8WCCA
8th World Congress on Conservation Agriculture

PROCEEDINGS OF THE 8th WORLD CONGRESS ON CONSERVATION AGRICULTURE

The future of farming

Profitable and Sustainable Farming with Conservation Agriculture

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8th World Congress on Conservation Agriculture

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FOREWORD

Not so long ago, if you suggested to farmers that they should plant crops without ploughing, most would have thought that you were crazy. Today, however, all across the world, millions of farmers – small and big – are now doing just this. More than 15% of the global cropland area is already being managed to produce crops without tillage, using an approach known as Conservation Agriculture (CA). This dramatic farming revolution has been driven largely by farmers who find themselves better off: they are the inventors of new locally adapted CA practices and they share their experiences internationally.

CA enables farmers to produce food profitably without damaging the environment. It delivers many environmental benefits to society such as climate change mitigation and conservation of land, water and biodiversity. Unlike tillage-based farming systems which are major emitters of greenhouse gases, CA systems sequester carbon within the soil and reduce emissions of methane and nitrous oxide as well as of carbon dioxide by reducing the use of fossil fuels, agrochemicals and other farm inputs.

Switzerland has played an active part in the global transformation towards sustainable farming systems and many of its own farmers are taking up CA-based sustainable land management practices. It was therefore appropriate that we should have hosted the 8th World Congress on Conservation Agriculture.

Given that sustainable land management policies are essential elements in policies for climate change mitigation, global food security and biodiversity conservation, they will play vital parts in reaching many of the UN's 17 Sustainable Development Goals.

I have taken note of the success of the 8th World Congress, of which we were proud to be hosts as well as active partners.

I am delighted to affirm Switzerland's commitment to doing all within its power to accelerate the enhancement and spread of CA at home and abroad.

Andreas Aebi, President,
Swiss National Council

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PREFACE

After a delay of one year, the European Conservation Agriculture Federation (ECAF) in close cooperation with its member association the Swiss No-Till and the Food and Agriculture Organization (FAO) organized the 8th World Congress on Conservation Agriculture (8WCCA) as an on-line event. The Congress was attended by 783 participants including representatives of farmer associations, international organizations, scientific institutions, private sector, non-governmental and civil society organizations, from 108 countries and from both the developed and developing world. Almost 250 presentations were received from participants in all five continents.

Under the banner: **The Future of Farming – Profitable and Sustainable Farming with Conservation Agriculture**, the 8WCCA highlighted the global contribution of Conservation Agriculture towards achieving these outcomes. It also explored how CA land use can help to address humankind's major global challenges of climate change, environmental degradation and food security while safeguarding the livelihoods of small and large-scale farmers. The proven benefits of CA in terms of erosion control, carbon sequestration, biodiversity regeneration, and improved water and nutrient cycling are all contributing to the achievement of the manifold objectives of the international conventions and agreements including the Sustainable Development Goals, European Green Deal and F2F Strategy.

A major objective of the 8WCCA was to bring the achievements of CA Community to the attention of policy makers and relevant stakeholders in the public, private and civil sectors at the national and international level. This objective was supported by the attendance at the opening session of the Director General of the FAO, the European Commissioners for Agriculture, and for Environment, Oceans and Fisheries, the Chair of Agriculture and Rural Development Committee of the European Parliament, and representatives of the World Bank, Asian Development Bank, International Fund for Agriculture Development, the Global Farmers Network, the Consultative Group on International Agricultural Research, and the Intergovernmental Panel on Climate Change.

Transformation of tillage agriculture into CA is now occurring very rapidly through farmer-driven processes with support from national and international organizations. Consequently, millions of farmers and civil society are already reaping the wide range of economic, environmental and social benefits that CA offers. It was therefore very appropriate for the Congress to propose a global plan of action to transform 50% of global cropland area to CA by 2050.

The Congress noted that Europe still lags behind other regions in terms of CA adoption, and it is hoped that the 8WCCA will help to accelerate the uptake of CA in Europe.

Africa too needs special support to accelerate the adoption and spread of CA to address the challenges of food security, climate change and environmental degradation.

We therefore wholeheartedly embrace the decision at the 8WCCA that the next Congress, in 2024, will be held on the African continent, hosted by South Africa in collaboration with African governments and regional and national organizations.

Gottlieb Basch, President, ECAF
Emilio Gonzalez-Sanchez, General Secretary, ECAF
Reto Minder, President, Swiss No-Till
Wolfgang Sturny, Founding Board Member, Swiss No-Till

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OPENING SESSION

Dr QU Dongyu,

FAO Director-General

Distinguished Participants and Guests,
Ladies and Gentlemen,
Dear colleagues and friends,

I thank the European Conservation Agriculture Federation and the Swiss No-till Association for the opportunity to address the Congress.

The *Food and Agriculture Organization is the* Specialized Agency of the United Nations that leads international efforts to defeat hunger and malnutrition. The key challenge is to meet the growing demand for food, while reducing the pressure on natural resources and ecosystems. Current consumption patterns and existing agri-food systems are hindering efforts to achieve this. We see disturbingly high rates of food loss and waste, air pollution, greenhouse gas emissions, the loss of biodiversity, and resulting inequality. We urgently need to do things differently and act holistically to transform our agri-food systems. We have to create new solutions and find smarter ways to produce more with less input, while keeping in mind that there are no healthy foods without a healthy environment. That is why FAO's Strategic Framework endorsed last week by ministerial conference, focuses on the transformation to MORE efficient, inclusive, resilient and sustainable agri-food systems for better production, better nutrition, a better environment and a better life, leaving no one behind.

These 'Four Betters' represent a guiding principle and an innovative business model for how FAO is supporting the achievement of the 2030 Agenda. The 'Four Betters' also reflect the interconnected economic, social and environmental dimensions of agri-food systems. To produce more with less requires us to be truly innovative and environmentally thoughtful.

FAO is supporting its Members in achieving this delicate balance based on each local condition and priority. This includes **Conservation Agriculture,** integrated with other good agronomic practices, to prevent soil erosion, and promote biodiversity, biological interactions and efficient natural resource management.

Principles of Conservation Agriculture that **mitigate** climate change include:

- using no-till practices to sequester more carbon into soils;
- using fewer synthetic chemical inputs, and
- increasing the use of appropriate tools and modern machines, including adopting the latest digital and precision agriculture technologies.

Practices that **adapt** to climate change include:

- using quality seed, and planting superior crop varieties suited to specific environments;
- managing soil, water, nutrients and pests by retaining crop residue and growing cover crops;
- diversifying cropping systems; and
- applying integrated pest management strategies.

FAO promotes the creation of decent on and off farm employment opportunities, as well as reducing food loss and waste. To do so, it facilitates improved planning between urban, peri-urban and rural areas. We are fully aware of the need to engage more closely with the private sector to leverage innovations and technological advances. We recognize the complementary partnership between a thriving private sector and a public regulatory framework, and we support policies and strategies that can create enabling environments at national, regional and global levels.

Our new Strategy for Private Sector Engagement reflects this modern approach. FAO also recognizes the need for digital applications and the promotion of technologies. Advanced data systems, for instance, can inform management decisions for cropping systems in line with current climatic conditions. FAO's flagship Hand-in-Hand Initiative accelerates agricultural transformation and sustainable rural development to eradicate poverty (SDG 1) and end hunger and all forms of malnutrition (SDG2). In doing so, the evidence-based, country-led and country-owned Initiative contributes to attaining all of the Sustainable Development Goals. The initiative prioritizes countries where national capacities and international support are the most limited or where operational challenges, including natural- or man-made crises, are the greatest. It uses a range of metrics to support agricultural interventions, supported by a geospatial platform for aggregating big data.

Dear Colleagues,
To conclude**,** I would like to underscore that collective action by all and all tools in the box is essential, if we are to transform our agri-food systems. FAO is committed to engaging with all stakeholders to deliver meaningful and impactful solutions for farmers. Let us work together to attain the transformation of agri-food systems and achieve the SDGs.

I wish you all a successful Congress with a package of balanced solutions.

Thank you.

OPENING SESSION

Mr. Virginijus Sinkevičius

Commissioner for Environment, Oceans and Fisheries
DG Environment

A very good morning to all participants, and many thanks for this invitation.

You've asked me to say words about how the Commission supports sustainable agriculture, especially in the context of the European Green Deal. Every society is built on farming and food. The Green Deal reflects that – it's a broad quest for sustainability, in all the areas that matter. And that includes agro-ecology and Conservation Agriculture.

As you note in your title, we don't have a choice. The future of farming must be profitable and sustainable. Not just here in Europe, but all around the globe. Everywhere we look, we see existential threats. We see climate change and environmental degradation.

