accessing the market. Understanding the factors influencing participation in those marketing channels is also important.

MATERIALS AND METHODS

The study utilized data collected during the baseline survey for the Agricultural Productivity Programme for Southern Africa (APPSA) Lesotho in 2022. The survey covered seven districts in Lesotho. A structured questionnaire was used to collect data from 807 respondents in sampled villages in the seven districts. The study used multiple sampling approaches, including purposive sampling, snowball sampling, and simple random sampling. The study used purposive sampling to identify this group of farmers. The data was analysed using the multinomial regression model.

RESULTS AND DISCUSSION

Most farmers sold their produce through the consumer marketing outlet. The next biggest category of marketing channel, according to the results of the study, was street vendors. Gender, household income, Vehicle ownership and contract agreement coefficients are statistically significant. Gender is significant for retailer channels; household income is significant for farmers using street vendors' marketing channels. Vehicle ownership is significant in the retail market channel and consumer marketing channels. The contract agreement is significant for all market channels except street vendors. The age, literacy, occupation, field size, and farmer group coefficients were insignificant. Therefore, according to the study findings, these variables are not determinants of marketing channels for both CA and conventional.

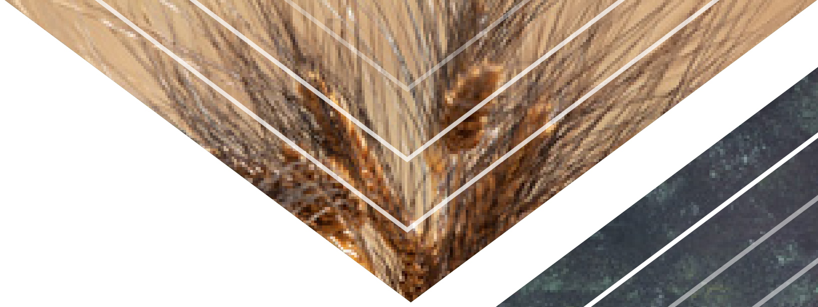
CONCLUSIONS

The adoption of no-till Conservation Agriculture in Lesotho's maize and bean cultivation holds most cases fail to meet. Training of small-scale farmers on Local Good Agricultural Practices (local G.A.P) and Global Good Agricultural Practices (Global G.A.P) will enhance local farmers' chances of penetrating formal markets. The other challenge that small-scale farmers encounter when practising CA is the small plot sizes due to the laborious nature of the potholing method.

Therefore, they fail to supply formal markets that require significant quantities. Mechanisation of CA can assist in improved production, which can positively influence formal market participation. Farmers must be encouraged to secure contracts with buyers, as the study results showed that contract agreements enhance participation in most market channels.

KEYWORDS

CA, Smallholder, Maize, Beans, Marketing, Channels, Determinants



GROWING RESILIENCE IN AGRICULTURE: EVALUATING THE RELEVANCY OF LONG-TERM CONSERVATION AGRICULTURE IN SOUTH AFRICA

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INTRODUCTION

The Western Cape is characterised by poor-quality soils and high climate variability, averaging about 150 to 550 mm of rain annually. Future climate projections estimate there will be decreased rainfall and warmer temperatures. This area is an area of commercial wheat and canola growing, and increasing the resilience of farming in this area is vital for sustainable food production.

The long-term conservation agriculture (CA) trials operated by the Western Cape Provincial Government support farmers to test and adapt to conservation agriculture farming methods. This study aimed to evaluate the research output for its relevance to increasing resilience. This study included a review of the peer-reviewed articles and postgraduate theses published since 2006 to evaluate the relevance of resilience. The articles assessed had to include 'long-term trial" or "conservation agriculture" and be part of the research database of the research farm.

MATERIALS AND METHODS AND RESULTS

Thirty-four peer-reviewed articles and theses were identified. The articles were categorized by their primary research aim: the impacts a CA practice has on yield (12), environment (8), and economics (9), assessment of production technology (2), assessment of the impact on the broader food system (1), and assessment of the research (2). Two articles explicitly refer to their relevance to climate resilience.

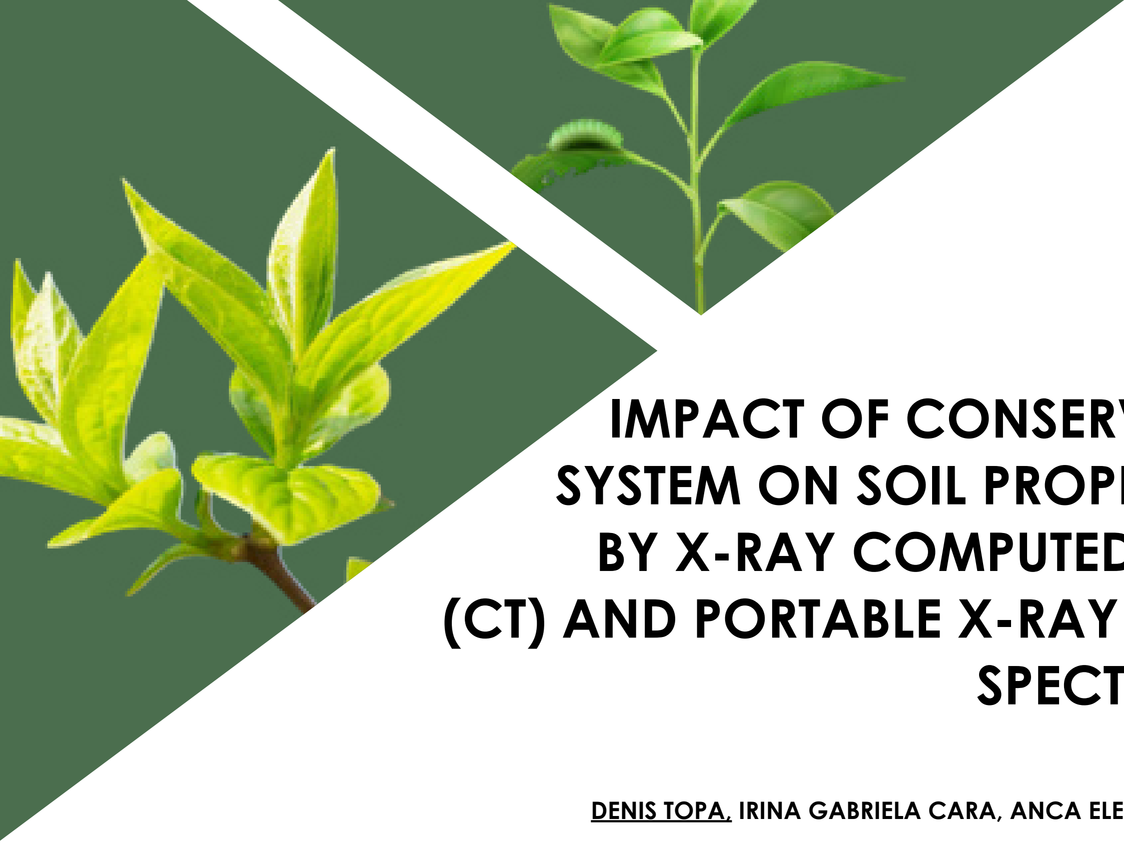
DISCUSSION AND CONCLUSION

Though climate resilience is not explicit in most articles, most research findings are relevant to increasing the resilience of wheat and canola production in a changing climate. This is especially true in terms of improving the overall condition of the farm system and identifying the necessary methods and technologies for a more resilient farm system. Examples include reducing risks from weeds, disease, and pests and increasing yield and financial viability from improved management techniques that are cost-effective compared to conventional farm practices.

These findings, based on research at government-run farm trials, suggest that establishing and maintaining an institution to support experimentation and knowledge sharing is essential for maintaining food security in the face of climate change. Further research is needed to define resilience for the local context, anticipate future environmental changes, and test additional farm practices that can increase resilience.

KEYWORDS

Climate Resilience, Conservation Agriculture, Knowledge Sharing, Food Security



IMPACT OF CONSERVATION TILLAGE SYSTEM ON SOIL PROPERTIES ASSESSED BY X-RAY COMPUTED TOMOGRAPHY (CT) AND PORTABLE X-RAY FLUORESCENCE SPECTROSCOPY (XRF)

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INTRODUCTION

The performance and sustainability of crop yields depend on the type of tillage technology adopted. In Romania, conservation tillage systems (including no-tillage - NT) have become an alternative to conventional tillage technology.

Conservation tillage systems minimize soil structure disturbance, intensify soil biological activity, improve the nutrient cycle, and increase soil water capacity. X-ray computed tomography and x-ray fluorescence spectroscopy are non-destructive, rapid, and multi-element methods of soil analysis, which can provide an elemental assessment of nutrients and quantify the soil macropore characteristics.

This study aimed to evaluate the effect of conservation and conventional tillage systems on soil morphological properties such as number and pore shapes, macroporosity, and soil connectivity. In addition, soil macro and micronutrients were analyzed using portable X-ray fluorescence spectroscopy.

MATERIALS AND METHODS

To achieve these goals, undisturbed soil columns (5 cm length and 1.5 cm diameter) were sampled from different soil depths (0-10 cm, 10-20 cm, and 20-30 cm) and tillage systems.

RESULTS AND DISCUSSION

The results revealed that conservation tillage increased soil nutrient contents (N, P and K) and decreased soil pH and C/N values compared with conventional management practices in 0-30 cm soil depth. Moreover, there was no significant difference between conservation and conventional tillage systems in the XRF analysis of total micronutrient (Zn, Cu, Fe Mn) content. The µCT images obtained differed for different soil depths and tillage treatments.

The highest contribution to the number of pores was based on large connected macropores with a volume >1000 mm3. The highest macroporosity was characterized by conventional tillage, while a greater fraction of mesopores and micropores under conservative tillage was noticed. Meanwhile, soil connectivity in surface 0-10 cm depth was larger in conservation tillage than in conventional tillage systems.

CONCLUSION

Since tillage systems considerably impact soil health, identifying the optimal system is crucial for determining whether the soil preserves favourable conditions for agricultural yields.

IMPACT OF CROPPING SYSTEMS ON WEED COMMUNITY DYNAMICS UNDER CONSERVATION AGRICULTURE IN SUB-HUMID ZIMBABWE

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INTRODUCTION

High infestation by a few dominant weeds in Conservation Agriculture (CA) remains a major constraint on crop productivity. Fewer, more diverse weeds could be less competitive with crops and provide ecosystem services. Sustainable intensification strategies aiming at reducing weed density and increasing diversity while ensuring good crop production are, therefore, essential for smallholder farmers. Integrating legumes into maize cropping systems is one promising option to achieve this.

MATERIALS AND METHODS

This study explores the relationship between cropping systems and weed communities under rain-fed conditions in CA. Field experiments were conducted at two research stations with contrasting soils over two growing seasons to capture the dynamic interactions within each cropping system. The cropping systems studied were maize monocultures, rotations incorporating maize with pigeon pea or cowpea, traditional intercropping of maize and pigeon pea and double row strip cropping of maize with cowpea or pigeon pea.

Employing a split-plot design, the experiment incorporated fertilized and unfertilized treatments. Data was collected on weed density, biomass, and diversity alongside grain yields and biomass.

RESULTS AND DISCUSSION

On average, intercrops had fewer weeds and low weed abundance. Maize-pigeon pea strip cropping (MZPP2) had the lowest mean weed abundance (262 weeds per m2), and all weed species were similarly abundant, with no single species dominating the community (Pielou index = 0.852) across sites and years. Maize within rotations was the opposite, with a high weed abundance of 551 weeds per m2 and low weed species evenness (Pielou index = 0.669).

Non-fertilised plots had slightly higher average species richness (9.2 species) than fertilised plots (8.65 species). Cropping systems containing pigeon peas had higher average crop biomass than other systems. MZPP2 had the highest mean total biomass of 4987 kg/ha, while maize monocrop (MZ) had the lowest biomass of 1841 kg/ha. Mean maize yields were significantly higher in MZPP2 (2623 kg/ha) than in other cropping systems, with MZ having the lowest yield (994 kg/ha).

CONCLUSION

Overall, cropping systems that produced more crop biomass were associated with better weed outcomes. MZPP2 could reduce weed densities, increase weed diversity, and increase food and feed yields. It could, therefore, be a rewarding cropping system for rain-fed CA in Zimbabwe. Hence, optimizing CA practices with diversified cropping systems is essential for food and nutrition security and for promoting sustainable and resilient smallholder agroecosystems in the face of climate change.

KEYWORDS

Biomass, Conservation Agriculture, Crop yield, weed density, weed diversity

THE FACTORS INFLUENCING ADOPTION OF NO-TILL CONSERVATION AGRICULTURE AMONG BEANS AND MAIZE FARMERS IN LESOTHO

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INTRODUCTION

Maize and beans production in Lesotho has declined since the 1970s from an average of 1.5 to 0.50 Ton ha-1. The decline is attributed to soil fertility depletion caused by topsoil loss due to a combination of sheet and rill erosion resulting from decades of conventional farming operations and nutrient mining of the soil associated with lack of and/or inappropriate use of fertilizer and manure amendments.

The situation is exacerbated by recent climate change trends and future projection models which indicate consistent evidence of climate change and Lesotho's vulnerability (LMS, 2017). Despite the numerous efforts to promote CA and its evident benefits, the adoption of CA is stagnant. This study, therefore, explores the factors influencing the adoption of no-till CA among beans and maize farmers in Lesotho.

MATERIALS AND METHODS

The study utilised data collected during a baseline survey for APPSA Lesotho in 2022. The survey covered seven districts in Lesotho, including Lesotho. A structured questionnaire was used to collect data from 807 respondents in sampled villages in the seven districts.

The study used multiple sampling approaches, including purposive sampling, snowball sampling, and simple random sampling. The study used Cragg's Double Hurdle Model to identify factors affecting adoption and the level/intensity of adoption of CA following Martinez–Espineira (2006) and Moffat (2003).

RESULTS AND DISCUSSION

The results of the study showed that gender, education level, lower household income, yield, field size and training on CA positively influenced the decision to adopt No-Till. Knowledgeable farmers understand the danger climate change poses to the environment and agriculture; hence, they appreciate the need for action, which demands the use of sustainable farming practices.

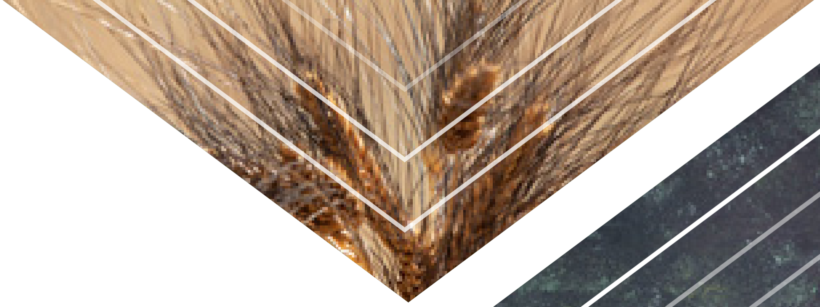
Farmer training was significant, and this finding points to the importance of extension services for farmers if nations can achieve the climatic change mitigation and adaptation goals in agriculture climate change. Age, household size, occupation, farming experience, soil fertility, access to credit, access to extension and group membership were insignificant.

CONCLUSIONS

The results confirm and contradict the priori expectations. The government should focus on making extension services more effective in the study area so that they can influence the adoption of CA. The study recommends that since education level is significant, those who seek to promote CA must target educated respondents since they can easily adopt and share the benefits with the illiterate or low-educated farmers who may take time to adapt.

KEYWORDS

CA, Smallholder, Adoption, Beans, Determinants, Maize, No Till



IMPROVING CROP POLLINATION BY PROVIDING NESTING RESOURCES TO BOOST THE POPULATIONS OF CROP-SPECIFIC SOLITARY BEES

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INTRODUCTION

Solitary bees are very diverse, and populations have been severely impacted by modern farming methods, including ploughing, the overuse of fertilizers, pesticides, and herbicides, and a concentration of flowering plants to limited times of the year.

Even though several studies have demonstrated that non-corbiculate solitary bees are more effective pollinators than honeybees, solitary bees are usually ignored and are rarely used as managed pollinators in commercial farms. This study explored ways to increase the abundance of solitary bees that are suited to different flower structures by providing nesting resources and flowers throughout the year.