Soils are increasingly degraded, wilderness is constantly being destroyed, and wildlife populations are in decline. The loss of biodiversity is especially severe in agricultural areas. Almost all species and habitats related to agriculture are affected, from plants and wildflowers to pollinating insects and farmland birds. Scientists say that if we fail to tackle this crisis, farmers will be the first to suffer.

There will be more soil degradation, more water scarcity, even fewer pollinators and less natural pest control. We can and must revert this trend! If we do restore ecosystems and their services, farmers will be the first to benefit, and those benefits will continue for future generations. So, it's time to fix our broken relationship with nature.

Conservation Agriculture, by keeping soil intact as a living ecosystem, tackles problems where they arise. It recognises soil as a multifunctional, living system, vital for the environment and for society. Soils are home to one quarter of the world's biodiversity. And they provide many services that are essential to our survival. They safeguard the food supply, regulate the climate and the water cycle, and help with pest control. So, if we want to tackle the crises in our biodiversity and our climate, we have to start with soil.

In the European Union, our top political priority is implementing the European Green Deal. Together with the Recovery and Resilience Facility, it brings decisive action, building sustainability into the EU economy. Last year we adopted two major elements – the new EU Strategy for Biodiversity, and Farm to Fork, our Strategy for sustainable food. They both set targets that are ambitious but achievable, enabling our society to live within the boundaries of the planet. Farm to Fork aims for long-term food security, transforming the way we produce, process, market and consume. The Biodiversity strategy takes an integrated approach to nature, with measures for all the pressures it faces. It includes a plan to restore rivers and degraded ecosystems back to health. It promotes biodiversity-friendly farming practices and increase landscape diversity, bringing back at least 10% of landscape features on agricultural land. Both strategies share common targets, to be achieved by 2030. They include a 50% reduction in the use and risk of pesticides, which is very relevant for Conservation Agriculture. They also propose action to reduce nutrient losses by at least 50%, and action to maintain soil fertility. And we will increase the share of agricultural land under organic farming by up to 25%.

Most of the Green Deal elements have now been adopted, but there are two more major items on the way. The first is a new strategy for soil, to improve fertility, protect soil biodiversity, and comprehensively increase soil organic matter. It will provide a framework for renewed policy action on protection, strengthening existing measures and reducing threats. A new Strategy for forests is also on the way. It will aim for sustainable management, protecting ecosystems and their biodiversity, and strengthening resilience in the face of climate change.

The global challenges are huge, but it's not too late to meet them. It will take substantial change, with farmers at the heart of the process. Our aim at the European Commission is to keep farmers on board, and help them through this process of transition. Our Common European Agricultural Policy will continue to support them, securing funding for sustainable measures. That way we maintain current levels of productivity, in a sector that thrives. We all understand how our economy depends on healthy natural capital. And as we move through the transition, we'll need more nature-based solutions, and more approaches that are close-to-nature.

Climate change is already here. Around the globe, biodiversity is in steep decline, and the nature urgently needs protection. This situation has to change. We need practicable solutions for sustainable agriculture. We'll deliver those solutions by working closely with the people involved – farmers and landowners, land planners, industry executives, mayors and ministers. With more collaboration at local, regional, national and global levels, promoting and implementing sustainable land management. That way we deliver what Europe needs – sustainable agriculture for the longer term, while supporting all three pillars of sustainability, the ecological, the economic and the social.

That's the promise of the European Union, and it's how we'll deliver the European Green Deal.

All the best for your conference – I wish you fruitful discussions.

Thank you.

OPENING SESSION

Mr. Norbert Lins

Chair, Agriculture and Rural Development Committee
European Parliament

Dear Director General Mr Dongyu Qu (FAO),
Dear Commissioners,
Dear President Basch,
Dear Mr Amman and Hofer,
Ladies and Gentlemen,

Thank you for hosting this World Congress on Conservation Agriculture, and giving me this excellent opportunity to share some reflections on Food Systems, Innovation and Natural Resource Management for European Agriculture.

As a Chair of the European Parliament's Committee for Agriculture and Rural Development, I can assure you, that the future of Farming, the protection of natural resources, climate adaption and mitigation and keeping our agriculture competitiveness, productive and attractive are of our interest and constitute a scope of direct and indirect discussions during the AGRI Committee meetings.

The COVID-19 crisis has significantly affected many sectors and economies. The EU agriculture has also suffered significantly. The pandemic has also revealed the weaknesses of our food systems and has affected unfortunately the most vulnerable among us Moreover, unfortunately there are still many unknowns about the scale of the impact of the pandemic on the economy.

It is clear that for the future crisis we have to do the utmost to be prepared. Not only for future crisis, but especially to our changing climate. The way we produce and consume food has a direct influence on our climate and environment. And agriculture is the sector most affected by climate change. But luckily, agriculture is also the sector who can store carbon and become climate neutral by possibly 2035 - If supported by the right tools.

I am happy that today we can and need to take stock of the issues observed, and use them, as an opportunity to identify what, and where, we have to be better.
In consequence, there is a need for a transition to more robust food systems, using innovative technics, with more sustainable use of natural resources and where no one is left behind. To accomplish it, we need all actors across the value chain, not only in the EU but also globally.

However, for any proposed transition, we must not forget to support our farmers. I would like to underline that, they play a crucial role in ensuring our food security, producing healthy and nutritious food for our citizens. Therefore, they contribute to the well-being of the people in Europe.

However, they are also the most affected by any changes, despite the difficulties they face.

Honourable speakers, we are aware of present risks in agriculture. Among other things, risks related to water scarcity, land degradation, losses of biodiversity. Unfortunately, I could continue listing risks that European farmers face in their daily life.

Therefore, we should be conscious of the urgent need for action to mitigate those risks in order to preserve and restore healthy ecosystems. Protecting these fragile and non-renewable resources is crucial to ensuring a healthy future. Our future.
The European Green Deal pursues wide-ranging actions to make Europe climate-neutral by 2050. It introduces new, sustainable and inclusive strategies to accelerate the economic transition that will allow for the improvement of the quality of life, of health, the care for nature, and leave no one behind.

Within its flagship strategy, the Farm to Fork, addresses the challenges of sustainable food systems and recognises the links between healthy people, healthy societies and a healthy planet. The Biodiversity strategy aims at reversing biodiversity loss and accelerating the EU's transition towards a resource efficient and green economy.

These two strategies have the same denominator - change. They both recognise that the change of current way of life is crucial and we have to act now.
Distinguished guests, our farmers need more options to respond to climate change to guarantee food security, and to help preserve biodiversity. This is when we should think about the innovation.

We are aware, that the research and innovation are the key drivers in accelerating any transition. I call to focus on the transition to sustainable, healthy and inclusive food systems from primary production to consumption.
We all know that with increasing digitisation and precision technique we can protect our environment by decreasing the use of fertilizers and pesticides without negatively impacting yields. It should never be a question of "either or" and rather a how do we protect our environment and climate while guaranteeing food security and production in Europe.

Moreover, the recent European Commission study has confirmed that the products of the New Genomic Techniques have the potential to contribute to more sustainable agri-food systems. The goals of the Green Deal and Farm to Fork are ambitious and new genome techniques will help achieving them. I hope that Europe will be more courageous when it comes to innovation and thereby not only support our farmers, but also our excellent scientists that developed the technology and its benefits. Therefore, I will dare to say that harnessing innovation and sustainability of food systems contributes to making our economy more competitive.
By investing in innovation, we are also meeting the objectives of the Green Deal and Farm to Fork Strategy, pursuing the EU's priorities and promoting visibility at global level.

Ladies and Gentlemen, the place to engage in the discussions on these matters is the Food Systems Summit that will take place in September 2021. This event is meant to seek ambitious policy outcomes for the future of farming and the global fight against hunger.

It is an excellent opportunity to launch new actions towards transformation of the world food systems into healthier and more sustainable. The EU has actively contributed to the preparation of the 2030 Agenda and has committed itself, to make the Sustainable Development Goals a guiding principle in all its policies and to promote them with its partners.

As AGRI and DEVE committee in the Parliament we jointly ask the Commission to put forward a renewed and enhanced EU commitment to achieve zero hunger and the right to adequate food. Furthermore, we need adequate financial commitments in order to reach the SDG 2 Zero Hunger given the current huge global funding gap. We also need to think of a new EU trade policy to support the global transition to sustainable agri-food systems. And also, how as EU we can support partner countries and their local farmers, fishers and foresters, as well as food producers in moving towards more sustainable practices in key areas such as animal welfare, the use of pesticides and the fight against antimicrobial resistance.
This is the chance for the EU to share its global vision and commitments with the world.

I am confident that by working together with the stakeholders, across all domains, we can move towards the transformation of the EU food systems to be more resilient, more sustainable, taking into account innovation and protection of biodiversity and natural resources. And let us among all questions not forget, that our farmers are in the middle of it all and produce daily our food on the table. I want take this opportunity and thank them for their work.