MATERIALS AND METHODS

Various nesting resources, such as logs with holes, paper and plastic straws, sandbanks, and excised Xylocopa colonies, were tested. The resources' size, length, and location were manipulated to attract bees from different families and genera.

RESULTS AND DISCUSSION

The logs with holes were occupied by a diverse range of bees which selected tunnels that matched their body size and life cycle. The smallest holes' most common bees (1– 5 mm diameter) were Allodapula, Ceratina, Braunsapis, and Hylaeus species. Megachilids mostly occupied the larger holes (6-10 mm). The longer holes (>20 times the diameter) were preferred over the shorter ones, regardless of whether they were made by borer beetles or drill bits. The logs supported a growing number of colonies over time, with up to 95% of the holes being filled at certain times of the year. The straws (7—and 9-mm diameter) were occupied by Megachile chrysorrhoea, which occupied the straws 300 mm in length more than the shorter or longer ones. The number of straws occupied doubled every six months.

The smaller, mainly long-tongued bees are effective pollinators of various crops, including blueberries. The larger megachilids are effective pollinators of Rosids, such as apples and pears. The logs with Xylocopa colonies were sustainable for over nine years, with a gradual increase in the number of bees over this period. The sand banks were occupied by mainly Amegilla and Anthophora species. These bees are all efficient buzz pollinators that could improve pollination of Solanaceae crops, such as tomatoes and eggplants.

CONCLUSIONS

By making small, low-cost modifications to the unused spaces around crops, wild bee populations can be preserved while enhancing the pollination rates of insect-pollinated crops.

KEYWORDS

Pollination, Solitary Bees, Megachilids, Xylocopa, Buzz-pollination, Nesting resources

IMPROVING THE PRODUCTIVITY OF LEAFY VEGETABLES GROWN UNDER RAINWATER HARVESTING AND CONSERVATION TECHNIQUES IN A SEMI-ARID AREA OF SOUTH AFRICA

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INTRODUCTION

Due to limited water resources availability in South Africa, it is critical to optimize rainfall use and maintain sustainable crop productivity, particularly in rainfed agriculture under arid and semi-arid climatic conditions. Rainwater harvesting and conservation (RWH&C) technologies can be combined to address rainfall variability and climate change impacts.

MATERIALS AND METHODS

A field trial was established in a semi-arid area of South Africa to test the effect of various RWH&C practices on the yield of two selected leafy vegetables (amaranth and Swiss chard) during two consecutive and diverse rainfall seasons. The RWH&C practices included in-field with bare and plastic catchments and tied-ridging combined with mulch on a sandy loam soil type.

Field measurements of fresh yield, canopy growth and soil water content were compared to simulated values from a parameterized version of the AquaCrop model. The adequate model performance achieved would enable one to assess the effects of increased rainfall variability on the productivity of the tested leafy vegetables under future climate scenarios.

RESULTS AND DISCUSSION

The RWH&C technologies investigated improved soil water conservation and overall crop productivity, particularly during the dry rainfall season. During the normal rainfall season (350-600 mm), the implementation of tied-ridging was sufficient to improve the harvestable yield of both amaranth (13% increase) and Swiss chard (3% increase) when compared to the conventional tillage (flat cultivation) practice. During the dry season (< 350 mm), maximum crop yield was obtained with the rainwater harvesting method with either a plastic or bare surface (28% increase for amaranth and 33% for Swiss chard) compared to the conventional flat cultivation practice.

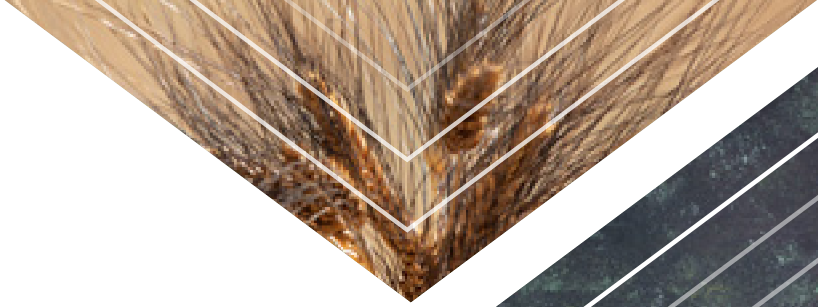
Profile soil water content was increased considerably by using tied-ridging and rainwater harvesting techniques, either with or without a plastic mulch. This, in turn, resulted in significantly higher crop productivity, particularly in a drier summer rainfall season, when the total amount of rainfall received during the growing season would not be sufficient to meet crop water requirements.

CONCLUSIONS

Harvesting and conserving rainwater within the vegetable field has shown to be a promising practice in South Africa to mitigate water shortage problems that often cause water stress and reduce the productivity of leafy green vegetables. Implementing these techniques also contributes to environmental preservation by reducing runoff, soil erosion and drainage from the cultivated areas, with consequent reduction of ground and surface water pollution.

KEYWORDS

In-field rainwater harvesting, tied-ridging, amaranth, Swiss chard



LOWER YIELD IS BALANCED BY LOWER INPUT COSTS IN A SYSTEMS-LEVEL EVALUATION OF CONSERVATION AGRICULTURE NET PROFIT: SOME EARLY RESULTS

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INTRODUCTION

Conservation agriculture (CA) is an agricultural system designed to manage agroecosystems for improved and sustainable productivity by conserving and enhancing soil health. This project aims to compare the overall performance of CA to a conventional crop management system using a systems-level field-scale experiment in which industry experts dictate the agronomic decisions and local farmers and contractors conduct all field operations.

MATERIALS AND METHODS

An experiment was set up at a 9.5 ha experimental site near Whitchurch, Shropshire (UK). It consisted of a systematic 24 m multi-strip blocked design of CA and conventional crop production. Data were collected on crop yield, soil characteristics, greenhouse gas emissions, and economics.

RESULTS AND DISCUSSION

There were no significant differences in spring bean yields between CA (5.21 ± 0.48 t / ha) and conventional (6.03 ± 0.36 t / ha) in the project's first year. The CA treatment produced a revenue of £1543 / ha, and the conventional revenue was £1752 / ha. Due to higher expenditure in the conventional treatment, the gross margins for both systems were similar (CA: £664 / ha; conventional: £676 / ha). However, in the second year of the project, there was a significantly ($p = 0.04$) lower yield in the CA treatment (9.4 t / ha ± 1.41) compared to the conventional treatment (10.96 t / ha ± 0.37) growing winter wheat, which resulted in a gross margin of £663 / ha in the CA treatment and £858 / ha in the conventional treatment.

The largest drivers of CO_2 and N_2O emissions were found to be soil temperature ($p = 0.03$) and nitrogen fertiliser addition ($p = 0.002$), respectively. When the yield-scaled global warming potential was considered, the CA produced significantly higher ($p = 0.027$) CO_2 equivalent GHG emissions (289.48 kg CO_2-eq / ha / t) in comparison to the conventional treatment (236.51 CO_2-eq / ha / t), however, this does not consider the indirect GHG emission data.

CONCLUSIONS

This experiment is ongoing; however, current results show that CA in the UK has the potential to reduce farmers' agronomic expenditures while remaining profitable. The results also highlight the importance of using a systems-level approach to CA experimentation to understand the complex system interactions and provide useful data to farmers to aid in the transition to CA.

KEYWORDS

Agronomic Performance, Conservation Agriculture, Crop Yield, Economic Analysis, Global Warming Potential, Greenhouse Gas Emissions.

MECHANISED CONSERVATION AGRICULTURE AS PART OF AGROECOLOGY TRANSITION IN SMALLHOLDER SYSTEMS IN ZIMBABWE

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INTRODUCTION

Food systems should drive stability, food and nutrition security, poverty reduction, and economic growth. Instead, they are responsible for much of the world's greenhouse gases, deepening social inequalities, degrading biodiversity and depleting natural resources. In response to these challenges, agroecology is gaining prominence as an approach focusing on sustainable and resilient territorial agriculture and natural resource systems.

Promoting synergies within and among agricultural and natural systems requires collaborative initiatives. However, existing knowledge gaps on suitable technologies, drudgery in the transformation of the farming systems, resource suitability and availability, and increased disease pressure could affect the trajectory and sustainability of agroecology transitions.

MATERIALS AND METHODS

The Agroecology Initiative (AE-I) in Zimbabwe, through a network of interconnected living labs embedded in agroecology living landscape (ALL), established several demonstration sites where farmers, researchers, and other stakeholder could innovate, test, and localise known technologies that can aid actualising agroecology.

Testing technologies include conservation agriculture (CA) and alternative intercrop systems for increased resource use efficiency and push-pull and bio-insecticides for insect pest management. To address drudgery associated with CA and intercropping, two-wheel tractors with rippers and basin diggers were introduced.

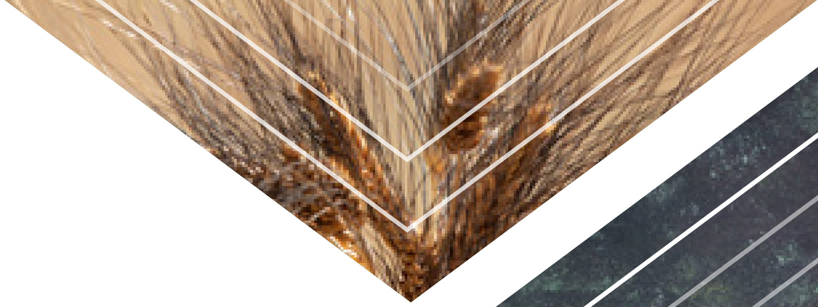
Initial results show that farmers are more likely to adopt CA if it is mechanised. Additionally, farmers' perceptions of CA are positive, with most farmers ranking it highly for increasing yield and conserving soil.

RESULTS AND DISCUSSION

The demonstration plots showed that CA had higher yields in areas receiving less than 500 mm of rainfall. The factors that influence the performance and adoption of CA in different contexts need to be understood.

CONCLUSION

Conservation agriculture is a promising technology, but more work needs to be done in quantifying its benefits and tradeoffs for agroecology in Zimbabwe's farming systems



METHODOLOGY TO QUANTIFY ENERGY CONSUMPTION IN ANNUALS AND PERMANENT CROPS PRODUCTION

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INTRODUCTION

The increase in the use of agricultural inputs aimed at satisfying global food needs is triggering an acceleration of climate change. The agricultural sector generates direct emissions, mainly carbon dioxide (CO_2), associated with the energy of input manufacturing. At a global level, this sector is responsible for 13% of CO_2 emissions. Nowadays, there is a scarce quality bibliography that quantifies the production energy of agricultural inputs and associated emissions (carbon footprint). This is due to the lack of proper data during manufacturing.

MATERIALS AND METHODS

A new quantification methodology in cropping systems is proposed for energy consumption and their associated CO_2 equivalent emissions to study management in agricultural ecosystems for either annual or permanent crops. Several existing methodologies were developed by authors worldwide, and the objective was to unify factors and information of interest, which became extrapolated to any edaphoclimatic zone. The International Federation of Institutes for Advanced Study (IFIAS, 1978) lays out a methodology, in operation at present, that has been adapted to this work. IFIAS does not consider the energy source in the production processes, thus non-renewable energy is associated with each factor when manufacturing.

RESULTS AND DISCUSSION

Energy consumed in field operations, including the processing energy of the used fuel and those consumed in the inputs manufacturing, are considered. Fertilizers, crop protection products, and seeds are considered, therefore, the richness of the chemical products must be known. In the case of irrigation, the required energy should be determined; that is, the water resource, the pumping type, the necessary manometric height, and the pipeline characteristics need to be known. The indirect energy associated with the machinery manufacturing and the transport out of the farm of the final harvested product is not considered. Attention must be given to the study carried out by Camargo et al. (2013), which provides factors to determine the total energy based on an exhaustively contrasted bibliography at the national and international level.

CONCLUSION

This methodology indicated easy steps to follow in energy and emissions studies of the agricultural sector, providing valuable data for carbon emissions balances. It is useful to compare different fertilization, irrigation, and soil management strategies, observing the best climate change mitigation strategies. Likewise, this methodology enhances good agricultural practices with mitigation potential, such as those based on Conservation Agriculture.

KEYWORDS

Agricultural inputs, carbon emissions balances, CO_2 equivalents emissions, soil management strategies

ACKNOWLEDGEMENTS

To the LIFE Innocereal EU project (LIFE21-CCM-ES-101074009) for co-financing.


NO TILLAGE CONTRIBUTION TO CLIMATE CHANGE MITIGATION EMISSIONS BALANCE IN A CEREAL FIELD WITH DIFFERENT FERTILISATION AND IRRIGATION STRATEGIES

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INTRODUCTION

Agricultural soil is negatively affected by the intensity of agriculture and livestock activities. Efforts are being made to increase the productivity of agricultural land to supply food for the growing population. This productivity enhancement is depleting natural resources such as freshwater and increasing the use of N fertilisers, which implies higher greenhouse gas (GHG) emissions. Thus, the agricultural sector contributes to global warming; reducing its environmental impact by producing food sustainably is a challenge to be addressed. The adoption of best management practices, such as no-tillage with direct drilling and permanent soil cover with cover crops and residues, which constitute two pillars of Conservation Agriculture (CA), can provide answers to this challenge.

MATERIALS AND METHODS

These best management practices were introduced in a maize crop field during three growing seasons under Mediterranean agroclimatic conditions. Several fertilisation and irrigation strategies were established to study their contribution to climate change mitigation through a balance of the main GHGs from soil: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and soil carbon sequestration. The several strategies considered three different N sources: urea (U), ammonium nitrate (AN), and ammonium sulphate nitrate with nitrification inhibitor (NI). They also considered two irrigation doses: full crop demand (100%) and deficient dose (75%). GHG emissions were measured through the static chambers' method, and global warming potential factors of 265 (nitrous oxide) and 28 (methane) were used to determine the CO_2 equivalents. Soil samples were taken and analysed to calculate carbon sequestration.

RESULTS AND DISCUSSION

In general, cumulative CO_2 emissions showed higher values under deficit irrigation, especially in the second and third seasons. This pattern differed for N_2O and CH_4, the latter providing negative values (oxidation). Several strategies positively impacted the soil carbon sink effect with positive soil organic carbon balance at the end of the study period. The impact was higher with deficient irrigation for all N sources. Among the obtained results, NI-75% was the optimum combination from both agronomic and environmental points of view, being a strategy with a high mitigation impact without production depletion. Nevertheless, U-75% showed the highest carbon sequestration but a significant yield reduction of 42.3% compared with U-100%.

CONCLUSION

This study provides knowledge on fertilisation and irrigation strategies for cropping maize without tillage, implementing more environmental agricultural techniques, preserving soil and water, and contributing to climate change mitigation.

ACKNOWLEDGEMENTS

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KEYWORDS

Carbon sequestration, Conservation Agriculture, greenhouse gas emissions, Mediterranean agroclimatic conditions, nitrification inhibitor

NO-TILLAGE FOR SUGARCANE-PEANUT CROP ROTATION SYSTEM

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INTRODUCTION

The conservation principles applied to peanuts can reduce soil erosion and production costs when cultivated in rotation with sugarcane and increase the stock of soil carbon. Still, soil compaction is the leading cause of doubts about the efficacy of soil conservation practices. Moreover, sugarcane is normally planted in conventional tillage after peanuts, which may reduce the benefits of low soil disturbance. We raised the question of the impact of no-tillage on sugarcane in rotation with peanuts on yield and soil quality. This research aimed to study the interaction between four soil management strategies performed in the peanuts cycle and two tillage treatments before planting sugarcane on agronomic characteristics and soil properties.

MATERIALS and METHODS

The experiment was done in the MEIOSI system (an intercropping method). The trial was conducted in 2019-2020 in Planalto (Sao Paulo, Brazil) in a field after seven cuts of green-harvested sugarcane, using a randomized complete block design. For peanuts, the treatments consisted of conventional, minimum with chisel, strip-tillage, and no-tillage, with five replications. After the peanut crop was harvested, each plot was divided into two treatments before planting sugarcane (var. RB966928): no-tillage and deep tillage (with and without application of CaO-300 kg/ha).