Ladies and Gentlemen, I wish you a good conference with constructive discussions and innovative ideas!

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OPENING SESSION

Mr. Christoph Ammann

Member of the Government of the Canton of Berne
and Minister for Economic Affairs, Energy and the Environment

Welcome to the Canton of Berne
Bienvenue dans le Canton de Berne
Herzlich willkommen im Kanton Bern
Ladies and Gentlemen

How can we produce our food more sustainably?

This question is extremely complex, and unfortunately there are no simple solutions.

I am pleased to be speaking to you today – to people who accept this challenge. Welcome to the 8th World Congress on Conservation Agriculture here in the Canton of Berne.

I am proud that the Canton of Berne, with its experts from the administration, teaching and research, can contribute to the strengthening and dissemination of a soil-conservation cropping system.

Switzerland, and the Berne region in particular, is predestined to host the World Congress – even if not all participants were able to travel due to the Corona pandemic. The Canton of Berne, with its diverse landscapes and different sizes and types of farms within a very small area, offers the best opportunities for Conservation Agriculture.

Switzerland, and in particular the Canton of Berne, has been researching and testing soil-conservation farming systems for many years. Today, 5 percent of the arable land is cultivated with direct seeding.

Efforts are also being made to introduce a soil-conservation cropping system in organic farming and vegetable growing.

In Switzerland, two of the basic principles of Conservation Agriculture – permanent soil cover and diverse crop rotation – have been legally prescribed since 1997. In the canton of Berne, many methods have been tested, and soil-friendly cropping systems have been promoted with financial incentives since 1993. Bernese agriculture has done pioneering work in this area.

The Online World Congress 2021 in Switzerland is intended to highlight the importance of soil protection. The public and political decision-makers should be made aware of this issue. I am sure that you will succeed in this endeavor.

As Minister of Economic Affaires responsible for agriculture, I am committed to ensuring that the Canton of Berne continues to move ahead in this area. The Canton of Berne will continue to work hard to find solutions for sustainable agriculture.

I would like to thank all those who contribute to this effort. I thank all those who build networks to exchange knowledge, share their results and support each other. I thank all those who have made this World Congress possible. A big thank you.
I wish you all a successful World Congress.

OPENING SESSION

Mr. Christian Hofer

Director, Swiss Federal Office for Agriculture

Dear participants of the Conservation Agriculture congress, dear organizers,

Also, from my side a warmly welcome to you to this outstanding event and many thanks for giving me the opportunity to address a few words to you.

When you think of Switzerland, you probably imagine snow-covered mountains, lush meadows and clear lakes. As diverse as our landscape is, so is our agriculture. Swiss farmers cultivate soils from the flat central plateau on 300 meters above sea level to steep mountain slopes up to 2’500 meters above sea level. They produce crops, fruits and vegetables on about 400’000 hectares, and use pastures either year-round on about 600’000 hectares or only in the summer months on more than 460’000 hectares.

Swiss agriculture is almost completely soil based. We have the advantage that we can produce our agricultural goods on young and very fertile soils. Therefore, we have to take especial care on this precious resource. The sustainable use of soils is even stipulated within the Swiss constitution. Already back in 1996, the Swiss population voted with almost 80 percent in favor of an initiative calling for a multifunctional agriculture. Therefore, Swiss farmers fulfill nowadays far more tasks than solely producing food, as they are also shepherds of our landscapes and our cultural heritage. Within our multifunctional agriculture, farmers ensure the maintenance of many services for our society and are well aware of their responsibility. More than in almost any other country, farmers are constantly under the scrutiny of the society and try to make people aware of the diverse demands on agriculture they have daily to deal with, and to create understanding for their practices.

With only 4 ares of arable land available per inhabitant, the pressure on the most fertile soils is tense. Around 1 square meter of arable land is lost every second in favor of settlements, infrastructure or forestation. In order to preserve the most fertile soils for agricultural cultivation, Switzerland developed a spatial development program almost 30 years ago which was renewed just last year. In this manner, each canton is obliged by law to protect a certain area of highly fertile cropland, based on its size and natural and climatic conditions.

To ensure that also future generations can also utilize soils according to their needs, the federal office for agriculture developed together with the federal offices for environment and for spatial development a national “soil strategy”. This strategy pursues the vision that soil functions shall be conserved permanently and cultivated sustainably. To this end, various goals and paths have been defined that should lead to the preservation of the manifold soil functions. For the agricultural sector, the aims are – among others - the prevention of soil compaction and erosion, and the preservation of soil organic matter and soil biodiversity. As you can see, these are almost the same aims, which are in the focus of Conservation Agriculture.

However, knowledge about Switzerland's soils is still rather poor and very patchy. Therefore, the Federal Council created a center of excellence for soils. This center functions a national hub for soil information and provides all kinds of soil related services to as many user groups as possible. Detailed information on the state of soils and the functions they provide is highly needed on many different levels, from the political decisions makers to our farmers, who are working daily on their soils.

The conditions for Swiss farmers are quite different from the conditions for many other farmers in other countries. As Switzerland consists mainly of small-scaled landscapes and many fields are on rather steep slopes, cultivating the fields is labor-intensive. For these difficult production conditions, the high societal demands on production systems and the difficult economic environment for agriculture – Switzerland is not exactly known to be a cheap country - Swiss farmers are supported by the government with direct payments.

These direct payments are rewarded to farmers for their achievements in preserving the culture landscapes, food production and the responsible use of natural resources. In order to receive these payments, a number of conditions must be fulfilled, including an appropriate soil protection. This obligates farmers to take care of their soils, to maintain a balanced nutrient regime and to plant a broad crop rotation. Additionally, to this mandatory requirements, financial support programs are in place since 2014, which promote the application of soil conserving practices like no-till, strip tillage and mulch tillage. In addressing the conflict of interests between reduced soil tillage and the broad use of herbicides, the financial support is linked to the condition that a certain application rate of herbicides cannot be exceeded. Meanwhile, almost 20% of all Swiss farms participate in this soil conserving program.

Such programs for the sustainable use of agricultural soils are even planned to be extended in future agricultural policies. Additional reward programs will be set up that will stimulate not only reduced soil tillage but also a maximal duration of soil cover and an evenly balanced humus management on the farm level. Together with the already mandatory broad crop rotation, Swiss farmers will thereby be almost completely rewarded for the application of Conservation Agriculture practices.

You see, the sustainable use of soils is not only in the center of farmers daily work but also in the focus of many decision takers, and the resource soil with all its providing functions should be even much more appreciate in the future as it was so far. For this, we need your dedicated work on practices preserving our soils more than ever before, and I hope that we all can learn a lot by the outcomes of this conference. I wish you all very inspiring talks and fruitful discussions, and this not only for the duration of this congress, but also for your ongoing work.

Thank you very much for your efforts!

OPENING SESSION

Mr. Qingfeng Zhang

Chief of Rural Development & Food Security (Agriculture) Thematic Group
Asian Development Bank

Mr. Chair, Vice Chair, and moderator of this session; FAO Director General Mr. Dongyu QU, distinguished speakers, and respected participants; good morning, good afternoon, and good evening depending on where you are.
First of all, I would like to congratulate the organizers for successfully organizing the 8th World Congress on Conservation Agriculture in this difficult time. The theme of 2021 Congress -- **The Future of Farming: Profitable and Sustainable Farming with Conservation Agriculture**, resonates with ADB's strategy 2030 and our escalated focus on supporting our developing member countries (DMCs) for their green, inclusive, resilient recovery.

Asia has made remarkable progress in reducing hunger since the introduction of the Green Revolution in the mid-1960s. But despite that progress, Asia is still home to more than half of the total undernourished people in the world – an estimated 381 million people in 2019. Asia is also one of the most agricultural resource-stressed regions in the world. Agricultural land and water bases are declining, and the agricultural workforce is shrinking. The two-way nexus between agriculture and climate change is intensifying. Against these backgrounds, Conservation Agriculture to prevent losses of arable land while regenerating degraded lands is very important in Asia.

Recognizing the importance of Conservation Agriculture, Asia started to work to promote this but very slowly. A number of factors have hindered the progress, including the mind-set – overcoming the culture of the plough, need for local manufacture of the adapted equipment, lack of extension services throughout the region, and finally competition for crop residues which are sometimes also used as animal feed.

Despite of these difficulties, a number of DMCs in Asia have made good progresses in Conservation Agriculture. Countries like China, India, Pakistan, Bangladesh, Laos, Vietnam, Cambodia, and Philippines are not only very keen to transform their agriculture into a sustainable base, but also have research and extension activities on Conservation Agriculture. Among them, China and India have a significant area already under no-till crops. Up to 2016, Conservation Agriculture systems have been extensively implemented in China to reach an area averaging as much as 8 million ha. It was also reported that India's Conservation Agriculture programme saved USD 164 million with an investment of USD 3.5 million with internal rate of return of 66% which was the highest amongst all the CGIAR programmes. To promote knowledge sharing on Conservation Agriculture, regional networks for Conservation Agriculture for both South Asia and Southeast Asia have been established. These networks aimed at identifying the best practices and promoting the best policies and technologies among these DMCs.

Together with other development partners, ADB has assisted the DMCs in promoting Conservation Agriculture's research & development, knowledge sharing and demonstration. One example project was Dryland Sustainable Agriculture project that ADB had supported since 2009. This project covers 27 counties in Gansu, Henan, and Shandong provinces, and after 6 years, the project has delivered considerable number of outputs in terms of Conservation Agriculture techniques such as returning crop residues to the soil, and also facilities established and farmers engaged, showing promise in achieving its outcome.

ADB has also started to prepare another project in Indonesia with focusing on dryland farming as well. The project design includes soil and water conservation measures, retaining and increasing soil quality. The project will provide selected farmers with soil kit test equipment to independently monitor soil quality, analyze results, and decide on actions to improve fertility. In partnership with the International Rice Research Institute (IRRI), the ADB completed a field demonstration of direct seeding of rice in 2019 in Nepal and Cambodia to disseminate the benefit of minimum and zero tillage to farmers. In Nepal, labor shortage is a major problem in rice production as the primary method of crop establishment is transplanting, which requires a high labor input. The experiment showed direct seeding requiring zero or minimum tillage to reduce the total cost by 30-40%. This generated interests among the policymakers of the country to scale up Conservation Agriculture in the rice-based system of the country. At the field level, it created reliable local individual and institutional champions. Similar findings obtained from field experiments in Cambodia as well.

These are some of the examples of the ADB's initiatives to promote Conservation Agriculture in Asia. We need a lot to do to promote Conservation Agriculture in Asia which is dominated by the rice-based system. As I mentioned in the beginning, the ADB is committed to green, inclusive, and resilient rural recovery from the aftermath of the Covid-19 pandemic. Responsible production with minimum impact on nature, greening of the agricultural value chain with minimum carbon footprint, conservation of biodiversity through natural capital investment are the key priorities for us.

Finally, scaling up Conservation Agriculture in the region requires more profitability in adopting conservation practices and private investment in this area. ADB has established a working group to expand upon experiences in China and the Mekong subregion through a regional natural capital lab. The lab is designed as a living and virtual platform to incubate, accelerate, and expand natural capital investment, which will prioritize the support for greening of the agriculture value chain in developing Asia. The lab will leverage existing accounting tools to quantify the ecosystem service value of green agricultural value chains, strengthen eco-compensation or payments for ecological services to incentivize behavior change among small farmers, and establish a financial facility to convert ecosystem value or assets into the revenue model of agribusiness.

The lab will act as an enabler for blended financing to promote green, inclusive, and resilient solutions to build sustainable food system. I will invite you to join in this initiative which can potentially contribute to Conservation Agriculture.

I would conclude again thanking the organizers for organizing this very important and timely congress. Looking forward to a very interactive and useful discussions leading to pragmatic solutions to promote Conservation Agriculture.

Thank you all.

OPENING SESSION

Mr. Martin Kropff

Director General of the International Maize and Wheat Improvement Center – CIMMYT
Global Science Director for One CGIAR's Resilient Agri-food Systems science area

Colleagues,
It is wonderful to be part of the *8th World Congress on Conservation Agriculture*.
My name is Martin Kropff and I am the Director General of the International Maize and Wheat Improvement Center – CIMMYT – and the Global Science Director for One CGIAR's Resilient Agri-food Systems science area.

Across the CGIAR, many scientists already engage in Conservation Agriculture and I am happy to be here today to shed light on some of CIMMYT's success stories.

We all know that if not practiced sustainably, agriculture can have a toll on the environment.

It can introduce an unsustainable use of agro-chemicals. New insects and pathogens may become a serious problem and it reduces and alters wildlife habitats. Agriculture also contributes to greenhouse gas emissions linked to climate change. Regenerative and nature friendly farming methods such as applied in Conservation Agriculture (CA) can help to combat these impacts and boost farmers' incomes.

Around CA, conducive decision making and business environment can create better income opportunities for entrepreneurs and innovators. It is not just a cost-cutting and resource-conserving concept. It is a strategy to address present and future challenges and reap opportunities in agriculture.

Over time, CIMMYT's research has moved from a plot to a landscape approach.
We consider the 3 principles of CA, minimum tillage, soil cover and diversification the base for the construction of an efficient and resilient production system. But we know that we need to go beyond those. We need to include precision, data driven, geo-spatial and digital agronomy inputs, as well as foresight and targeting and business models for scaling to generate real transformation of the agri-food system. The key for me is that we use science and evidence-based approaches in improving agricultural systems toward resilient livelihoods.

I would like to share a couple examples from our work and link them back to why CA is an excellent opportunity to address present and future challenges in agriculture.

CA methods can help to increase resilience to climate change.
For example, for maize, drought stress and extreme temperatures work together to reduce yields. Drought reduces the crop's ability to cope with excessive heat and, according to projections, this will only get worse.

I would like to share an example from our work in Africa.

Over 14 seasons and across 10 communities in Malawi, we tested if changes in crop management – based on CA – could make cropping systems more adaptive to climate stress. And indeed yes: results showed that by using stress-tolerant maize varieties, embedded in Conservation Agriculture that uses legume rotation, stover retention and minimum tillage, some of the negative yield effects of heat and drought stress were reduced.

The same thing is happening in Latin America.

Mexico is currently going through one of the worst droughts in decades. This will only become more frequent due to climate change.

In the summer of 2020, in our headquarters close to Mexico City, we experienced only two thirds of the usual rainfall. In those conditions, CA yielded twice as much maize grain than the conventional practice including tillage, monoculture and residue removal (5.6 t/ha vs 2.2 t/ha). For wheat the difference was even bigger. Wheat yields were four times bigger in Conservation Agriculture than when conventional practices were used (5.1 t/ha vs 1.3 t/ha).

CA methods can help to protect biodiversity. Let me tell you about our work on fighting the Fall Armyworm.
Fall Armyworm is an insect-pest native to the Americas and several years ago it began its march across the globe, eating everything in sight. Unfortunately, maize is one of its favorite foods.

CIMMYT and partners have studied ways to battle Fall Armyworm. In December 2020, we released 3 Fall Armyworm-tolerant elite maize hybrids for eastern and southern Africa. Currently, the varieties are undergoing the process of national performance trials across 14 African countries. The plan is to distribute these seeds to farmers in 2021.

But seeds *alone* won't increase farmers' yields.

You also need good agronomic practices such as the integration of legumes in climate-adapted push pull systems which will make CA systems a strong ecological response and solution against Fall Armyworm that is accessible to farmers.

In Zimbabwe, we integrated seeds with CA and the best diversification strategies adapted to the environment. By doing this, we experienced significant reductions in Fall Armyworm due to ecological control by ants and other predators. *Again*, this type of system is important because farmers often cannot afford to buy or access crop protection chemicals and, plus, they may pose risks to the environment and the farmers themselves.

In Mexico, where Fall Armyworm is native, we are integrating agroecological pest management into our work with farmers to address the pest, together with our national counterpart, INIFAP.

Fall Armyworm sex pheromones were first used to monitor populations to understand insecticide application needs and are now used for massive capture and mating disruption. Through capacity building with farmers and extension agents, we succeeded in reducing the application of broad spectrum or highly toxic insecticides. In fields in CIMMYT's projects, we went from 90% of registered insecticide applications in 2012 down to 40% in 2019.

CA methods sustainably use natural resources and improve incomes.
CA reduces soil erosion, improves soil water retention and nutrient availability for crops and gradually increases soil organic matter accumulation. While these are fantastic biophysical benefits, what convinces farmers to integrate CA in their fields is the fact that it reduces the *costs of production* and ultimately raises their incomes.

For many years, CIMMYT has worked with partners to transform the African landscape from manual to mechanized. It is super important to transform smallholder farming systems through small scale mechanization tools like 2-wheel tractors. Just recently, the Permanent Secretary in the Ministry of Agriculture in Zimbabwe initiated a new Strategic Alliance with CIMMYT and the private sector to out-scale access to mechanized Conservation Agriculture to a million of smallholder farmers by 2025. This will not only help to reduce drudgery of farming but create new business opportunities for women and youth.

Let's look at an example from Asia.

The rice-wheat rotation of the Indo-Gangetic plains is South Asia's food bowl, but it is becoming unsustainable. If status quo persists, the region will face complex agricultural sustainability challenges and implications on human health. All of this because of air pollution resulting to crop residue burning, inefficient water and agro-chemical uses.