RESULTS AND DISCUSSION

Although no differences were verified in soil bulk density and porosity among treatments in the peanuts cycle, the highest soil strength values were observed in no-tillage measured before planting, at flowering, and before and after harvesting, compared with conventional tillage. The differences in soil penetration resistance among the treatments diminished from planting to the end of the cycle. Furthermore, low soil disturbance and maximum straw soil covering of conservation practices significantly increased the available water capacity.

They reduced the incidence and severity of the virus (GRSV) in peanut plants. Consequently, both minimum-tillage and no-tillage increased pod yield on average by 695 and 991 kg/ha more than strip-tillage and conventional tillage, respectively, with no effect on grain quality and pod losses. For the plant cane cycle, the association of strip tillage in peanuts and direct planting in sugarcane caused an increase of 12 Mg/ha in stalk yield without affecting the root system. In the first ratoon, an increase in stalk yield was verified with the application of CaO.

CONCLUSION

In conclusion, it is feasible to adopt conservation agriculture for sugarcane-peanut crop systems, which would increase yield, root system, and soil quality.

KEYWORDS

Groundnut, Saccharum spp., soil compaction, conventional, strip-tillage, soil carbon

PERFORMANCE OF MAIZE VARIETIES UNDER MINIMUM TILLAGE IN SEMI-ARID CONDITION OF O.R TAMBO DISTRICT, SOUTH AFRICA

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INTRODUCTION

The Eastern Cape Province's smallholder farmers consider maize their most crucial summer crop. A typical yield of less than two tonnes per ha is achieved in the smallholder sector. Conventional tillage (CT), residue removal, and mono-cropping cause production losses.

Poor varietal selection by smallholder farmers contributes to the maize yield gap. Prioritization of cost-reducing, yield-enhancing and resource-conserving farming methods is vital to catalyze a shift towards sustainable and resilient maize agri-food systems. Selecting suitable varieties with high prospects and wide acceptability is of utmost importance.

MATERIALS AND METHODS

The trial was conducted at Dimanda Senior Secondary School (31° 33'' 12.95'' S and 28° 54' 28.69'' E) in O.R Tambo district to evaluate the performance of 24 maize varieties under minimum tillage (MT). An experiment was conducted using three replications of Randomized Complete Block Design. The net plot size of the study was 5m x 4m. The light disc cut through the maize residues at a soil depth of 15 cm, followed by direct planting of maize using a no-till planter with a planting density of 40 000 plants per ha.

Fertilizer was applied to maize crop at 90 kg N, 45 kg P and 60 kg K per ha in all plots. Pesticides were used when pest and plant diseases were observed. Growth and yield parameters were collected and subjected to variance analysis using Genstat's fourteenth edition.

RESULTS AND DISCUSSIONS

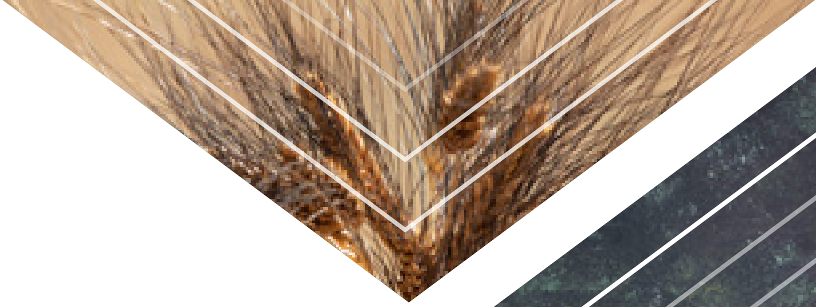
Maize variety US9729R recorded high moisture content and differed significantly ($p<0.05$) from all other maize varieties except US9749BR, DKC76-75B, DKC78-78BR and DKC74-74BR. Maize variety DKC76-75B had the highest number of plants per plot and differed significantly ($p<0.05$) with LG31.750BR, PAN3P-924PW, LG31.750 and KKS8410B2R which recorded the least number of plants per plot. Maize variety KKS8410B2R recorded the highest yield and differed significantly with P2636, P2362PW, PAN3P-924PW, P2432BR and DKC76-77BR which recorded lower yield. Maize yield was positively correlated to plant population and number of cobs per plot.

CONCLUSION

Maize variety US9729R recorded high moisture content at harvest and could be susceptible to moulding. Maize variety KKS8410B2R had the highest yield and was among the varieties that recorded an increase in the number of cobs per plot. This short-term study showed that various maize varieties yield more grain even when grown with an MT.

KEYWORDS

Minimum tillage, maize variety, yield



ROOTING FOR RESILIENCE: CULTIVATING PROSPERITY THROUGH CONSERVATION AGRICULTURE IN SOUTH AFRICAN VEGETABLE SOILS

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INTRODUCTION

Conservation agriculture (CA) adoption has increased steadily, accounting for 12.5% of global croplands. While CA is becoming more common in grain production systems in South Africa, its implementation in vegetable production systems remains low.

As its high nutrient and water requirements constrain vegetable production, and crops are vulnerable to pest and disease attacks, implementing sustainable farming practices in these intensive systems is essential for sustained food production. This study investigated the farm-level implications of shifting to CA in an irrigated vegetable production system in Vredendal, South Africa.

MATERIAL AND METHODS

The effects of three treatments—control, mulch, and cover crop—on various soil health indicators in the first and third years after adopting CA in an irrigated vegetable production system located in Vredendal, South Africa, were determined. Soil health indicators included soil pH (KCl), Olsen-P, organic and active C, available N, microbial activity, acid phosphatase, β-glucosidase, and urease activity.

RESULTS AND DISCUSSION

In the first year of adopting CA, treatment effects were only found for organic C. However, active C and acid phosphatase differed significantly between treatments in the third year of CA implementation. A short-term study by Herencia et al. (2008) investigating the effects of transitioning from conventional to organic vegetable production emphasised that at least two years were required to notice significant changes in soil health, supporting the results of this study. Farms strongly influenced most soil health indicators in all cropping years. Several studies in similar vegetable production systems (organic no-tillage systems) have found improvements in organic C, microbial diversity and activity, and macronutrients. These studies, however, all focused on longer-term trials ranging from 2 to 10 years.

CONCLUSIONS

Despite including indicators that respond quickly to management change, the results in the first year do not align with those found in longer-term studies with multiple cropping years. However, after year three, treatment effects were more noticeable, suggesting that the implications of introducing conservation agriculture to production systems may not be apparent immediately after its adoption.

Substantial site differences in soil parameters were evident. The CA strategies used by farmers may, therefore, differ across sites. While the sites were managed similarly in this study, the historical management of each site and its location in the larger landscape were likely different, which should be considered in future research.

KEYWORDS

conservation agriculture, vegetables, soil health, arid zones, irrigated systems, short-term

DEMYSTIFYING THE INTERMEDIATING ROLE OF CONSERVATION AGRICULTURE ON RESOURCE POOL DIVERSITY AND WEED-CROP COMPETITION IN MAIZE-BASED FARM ECOSYSTEMS

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INTRODUCTION

Typically, weeds are considered problematic and costly to control in all farming systems as they compete with crops for essential growth resources. Smallholder farmers, often constrained by limited resources and environmental degradation, require novel and innovative approaches to improve productivity while preserving natural resources. Conservation agriculture (CA) offers a promising paradigm for sustainable agricultural development by promoting minimal soil disturbance, permanent soil cover, and crop diversification. Adopting CA principles facilitates the development of a diverse soil resource pool. By minimizing soil disturbance, CA preserves soil structure and organic matter content, fostering a heterogeneous environment conducive to microbial diversity crucial for sustaining soil health and fertility. A three-year study (2020/21 to 2022/23 growing seasons) was carried out in Zimbabwe at the Domboshawa Training Centre (DTC) and the University of Zimbabwe Farm (UZ) on-station sites. We hypothesized that CA and weeding duration moderate crop-weed competition and result in enhanced maize crop yields.

MATERIALS AND METHODS

The main treatments were CA and conventional practice (CP) tillage systems with seven sub-treatments involving weeding duration (no weeding at 3, 6, 9, 3 and 6, 6 and 9 and 3, 6 and 9 weeks after planting). They replicated five times at each site in a randomised complete block design. Linear mixed models were used during data analysis to assess the effects of treatments on the variability of soil nutrients and maize grain yield.