Integrating CA with adapted varieties has shown tremendous potential for resource conservation, adapting to climatic risks, reducing greenhouse gases and increasing yield and farmers' incomes across the Indo-Gangetic plains.

Our work with partners in West Bengal has seen integration of various CA implements become compulsory in any government-supported custom hire center which is seeing substantial leaps in uptake across the state.

In India, by using a tractor attachment called the Happy Seeder instead of conventional tillage tools, farmers are making 20% more profit while applying less fertilizer and less water with significant reduction in greenhouse gases.

How does it work? The Happy Seeder cuts and lifts rice straw, sows wheat into the soil, and deposits the straw over the sown area as mulch with little disturbance to the underlying soil. This eliminates the need to burn straw residue thus removing the main source for air pollution in parts of India where the air quality level is 20 times higher than the safe threshold defined by the World Health Organization.

Given the depletion of aquifers and labor shortages, the development of direct seeding technologies is leading to increased investments and adoption of direct-seeded rice. This is a win for the farmers *and* the environment.

Recent work has also highlighted how CA is linked with improved gendered outcomes and livelihoods in South Asia, with women often benefiting more in terms of time saving than their male counterparts. They are able to use that time differently. Some women chose to use it for household responsibilities or further diversifying their agricultural production and non-farm activities. This is beneficial to their food, nutritional and economic security, as well as links to potential improved educational outcomes for their children.

In conclusion, challenges still remain for the widespread adoption of new methods and techniques to make farming systems more sustainable. Because of this, we need to work on the socio-economic interface with farmers and at the policy level. There is no one silver bullet for making farming more sustainable. But as we will hear throughout this conference, it is not a choice. We must increase food production and we cannot allow agriculture to continue to destroy the environment and the natural resources we depend on.

The development and use of agroecological approaches, as I call them, based on biological scientific evidence, is not only a smart investment for people and nature – it is an *imperative* for sustainably feeding the anticipated global population of 9.1 billion by 2050.

But there is much we still need to know.

There are considerable knowledge gaps that need investment, collective efforts, and joint research:

- Suitable and profitable crop diversification options for a variety of cropping systems that can sustain healthy diets
- Residue retention – the processes in the soil and its real potential for climate mitigation under tropical and sub-tropical conditions
- Soil health dynamics when changing from conventional tillage to Conservation Agriculture (bacteria, mycorrhiza fungi, etc.)
- The role of intercropping systems in the suppression of pests and diseases and in offering financial entry points for short term benefits
- Integration of green manure cover crops into smallholder farming systems and its integration with livestock
- Weed management and the reduction of herbicide dependency in CA because no till results in more weed pressure; factors affecting the feasibility, profitability and viability of weed management practices
- Smallholder mechanization and developing successful and viable business models for scaling.
- Nutrient management and the management of organic inputs.

I hope that together we can work on finding answers and filling knowledge gaps and scaling of technologies that are based on scientific evidence together with our stakeholders, in the first place the farmers!

Thank you for your attention and I wish you a successful 8th World Congress on Conservation Agriculture!

OPENING SESSION

Ms. Mary Boote

Global Farmer Network

Good morning,

I bring greetings to you from the Global Farmer Network, who I serve as CEO. Currently comprised of 207 farmers hailing from 60 countries, 6 continents, the farmers who ARE the GFN are committed to a mission of "amplifying the farmers' voice in promoting trade, technology, sustainable farming, economic growth, and food security".

I would have enjoyed being with you in person. In the past 16 months, we have all experienced unexpected challenges, regardless of where we live, including a need to adapt and learn how to communicate with each other differently.

For an audience focused on using technology and strategies for the benefit of society and the environment, the ability to use technology to speak with you today is humbling and another example of how it can be used to share knowledge, support, connect, and encourage. Thank you to the delegation leadership for allowing me to connect with you in this manner.

Your theme: The Future of Farming – Profitable and Sustainable Farming with Conservation Agriculture lays out very succinctly the challenge and opportunity in front of us. We know that profitable and sustainable are reachable goals that can be achieved in tandem. The data to support that truth is available. The **challenge** before all of us is to make the case, share the information, support agriculturalists globally and work together. Collaboration is an imperative. As I look at today's agenda, I see an important session highlighting the farmer's role, followed by one focused on private sector innovation and engagement, to one that discusses the enabling role those public institutions play and followed by a session that is focused on civil society contributions. All very important in their own right. To drive action – collaboration between all is necessary.

Global Dialogues

Today, discussions regarding what a resilient global food and agriculture system looks like and how it should operate are being held on global and regional platforms from the UN and the Food Systems Summit to the EU Commission and its discussions around the Green Deal to the United States where President Biden, focused on climate change, endorsed cover crops in his State of the Union Address this past February to Africa, India, Latin America and SE Asia where the challenges of climate, pest, disease and policies are the focus of governments, NGOS, public and civil society, we have the opportunity – the responsibility - to speak up, reframe and foster constructive global dialogue.

Farmers are leading the way

One of the silver-linings uncovered by the global pandemic was the determination by every country in the world that agriculture is an essential industry. In addition to allowing the continuation of agriculture production without pause, it has provided farmers a unique window of opportunity to talk about what you are doing and why. Explaining that a farmer's basic duty is to protect the soil – not because the government tells them to – but because the economic, environmental, and social sustainability of his farm demands it. Farmers are leading the way in food production, protection of the soil, preservation of biodiversity, and meeting the global challenges of climate change. Their experience and practical expertise are needed to bring a sense of reality to policies discussed and created a long way from the field, in an ever-increasing virtual world.

People who are not engaged in farming often lose sight of this important fact. We, in this room, know that farmers are innovators who are applying technologies to the challenges of this moment in time. Conservation Agriculture is a tool that supports and is foundational to our joint efforts to build and maintain a science-based resilient, sustainable global food system. Unfortunately, the true results of Conservation Agriculture are invisible to many. You have to dig down- literally – to see evidence that Conservation Agriculture combined with other technologies and practices is improving soil health, nutrient cycling and water efficiency, storing carbon and as one of the GFN farmers from Iowa stated recently – "I'm growing more livestock under the soil than on top of it these days!" For many, this has required new thinking and conscientious planning. And as farmers, researchers, policy leaders and more in the Conservation Agriculture space, you have a positive story to tell about the role you are playing, together.

Exporting Knowledge

Global meetings like this Congress serve an important purpose – bringing together all stakeholders in the Conservation Agriculture sphere to share information, exchange ideas, develop new concepts, encourage, support, become re-engaged and for many of us, re-inspired to do more.

One of our Argentinian farmers and an Aapresid member shared a concept with me that I think bears repeating for this important audience: "Nobody knows more than we all know together". The positive impact driven by Conservation Agriculture is exponentially increased when that knowledge is exported. Farming is different everywhere but many of you have observed or benefitted directly from putting to use information others have shared, adapting to fit local conditions. In a world with a growing population and rising environmental pressures, sharing the strategy, techniques and technology of Conservation Agriculture to areas of the world under additional stress like Africa and India – have never been more important. Sharing not just the winning results but also the mistakes made – lessons learned – so they don't have to be made again. The exchange of information and experiences makes everyone better and our world enriched.

The power of collaboration

In January 2021, entrepreneur Elon Musk, the visionary talent behind Tesla, tweeted that his foundation would give $100 million for a break-through in carbon capture technology. On Earth Day 2021, the details for Musk's Carbon XPrize were released, offering an award for the creation of a technology that would annually remove 10 gigatons of carbon from the atmosphere and store it in the ground by 2050. Climate change and the challenges it is presenting around the world concerns Mr. Musk – it concerns all of us.

As participants in this World Congress for Conservation Agriculture, we know, that in addition to building soil health, retaining moisture and nutrients, boosting yields, and ultimately increasing a farms resilience, the impact of Conservation Agriculture is turning fields into factories of carbon sequestration.

A single farm using Conservation Agriculture cannot solve the challenge of climate change but imagine what is possible if all of the farms of the world were to work together. Farmers' every day actions are uniquely important, and as a collaborative force, they are a force for good. When you see and share with the world that part of the solution to our building and maintaining a sustainable, resilient global food system while dealing with the challenge of climate change, is below our feet, the power of Conservation Agriculture can be a game changer.

I appreciate the opportunity to address you this morning and look forward to joining you in person soon. I wish you a successful and impactful Congress focused on sharing information with each other, learning, encouraging, and laying out a future of farming that is truly profitable and sustainable for all.

Thank you.

The future of farming
Profitable and Sustainable Farming
with Conservation Agriculture

8 WCCA
8th World Congress on
Conservation
Agriculture

INAUGURAL SPEECH
BENEFITS OF CA FOR FARMERS, SOCIETY AND ENVIRONMENT

Prof. Amir Kassam

Moderator, Global Conservation Agriculture Community of Practice (CA-CoP),
amirkassam786@googlemail.com

Friends,...

This is an historic day for the CA movement. It was twenty years ago that ECAF, the European Conservation Agriculture Federation, organized the First World Congress on Conservation Agriculture in partnership with FAO. Today, thanks to continued support from FAO and ECAF as well as other sponsors and especially SWISS NO-TILL, we are gathered together here in Bern and all around the world to celebrate our success as the drivers of the biggest farming revolution to have occurred in our lifetimes.

Let us celebrate our joint engagement and contribution to transforming farming from being the main source of land degradation globally, to becoming a driving force for conserving and rebuilding healthy soils and agroecosystems so that they can sustainably meet the world's future needs for food and other farm products while helping to slow the pace of climate change and ecological breakdown. Let us celebrate our part in the transformation of farming, from being a contributor to the many interconnected crises facing the world, to being a key part of the solution.

It is no exaggeration to claim that our achievement in engaging millions of farmers across every continent in what has become known as Conservation Agriculture –or CA– has been a massive game-changer.

We can and should take great pride in all we have done but we still face huge challenges to complete our revolution so that what we have pioneered is steadily improved and becomes the global norm in farming. Our task during these 3 days on-line, and in the field days, is to shape the future directions in which we need to move together to achieve this in the shortest possible time. For this, we must apply lessons from our collective experience over the past 50 years or so.

We have come this far because of the foresight and determination of some remarkable visionaries and pioneers –mostly farmers– in the USA, South America, Asia, Africa, Europe and Australia. These pioneers saw that conventional tillage, involving frequent inversion of the topsoil, was damaging the structure of soils, reducing their organic matter content, and making them susceptible to erosion by wind and water. They showed us that we could grow productive crops without digging or ploughing, and they devoted their lives to improving CA technologies and sharing them with others in their own countries and beyond.

Rather than list these pioneers by name, I invite each of you to think back to the beginnings of CA in your own country and to reflect on the exceptional people who challenged conventional wisdom and put their ploughs aside.

One of the most notable of the early CA pioneers in the Global South was Dr. Herbert Bartz who sadly died recently. In 1972, with encouragement from Rolf Derpsch from GTZ, he became the first Brazilian farmer to throw away his plough. From then on, he devoted his life to improving CA techniques and promoting CA in Brazil and globally. Now, Brazil has become a leading CA nation with 43 million ha – or nearly 80% of its annual cropland - under various forms of no-till agriculture.

Herbert was hoping to be with us today and had prepared a brief video message to inspire us to follow in his footsteps. I am delighted that his daughter, Marie, has joined us in this Congress, and she will have more to say abou t her father this evening at the Social event where she will be showing the video.

I invite you to watch another video now which Herbert made not long ago for a CA Congress in Africa.

https://www.dropbox.com/s/7sy1hu5kfv54q3m/chamada%20herbert%20bartz-v2.mp4?dl=0

Let me now briefly touch on our achievements.

When the pioneers of No-Till said that good crops could be grown without digging or ploughing, most farmers laughed in disbelief and dismissed them as dreamers. Now, just half a century later, millions of farmers all over the world have taken them seriously. They have embarked voluntarily on all kinds of CA systems, no longer carrying out any tillage on their farms.

The global area farmed using CA systems has risen from less than 1 million ha in 8 countries in 1970 to 205 million ha in 102 countries in 2019. This is 15% of the world's cropland area. In Argentina, Australia, Brazil, Canada, Paraguay, South Africa, Uruguay and the USA, CA methods are applied on more than half their cropped area.

From 1990 to 2009, the CA area globally increased at an average annual rate of 5.2 million ha, reaching about 100 million ha in 2008. From then on until now, the CA area expanded at double that rate, attaining an average of 10.5 million ha per year. This was largely because the global CA Community of Practice (CA-CoP) was established in 2008, with its own communication and networking platform, and began to globalize CA through the farmer-led CA movement worldwide.

The CA-CoP, of which I am Moderator, is a fast-growing open-ended community in which any person or institution interested in CA is welcome. While its network and mailing lists extend its reach, it has no list of members, no membership fees, no hierarchical structure and no officers with executive powers. It is glued together by its adherents' commitment to farming without soil tillage, their natural inclination to innovate and their enthusiasm to share their experiences. This has led to the formation of many local CA groups which, in turn, are linked to regional groups in regular contact with the Moderator.

With the valuable patronage of FAO and much goodwill and support from other international entities, the Global CA-CoP has come to play an important catalytic and facilitating role, including the promotion of regional programmes and national activities, sharing experiences, making information, especially on innovations, widely accessible, and engaging donors and financing agencies in funding local CA programmes.

All of this has been done with the intent that farmers remain in the driving seat. The triennial Congresses provide the opportunity for all interested parties to take stock of progress, to share experiences and ideas, and to chart the future directions in which the Community will seek to move.

This has clearly succeeded! CA is now practiced in all major climate zones in which there is farmed land – from the warm humid tropics to the cool temperate areas. And it is applied in all the world's main farming systems. It has taken hold in rainfed and irrigated areas, short-term and perennial crops, mixed crop-animal farms and organic systems. It has been adopted by large-scale mechanised farms and by smaller farms where most of the work is manual.

CA has also evolved into a wide range of complex farming systems which make the most of the improved soil conditions created by the absence of tillage.

But in spite of all of this, our movement remains vulnerable to possible changes in the governance of our global food system.

A surprising threat could come from transnational corporations, convened by the World Economic Forum in Davos, which have declared a 4th industrial revolution. This would be based on harnessing 'big data' to tell every farmer what to grow and when to plant, and to manipulate consumers' food choices. While they claim that this will cure the ills of the global food governance system, I feel bound to ask: Will this address degradation of our common resources and the planet? Will this meet the needs of small-scale farmers and protect their seed, land and food sovereignty? Will this change our food distribution system to a more equitable one that would eliminate hunger and lead us to healthier diets?

In raising these questions, I am not denying that there are many valuable opportunities for widening the use of digital tools to empower farmers and consumers to make better choices – but without infringing on their rights to make their own decisions.

The reality is that we are the great farming revolutionaries of our time for large- and small-scale farmers. Together, by translating our knowledge and convictions into practical action on the ground, we are leading the most transformational revolution in how land is farmed since the inversion plough was invented in the mid-17th century. We have successfully challenged the universally held assumption that most land has to be regularly and intensively tilled and chemicalized to be productive and profitable. We are also proving that the widely held view that smallholders have no future is nonsense.

We do this because we believe in it, based on the evidence generated by the early no-till farmers. Nobody has had to order us to stop ploughing and digging and nobody has had to pay us to change our ways!

Farmers are the initiators and drivers of the CA movement, its main innovators, and its main promoters. Their success, including spreading and adapting CA into new ecologies and farming systems, has led to the growing involvement of scientists and created a demand for specialised equipment and inputs that has expanded the participation of the private sector in our revolution.

The main motivation for farmers' engagement has been CA's potential for net gains in productivity and incomes. By eliminating tillage, larger farmers have cut spending on farm machinery, inputs and fuel, while small-scale farmers have not only made big savings in time and human energy from excluding deep hand-digging, but they have also found that they can move into CA with few purchased inputs and rely on their own seeds.

Formal research systems have become increasingly engaged in comparing the impacts of different CA interventions especially on soil structure and biology, moisture retention, carbon sequestration and pesticide-free weed and pest-management. There is now a huge raft of easily accessible scientific studies on almost every dimension of CA applications. Thanks to the expanding databases of CA networks, FAO and Cornell University, information is easily accessible on almost every dimension of CA in text-books, and in scientific and technical studies. In future, however, researchers and farmers must do much more to team up in generating new CA systems knowledge.

One feature of CA is that its adoption and spread does not follow traditional linear agricultural extension models that transfer the findings of researchers to farmers. Instead, farmers themselves play the major role in innovation through CA Farmer Associations, Farmer Field Schools, Clubs and Networks as well as through community engagement. These social institutions offer opportunities for sharing knowledge and for cultivating solidarity that stimulate change and self-empowerment. This works effectively for all farmers when their skills, and needs for seed, land and food sovereignty are respected and supported by governments and stakeholders in the public and private sectors.

True, the private sector has responded well to demand especially for machinery and inputs, but in many places, CA farmers call the shots and the private sector has to offer a mutually beneficial service support along the value chain.

We are pushing ahead with CA and improving it as we go, mainly because we have found our incomes rising and the quality of our farmland improving.

CA differs from the dominant ‘industrial’ approaches to tillage farming that have been driven by the goal of ever greater intensification, aimed at maximising yields. They use more and more inputs and need ever bigger investments. Over time, they all too often damage or destroy the soils and environment that provide the foundations for food production and environmental or ecosystem services, and also put human health at risk of nutritional disorders.