RESULTS AND DISCUSSION

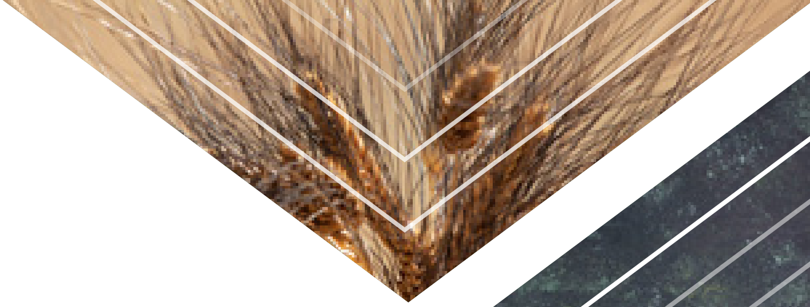
Overall, CA achieved higher grain yields than CP in all cropping seasons and sites. Weeding twice after planting resulted in higher maize grain yield at all sites than other weeding durations. In addition, CA has a higher potential to sequester more organic C despite the weeding durations as opposed to CP, while combining CA and weeding once after planting at UZ posed a great potential in increasing soil organic C as well with least in CP combined with weeding twice after planting.

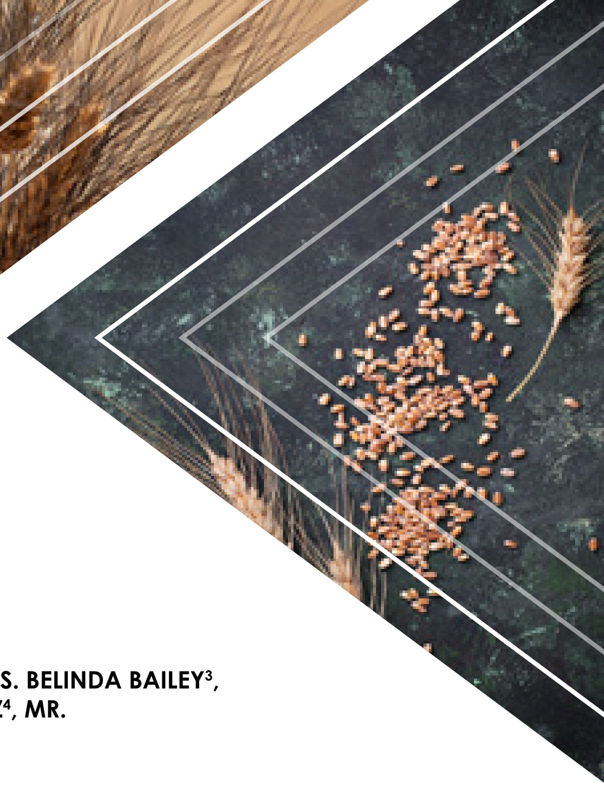
CONCLUSION

The results suggest that integrating CA practices improves soil health and productivity and enhances the resilience of smallholder farming systems to environmental stresses and climate variability. In conclusion, adopting CA practices holds significant promise for promoting agricultural sustainability in smallholder farming systems. By enhancing soil resource pool diversity and reducing weeding frequency, CA fosters resilient and productive agricultural ecosystems, offering a pathway to food security and environmental stewardship in a changing world.

KEYWORDS

crop yields, promising, soil health, sustainable, weeds





SUSTAINABLE SYSTEMS BASED ON CONSERVATION AGRICULTURE FOR COST SAVING IN WESTERN EUROPE

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INTRODUCTION

Current agriculture must satisfy the increasing demands of the growing population, protect natural resources, and contribute to the agricultural economy. Several agricultural systems were tested to assess global sustainability. The aim of this study has been to evaluate the potential benefits of sustainable agricultural practices based on Conservation Agriculture (CA) in several fields from Western Europe.

MATERIAL AND METHODS

The study was carried out during five seasons in two countries with different climates: two pilot farms in the UK (oceanic climate) and two in Spain (Mediterranean climate). In the UK, each farm gathers 5 and 4 different crop fields, while in Spain, each farm gathers 3 crop fields. Every crop field compiles three plots where three agricultural systems were developed: conventional system (CT), Sustainable system 1 (S1), and Sustainable system 1 (S2). CT consisted of inversion tillage, no cover crops (CC), standard crop protection products (CP), N fertilisers, and seeds. S1 (only in the UK) used non-inversion tillage, CC, and adjusted CP, fertilisers, and seeds. S

2 performed sowing through light tillage/direct drill in the UK and no-tillage/direct drill in Spain used CC (only in the UK), and adjusted inputs like S1. Wheat, beans, barley, oilseed rape, oat and peas were established in UK farms. In Spain, the crop rotation was wheat, sunflower and chickpeas/peas. Economic sustainability was assessed by recording productions and incomes and operational costs: machinery passes (fuel consumption), CP, fertilizers and seeds.

RESULTS AND DISCUSSION

On a five-year average, a non-significant yield reduction of only 3% was found when the sustainable systems were compared to CT. Productions were much higher in the oceanic climate, but the percentages of reduction between systems were similar in both countries studied. The slightly lower production of sustainable systems was compensated with decreased operational costs, which made these systems more profitable.

Costs were higher in the UK than in Spain as well as incomes, but the reduction in operational costs was higher in the Mediterranean climate (17%) than in the Oceanic climate (7%). Cost savings were mainly due to the significant reduction in machinery costs, 23% reduction in the UK and 30% in Spain, which offset the increases in CP, including herbicides, with sustainable systems.

CONCLUSIONS

In addition to CA's social and environmental sustainability, sustainable systems also improve economic sustainability since the significant cost savings and similar incomes make them more profitable.

ACKNOWLEDGEMENTS

To the Soil Health and Conservation Agriculture Enhancement Project funded by Syngenta and the project's partners

AGRICULTURAL FINANCE AND EXTENSION SERVICES FOR SMALLHOLDER MAIZE FARMERS PRACTISING CA IN LESOTHO- DETERMINANTS OF ADOPTERS AND NON-ADOPTERS ACCESS TO FINANCE AND EXTENSION SERVICES

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INTRODUCTION

Agricultural finance and extension services are crucial in supporting smallholder maize farmers. These services enable farmers to access the necessary financial resources and knowledge to improve their farming practices and increase productivity. Most smallholder farmers are resource-constrained, which negatively affects their production and participation in lucrative markets.

Some empirical studies analyse factors that influence farmers' access to credit. These studies report that among other factors, the significant factors affecting access to credit include farmer's age, farm income and non-farm income, financial assets (savings), remittances and pension, farm size, family labour, land ownership, credit awareness, gender, education level and repayment ability (Foltz, 2004; Nuryartono et al., 2005; Subbotin, 2005; Eze et al., 2009; Sidibé et al. 2014; Motsoari et al., 2015; Ogundeji et al., 2018). This study aims to explore and compare the determinants of adopters and non-adopters of CA access to finance and extension services.

MATERIALS AND METHODS

The study was carried out in the seven districts of Lesotho. Cross-sectional data was obtained from 807 farmers in the seven selected study areas. The data was collected by means of a structured questionnaire through interviews using the KOBO tool in a baseline survey conducted in 2022.The interviewed farmers were selected from the two largest agro-ecological zones in Lesotho—the Lowlands (both Northern and Southern) and the Highlands regions. Data was analyzed using a bivariate probit model following Katchova (2013).

RESULTS AND DISCUSSION

Smallholder maize farmers have limited access to credit and extension services. The bivariate model results for both adopters and non-adopters showed that access to both credit and extension services was significantly influenced by household income, use of social networks, gender, occupation, farmer group membership, source of credit, source of extension service, farming experience, age, educational level, market information, labour, and marital status for adopters and non-adopters.

CONCLUSIONS

The study strongly recommends that farmers keep proper financial records of their farming business operations to increase their creditworthiness. We also encourage farmers to form or join farmer organisations to enable them to access credit, enjoy group dynamism, and have access to farm inputs, including new technology, that would help them improve their farm productivity through the association. Innovative financial tools can also assist farmers with access to credit.