In spite of CA’s rapid spread, tillage-based agricultural intensification continues to cause vast physical and biological soil degradation and erosion, forcing the abandonment of once productive agricultural lands, increasing the frequency of flood damage, polluting our environment with toxic chemicals, releasing high levels of greenhouse gases, wiping out biodiversity, and reducing adaptability and resilience to biotic and abiotic stresses as well as fostering resistance to antibiotics.
It seems to come naturally nowadays for humans, at least in so-called ‘developed countries’, to think that more is better. We now realise that satisfying the desire for more and more material things without considering their environmental impact is putting at risk the future of our children and grandchildren, and of all those with whom we share the planet.

CA’s success comes from deliberately moving in exactly the opposite direction. We are getting more from less and bequeathing a healthier planet to future generations. We have already shown the ability of CA’s core practices of no-till, soil mulching and crop diversification to provide an effective foundation for integrated biological pest management and for drastically reducing agrochemical use. We have also shown in several environments with smallholders and large-scale farmers the avoidance of the use of pesticides for controlling weeds, insects and pathogens through for example Push-Pull strategies, techniques of planting green involving green manure cover crop mixtures, and manipulation of soil fungi-to-bacteria ratios. And many smallholder farmers are practicing CA without the use of any agrochemicals. This is why FAO placed CA at the core of their ‘Save and Grow’ global strategy for sustainable production intensification.

CA is good for all farmers, good for the land, good for the planet and good for people.

Let us now look to the future of CA

There is no doubt that CA is a success story that is here to stay and that it will continue to grow fast. But what about our expectations for the outcomes of this Congress?

The organizers of the Congress are convinced that CA must be the mainstay of the shift that the world has to make urgently towards sustainable farming and food systems. This is because we know that, for as long as most soils continue to be damaged by tillage, the world cannot reach the goal of making food systems sustainable.

But we also recognise that some aspects of No-Till systems, as they are now generally practiced, are restricting sustainability. Specifically, some No-Till systems with poor cropping diversity still remain too dependent on pesticides (especially herbicides), on mineral nitrogen fertilizers, and on unduly heavy farm machinery driven by fossil fuels.

I am sure that you will all agree that this has to change.

Within our global Community there are many precedents for moves in the right directions, but we need to throw our weight behind accelerating their enhancement and uptake, so that CA becomes synonymous with sustainable farming for the future.

We also know that we cannot go it alone. We must engage globally and locally with the champions of other essential elements of sustainable farming, especially those engaged in organic farming, integrated pest management, agroecology and regenerative farming systems in their various guises. In return, all these farming systems can be helped to harness CA principles and practices. If we do not share our experiences, help each other and pull together, many of the international Sustainable Development Goals – the SDGs – relating to food, natural resources management and climate change will be unattainable. We also have an important role to play in the recently launched UN Decade on Ecosystem Restoration 2021-2030.

I also suggest for your consideration that the time may have come for our Community to begin to help to shape food consumption patterns in ways that will relieve pressure on the world's finite area of cultivable land rather than destroy forests and other vulnerable ecologies to expand farmed land, with doubly negative effects on the rate of climate change. Fortunately, we are faced with a win-win-win opportunity, as the area under farming can be greatly reduced, environmental damage curbed and human health improved by inducing a shift towards predominantly plant-based diets: this, in turn, would cut demand for livestock feeds which has been a main driver of the recent damaging expansion in cropped areas especially in tropical regions.

It is against this background that I suggest that this Congress may wish to signal its support for a notional goal of having good quality CA-based systems fully applied on at least 50% of the world's annual cropland area or 700 million ha by 2050.

I believe this is an attainable goal given that the global CA movement doubled the rate of uptake of CA during the last decade. The big challenge will be to graft the other essential elements of sustainable farming into all our programmes – including those in the existing 200 million ha already applying CA.

Achieving this goal would require a massive boost to the momentum of our Community's activities with a concentration on the following six themes:

1. Catalysing the formation of additional farmer-run CA groups in countries and regions in which they do not yet exist and enabling all groups to accelerate CA adoption and enhancement.
2. Greatly speeding up the invention and mainstreaming of a growing array of truly sustainable CA-based technologies, including through engaging with other movements committed to sustainable farming.
3. Embedding the CA Community in the main global efforts to shift to sustainable food management and governance systems and replicating the arrangements 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 CA programme expansion.
6. Building global public awareness of the steps being taken by our CA Community to make food production and consumption sustainable.

To move forward with this, strengthening of the Moderator capacity within the CA Community is now needed. Much thought must still to be given to this, but one thing is clear: we must retain the concept that, as now, our future actions must be guided mainly by a growing team of volunteers coming from within our midst who are committed to giving their expertise, time and energy to enhancing and spreading CA systems.

Earlier, I paid tribute to our pioneers and champions. With millions of farmers now applying CA in its many variants across the world, I feel confident that plenty of people will signal their willingness to dedicate themselves to moving our activities forward.

One of the few positive by-products of the COVID pandemic is that it has stimulated great advances in information and communications technology. We are applying some of these in this largely virtual Congress. Any new actions need to take the fullest possible advantage of these innovations. One important implication is that all those involved in any new programme moderation arrangements can make most of their inputs from where they live.

Of equal significance is the huge opportunity that these technologies offer for accelerating the spread of advances in knowledge across our Community and beyond. The Community's strength has been built on farmer-to-farmer sharing of experience, usually within their own localities and sometimes through country exchange visits. Now these farmer-to-farmer exchanges can instantaneously become global.

And so, we shall nurture the emergence of a stronger moderating mechanism that will function almost entirely virtually. It would enjoy the guidance of an advisory panel, representing regional and national interests and those of cooperating institutions. It would have the capacity and power to set up task forces to push forwards on each of the 6 main themes – and any more that might be added. And it would need to have a permanent IT systems development and operating capacity. It would also oversee and support future processes for convening CA World Congresses. Finally, it would have to be set up as an entity – perhaps as a non-profit organisation -- with sound financial management, programme monitoring and reporting capacities.

Finally, though this may seem a minor issue, I also propose that we convene a small working group to set up arrangements for honouring our pioneers through creat-

ing a CA Hall-of-Fame in time for the 9th Congress.
To get started immediately on this expanded agenda, ECAF has generously agreed that elements of the Congress Secretariat can continue to assist the Moderator in moving ahead with these new arrangements. I hope that we can also continue to benefit from the patronage offered by FAO since our work began.

I am confident that this Congress will, like earlier ones, give a great boost to our efforts and set the stage for a very bright future – a future in which our Community will play a hugely important part in the race to make the world's food systems properly sustainable.

Thank you all for joining us at this challenging moment in our history.

My very best wishes to you all for a truly inspiring Congress.

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FARMERS´ ROLE IN MAINSTREAMING CA WORLDWIDE

Mr. Kofi Boa

Farmer

Farmers, big or small are the exhibitors of the real value of CA and so for the technology to attract the attention of all other groups of people, we farmers must assume the role of the protagonists and play the advocacy role.

Come to think of it this way. How many agricultural researchers are farmers themselves and are applying their own recommendations at scale? And how many agricultural extension officers out there are also farmers farming themselves? Majority of them are mostly people who are doing research and extension as a means of earning a salary and especially in most developing countries, they continue to enjoy salaries and fringe benefits whether the soils are still eroding or not. They only provide knowledge and guidance to keep our CA candles burning.

The realization is that, it is the one who has seen the light and carrying the light around that can lead other people out of darkness and so those of us farmers who either by dint of tragedy, by trial and error or out of perseverance that have seen the real value of CA should without any reservation, be the ones to show up the worth of CA to the whole world for we will never ever sound convincing enough and win the attraction of the world if we have nothing visible to show.

When we commit ourselves to exhibit CA in terms of its impacts on our food systems, on our health and other ecosystem services we will surely attract the attention of everybody and therefore push CA to the heights. We at the CNTA are doing this, Gabe Brown is doing it and farmers in Brazil, Argentina and elsewhere are doing it. AND what about you my dear CA farmer?

We need to come together and encourage knowledge sharing and exhibition of the benefits and evidence of CA not just at big sessions like the WCCA, ACCA and others but right from the community level to start blowing the horn. More so in Africa, it is at that level where the bulk of the food is produced and so if you are out there thinking that you are not a farmer and therefore you don’t care much about what happens on the farmland, farmers will in the first place lose their job and, in the end, everybody including you will die out of hunger.

CA is helping to build healthy soils to support the growth of healthy plants to produce abundant food to feed healthy people like all of us at this congress so no matter what you do for a living, help us the farmers to push our governments all over the world to institutionalize CA in national agricultural systems because no single nation can do it and think that it is safe.