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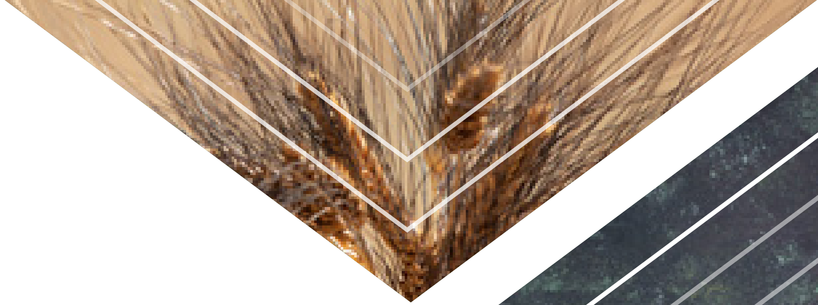
KEYWORDS

Access Credit, Smallholder, Farmers, Extension, Conservation Agriculture



WOMEN AND CONSERVATION AGRICULTURE: A WIN-WIN RELATIONSHIP

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INTRODUCTION

Conservation Agriculture (CA) has become an essential agricultural management strategy that positively impacts environmental sustainability, combats climate change (Kassam et al., 2022) and benefits farmers, including women engaged in agriculture (CGIAR), through social, economic, cultural, and quality-of-life benefits.

MATERIAL AND METHODS

A literature review analysed the mutual benefits between CA and women and the gender-based barriers to its adoption that persist today.

RESULTS AND DISCUSSION

CA elevates crop productivity and enhances food quality (Beelman et al., 2021; Montgomery et al., 2022), supporting food security and nutrition in rural communities, a notable advantage for women who lead food production and preparation. CA increases agricultural profitability economically (ECAF, 2017), empowering women to invest in their needs and businesses.

Simultaneously, CA reduces the operational costs and the external inputs needed, which is advantageous for women facing resource constraints. Culturally, CA promotes traditional agricultural practices, primarily guided by women, fostering gender equality and social inclusion (IAASTD, 2008) and enhancing women's participation in agricultural decision-making. Regarding quality of life, CA saves time and effort on agricultural tasks (ECAF, 2017), giving women more time for family, education, and personal development.

Women play relevant roles in agriculture, particularly in developing countries where they undertake the main agricultural tasks. Their expertise is crucial for adopting sustainable agricultural practices, positioning them as essential change agents (NL4WB, 2017).

Women are also custodians of ancestral knowledge and traditional wisdom, preserving cultural values, protecting genetic resources of global importance, and contributing to the development of sustainable agricultural systems, food security and sovereignty (Agüero, 2013). Finally, rural women, deeply connected to nature, utilise its resources sustainably. Integrating women into decision-making can foster more equitable and sustainable resource management practices globally (NL4WB, 2017).

Considering the above, it can be argued that women's roles in agriculture and rural decision-making influence the global CA uptake. However, female farmers lag behind men in adopting CA due to gender-related obstacles like unequal access to land, inputs, extension services, and education. These constraints limit their embrace of sustainable farming and involvement in community activities and decision-making within households and communities.

CONCLUSIONS

CA benefits agricultural productivity, food security, and gender empowerment. Women's role in sustainable agriculture, rural economy and social development is crucial. However, gender-related challenges persist, hindering women's full participation in agriculture and CA implementation. Addressing gender gaps is essential to promote CA-based sustainable practices, improving food security and environmental conservation, and building more equitable societies (FAO, 2011).

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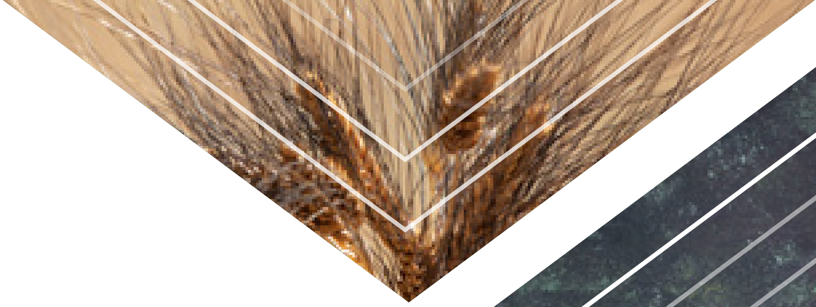
KEYWORDS

Gender equity, Women and agriculture, Gender-based barriers



ZERO TILLAGE PLANTING INTO A PERMANENT TROPICAL LEGUME SWARD - THE NEXT REVOLUTION IN CONSERVATION AGRICULTURE

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INTRODUCTION

The first zero tillage planting into a legume sward was done in the Atlantic Forest biome by the first author, in Matão, São Paulo state, Brazil, in 1976. But the farm was sold, and this was discontinued. Further development occurred in 1988, in Morrinhos, Goiás state, Cerrado biome. Before research recommendations were available, exploratory on-farm tests were executed to identify a maximum number of promising zero tillage (ZT) practices for early ZT adopters (Vasconcelos & Landers, 1992).

This project executed by the above co-authors (1988-1992), was financed by Manah S.A., a forward-looking fertilizer company. It spawned the Associação de Plantio Direto no Cerrado (APDC, 1992 - Farmer Association for Zero Tillage in the Cerrado), a network of 49 Friends of the Land Clubs, multiple ZT short courses, distribution of specialised zero tillage equipment to small farmers, a quarterly popular ZT journal (49 issues with10,000 circulation), organization of many ZT promotional events (estimated 24,000 total participants).

Starting from zero in 1980, there are today an estimated 17 million hectares of ZT/ Conservation Agriculture (ZT/CA) in the Cerrado, or some 10 per cent of the world total (Kassam et al., 2017). This eliminated serious erosion of Cerrado soils and paved the way to sustainability.

It is necessary to observe that this technology depends on the enhanced soil biological activity engendered by zero tillage, without which it will not work; personal communication, Alysson Paolinelli ca. 1994 - ex-Brazilian Minister of Agriculture and pioneer of tropical ley farming.

MATERIALS AND METHODS

In 1988, to maximize the number of promising practices tested, a series of non-replicated on-farm tests was carried out, in one-hectare plots and planted in October 1988. A new technology was conceived using forage legumes undersown in hybrid maize, using farmer equipment at 80 cm spacing. At that time, only one crop a year was planted, due to the long cycles of both current maize and soybean varieties. Five forage legume species were tested: Siratro, Macroptilium atropurpureum, late-flowering perennial soybean, and Neonotonia wightii.var IRI 1394, Calopo, Calopogonium mucunoides, tropical kudzu Pueraria phaseoloides and pigeon pea, Cajanus cajan. The latter three were common varieties.

The legume seed was mixed with the maize top-dressing immediately before planting in the maize inter-row, 30 days after maize planting, at a shallow depth. At the end of the rains, the legumes were allowed to establish deep tap roots after the first maize harvest, in 1989. For this reason, no stover grazing was practised in the first year. Thereafter, light, dry season and stover grazing still left adequate soil cover (>70%). No measurements of carrying capacity were possible. The four stoloniferous legumes climbed the maize and, after harvest, re-sprouted, covering the maize stover. Maize yields were estimated by counting the ca.60 kg sacks from the combine to the nearest whole sack.

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Glyphosate levels, pre-tested for legume re-sprouting ability, determined 0.72 lit/ha of active ingredient as ideal for this purpose on the climbing legumes. All treatments received similar fertilizer applications and pest/disease controls.

RESULTS AND DISCUSSION

In the dry season, at varying times after maize harvest, the legumes lost their leaves: Tropical Kudu, Calopo, Siratro, IRI 1394, and Pigeon Pea. The first four were perennial climbers and suppressed weed growth well by smothering. The latter was biennial and erect and did not suppress weeds; second-year woody growth was problematic for the combine. The best two legume treatments of the 1992 results were selected for financial analysis of cost per ton of maize and for late leaf drop in the dry season: these were Siratro and IRI 1394. Here, we used the conventionally tilled (CT) farm maize as the control for comparisons. An additional treatment was pure maize planted with ZT. The results are shown in Table 1 below.

Control Treatment			Reduction (%)	
	Yield (kg/ha)	Cost (R$/ton	vs ZT/CA Maize	Vs CT, Farm Maize, Control B.
Control A. Maize ZT	6000	64,0	0	10.2
Control A. Maize ZT + IRI 1394	4800	68,1	(-6.4)	3.4
Maize ZT + Siratro	5900	50,5	0	28.4
Control B. CT Farm Maize, disc harrowed.	6000	70,5	(-10.2)	0

The yield of two maize pure stands: A. ZT/CA maize in the test and B. CT farm maize, both with a yield of 6000 kg/ha, as controls, were compared to those of maize associated with Siratro and IRI 1394. This was the first demonstration of a ZT cost advantage in the tropics. Test results showed: maize with Siratro, competition reduced by disease, yielded 5900 kg/ha, only 1.7 % below the controls, whereas IRI 1394 completely smothered the maize at harvest, considerably affecting photosynthesis.

This resulted in a yield of 4800 kg/ha, a depression of 20 per cent as compared with the controls. The association with Siratro reduced the cost per ton of maize by 22.7% and 28.4 %, respectively, when compared with Controls A and B; IRI 1394, despite severe shading, increased cost per ton by only 6.4% (v s Control A) and still had a 3.4% lower cost per ton compared with Control B.

Shading would be (partly) counterbalanced by the extra legume nitrogen, stimulating early maize growth, especially from year 2 onwards. Better legume control (mechanical or chemical) could raise the IRI 1394 maize yield. Also, the extra legume N would increase carbon sequestration. These data demonstrate that the association of maize with a permanent forage legume sward can lower the production cost of maize in the Brazilian Cerrado.

Other benefits, besides the financial, are: (i) effective weed control (legume smothering), (ii) high protein, dry season, stover grazing, (iii) aerobic breakdown of crop residues, (iv) accumulation of soil organic matter, (v) total erosion control, (vi) extra organic, free, nitrogen, (vii) mulch-based moisture conservation, (viii) enhanced carbon sequestration due to additional legume N, (ix) Increased farm herd size due to increased dry-season carrying capacity and (x) elimination of annual cover crop costs. A win-win-win situation. In this project, electric fencing was successfully tested with a New Zealand-manufactured fencer.

The question of controlling the climbing of the stoloniferous forage legumes has three aspects: (i) excessive shading and possible competition for light and nutrients, as with IRI 1394, (ii) the capacity for smothering weeds that erect species do not possess and not fully compensated by high-density planting and (iii) incremental N for the system, either by direct transfer to maize roots from legume nodules or as a result of decomposition of mechanically- or herbicide-controlled legume biomass.

In fact, the egregious performance of Siratro was due to reduced vigour (i.e. less shading and competition for nutrients), because of a heavy attack by the fungus Synchitrium sp. This delicate balance must be resolved experimentally, and possible effects of Synchitrium spp. or other fungi on the health of grazing animals need to be elucidated.

In the early nineties, legume sward technology was rejected by researchers and farmers alike because there was no selective herbicide to control forage legumes in soybeans. The opportunity to resurrect this innovation with herbicide-resistant crops, which came later, has been totally overlooked.

Conclusions

- The lower cost per ton of maize with ZT/CA and the legume sward technology were proven
- • Innovating with herbicide-resistant crops will now allow this forgotten technology to be attractive for farmers to adopt
- This breakthrough needs honing for generalized farm use and should now be recognized as a vital accelerator of CA adoption and carbon sequestration
- This technology can be much enhanced by research follow-up, especially in:
    - Better control of the climbing legumes to reduce shading and nutrient competition would increase the commercial crop yield
    - Other crops besides maize must be included in a two-crop annual succession as part of a bi-annual rotation
    - The development of mechanical legume controls would extend this technology to pioneering ZT/CA organic farmers

TOPICS FOR FOLLOW-UP RESEARCH;

- GPS planting and twin straight discs 20 cms apart on both sides of the legume plant line. to cut tendrils, with 2-3 inch depth limiter
- Measurement of N fixed
- Weight or milk gains for stover grazing
- Grazing trials are complex and costly: measure the fodder offer and use 50% of this, or another factor, to determine carrying capacity
- 20-year farm models with/without legumes
- Possible incompatibility with less tall annual crops
- Reduction in combine speed with legume in maize
- Pre-harvest desiccation
- Tests of non-climbing COVER CROPS at high density for weed control and re-sprouting capacity after herbicide application. e.g. Styanthes spp. and 2,4-D
- Incremental carbon sequestration
- Define the carrying capacity of light dry season grazing that leaves >80% soil cover
- Adaption to freezing winters – perennial soybean can re-sprout from 30-40 cm depth
- Temperate P. montana climbing legume should be tested in temperate climates compared to P. phseoloides
- Effects of fungal spore ingestion on cattle health

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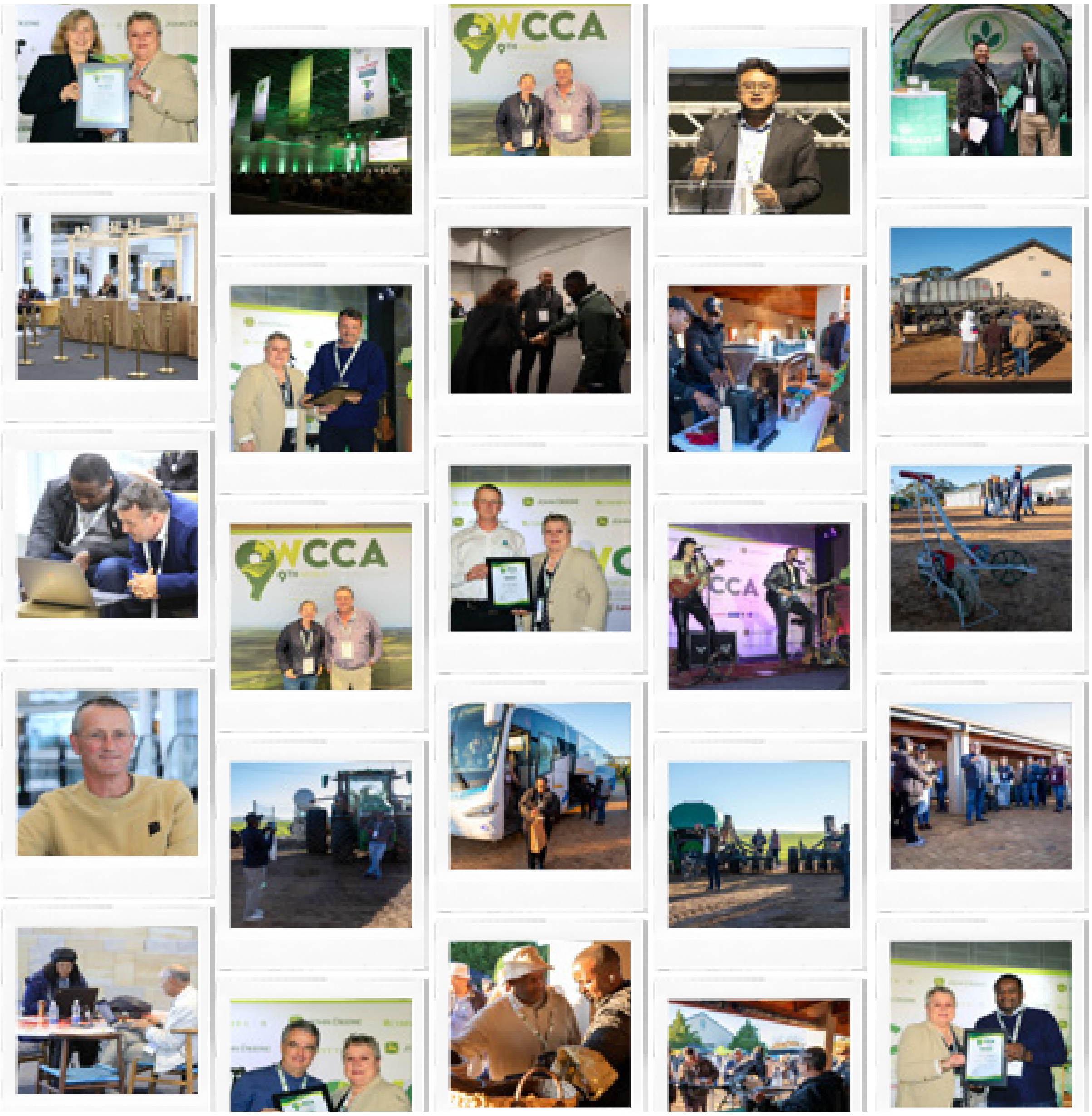
9WCCA
9TH WORLD CONGRESS ON CONSERVATION AGRICULTURE



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