The shift to CA will require not just value-aligned capital but also technical expertise and partnership especially for the growth-stage CA farmers and related companies. These will be the drivers to move the CA train from the North to the South and from the East to the West for the benefit of mankind and society.

Thank you

PRIVATE SECTOR INNOVATIONS & ENGAGEMENT FOR CA DEVELOPMENT

Mr. Juan González Valero

Head Sustainable and Responsible Business, Syngenta Group

Syngenta has always invested significantly in biodiversity and soil health. In 2013 the company began a major global programme of investment into innovation for sustainable farming. 2019 saw a move to seek more specific approaches to enhance farmer innovation and uptake, seeking increased farm productivity and sustainability.

Major investment areas in this programme are:

- Soil health, based on bio-stimulants, to improve nutrient uptake, plant stress resilience and water-use efficiency.
- Nutrient efficiency
- Root health development through genetics and seed dressing

Syngenta continues its major long-term commitments and co-operation in Europe on biodiversity and sustainability but has also committed an investment of 2 billion euros over the next 5 years to global programmes. One example of their large-scale field programme, called Reverte, is in the Cerrados of Brazil. This aims to recuperate I million hectares of degraded soils via integrated cropping and livestock.

The Syngenta Resource Efficiency Programme aims to improve biodiversity monitoring with emphasis on:

- Indicators and sensors and to make these technologies more precise and available to a wider range of users to improve productivity and facilitate scale-up.
- New molecules and biological compounds to meet challenges and replace old technologies.
- Precision application of crop protection products and precision seeding and new genetic material.

Current policy is to continue to invest heavily in research and development in the above areas to assist the performance and adoption of improved farming systems and support Conservation Agriculture.

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CIVIL SOCIETY CONTRIBUTIONS TO SCALING CA

Mr. David Traynor

Concern Worldwide

Who are Concern Worldwide?

- Concern founded in 1968 in response to the Biafra crisis in Nigeria, has since grown with Concern working in 27 countries, and has a dual humanitarian and development mandate.
- These are either impacted by protracted humanitarian crises, and/or in the bottom 40 of the HDI.
- Concern launched its new strategic plan and involves responding to the climate, conflict and hunger crises in the poorest and most fragile contexts.
- With regards to Concern's Livelihoods programmes, they focus on livelihoods security for vulnerable households affected by disasters and shocks and extreme poor with both hunger and nutrition outcomes.

Why should an CSO do Conservation Agriculture?

- Many of the countries Concern works in are extremely fragile and are located in regions that have been disproportionately impacted by climate change. Four of these countries are in the Sahel, including Burkina Faso, Niger, Chad and Sudan.
- There have been major disasters in the Sahel, including escalation of conflict in Burkina Faso and Niger, prolong dry periods, erratic rainfall patterns. However, many of these "major disasters" often distract from the small shocks that smallholder farmers in the Sahel that rely almost exclusively on agriculture or livestock for their livelihoods, experience day to day.
- The Sahel is an extremely vulnerable agro-ecology.
- In the Sahel, insufficient or late rains, soil erosion, deforestation and degraded soil, pest and disease outbreaks can affect the performance of crops. Smallholders lack the means to purchase agricultural inputs, hire labour to prepare land and face inequality barriers based on gender, ethnicity, etc to build livelihoods.
- As Concern works in some of the most fragile countries, the state may lack the resources to provide sufficient extension and training services.
- This is where a civil society organisation such as an international or national NGO to a community group can fill these gaps. Concern has had Conservation Agriculture as its key element in its food security and livelihoods programmes throughout the Sahel.

How do we do it?

- In the Sahel, farming practices have been adapted to the semi-arid agro-ecologies over centuries and hence it is vital that local knowledge is incorporated when planning extension. Concern has used the lead farmer approach as a peer-to-peer extension method.
- This involves training female and male farmers selected by communities based on criteria such as having a good knowledge in farming, being able to teach others and having resources to take risks in new approaches.
- Lead farmers are then grouped with student farmers who are selected based on community-defined criteria, such as being from extreme poor socio-economic groups, more than three children under five, children enrolled in a malnutrition treatment programme, female headed households, vulnerable households caring for elderly, disabled, etc.
- A lead farmer is trained by Concern in the three principles of Conservation Agriculture, many of these such as *zai* holes or tools such as *hilaire* that can be used for minimum tillage have been used for centuries.
- Often the local state extension agencies has been contracted to provide the training to create a link with farmers and these services. These trainings are best done in a field nearest to the villages that reflect the local agro-ecologies rather than a demo plot in an extension centre that can be a more sanitised field with good fertility and free of pests and diseases.
- Follow-up after trainings is essential, using staff from the area who have good connections with local authorities and customary leaders for acceptance of the NGO. Recognising indigenous farming methods adapted to the Sahel is essential to support integrating with more improved Conservation Agriculture practices.
- In Niger, Chad and Sudan, we focus on smallholders famers and I think we can see that Conservation Agriculture provide very significant results in a context where yields.
- Conservation Agriculture by its nature, requires less inputs, less labour and can have impacts on protecting soil ecosystems.
- Civil society also need to consider other areas as well with Conservation Agriculture, such as:
    1. Environmental regeneration.
    2. Gender (addressing the barriers to livelihoods improvement).
    3. Protection (safety of female and male farmers in fragile contexts).
    4. Nutrition and health (preventing malnutrition and disease).
    5. water, sanitation and hygiene promotion (reducing disease and improving irrigation).

This is to have the maximum impacts for resilience of poor and vulnerable households.

What can we do after we finish our work?

- In many of the more fragile contexts, sustainability can be compromised by lack of extension services once the NGO finishes the programme.
- This is where an alternative is needed, and can involve supporting producer groups, farmers groups or federations and other grassroots community groups who can develop Conservation Agriculture techniques through trials in something like a Farmer Field School.
- Concern has been focusing on smallholders famers and I think we can see that Conservation Agriculture provide very significant impacts in the Sahel. I think there is a need for more evidence in terms of results and to study how far Conservation Agriculture can reach (communication channels, dissemination techniques, etc.) the most vulnerable households in an effective and efficient way.
- We also need to look at specific groups, such how it enables women and men and marginalised smallholders in the Sahel to have more secure livelihoods.

SUBTHEME 1

SUCCESSFUL EXPERIENCES AND LEARNINGS FROM CONSERVATION AGRICULTURE WORLDWIDE

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Successful experiences and learnings from Conservation Agriculture worldwide

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Since 2008/09, Conservation Agriculture (CA) has been expanding globally at an annual rate of more than 10 M ha of cropland. In 2015/16, the total CA cropland area was more than 180 M ha, corresponding to 12.5% of global cropland area. The spread of CA is expanding in Asia, Africa and Europe in recent years because more resources are being allocated towards supporting farmers to adopt CA. Perennial CA systems such as orchards, plantations and agroforestry are expanding worldwide. Globally, expansion of CA is largely farmer-driven and has become a multi-stakeholder movement comprising formal and informal CA networks at national and international levels, with support from individuals and institutions in public and private sectors.

Successful global experiences about CA are many. They show:

- The interlinked CA principles are universally applicable in all land-based production systems in all continents for all farm sizes and types of farm power.
- The core CA practices serve as underpinnings for ecological sustainability upon which a range of integrated crop, soil, nutrient, water, pest, energy management practices and benefits can be built.
- CA is a valid alternative agricultural paradigm that can address the weaknesses of the dominant tillage-based Green Revolution paradigm.
- CA is considered to be the best example of climate smart agriculture, but CA is also smart in several other ways including ecologically, economically and socially.

Learnings arising from CA experiences are also many. They show:

- Why CA works as a basis for sustainable intensification, i.e. the underlying science as to why CA systems are more stable, productive, profitable, efficient, resilient, regenerative, deliver a wide range of ecosystem services and are climate smart.
- The productivity, environmental, economic and social contributions being made by a large diversity of CA systems globally across a whole variety of agroecological zones, including at watershed and regional levels.
- The growing range of learnings related to CA system practices and benefits in terms of the role of crop and soil biodiversity, of soil biology, of cover cropping, and of integrated pest (weeds, insect pests, pathogens) management.
- New ways forward that are making it possible for CA systems to operate more biologically and organically, thus reducing or minimizing the use of agrochemicals.
- The important role played by CA systems in pro-poor agricultural development strategies.
- The role of farmer-led stakeholder networks in accelerating and sustaining the spread and quality of CA systems.

Several of these successes and learnings will be elaborated in the full paper and in oral presentation at the Congress, along with the latest information on the global adoption and spread of CA.

Keywords: *global, paradigm, adoption, climate smart, networks*

Conservation Agriculture in Eurasia

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The study allowed reviewing a history of agriculture development and perspectives of promoting Conservation Agriculture (CA) in Eurasia region, including 13 countries: Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Turkey, Ukraine and Uzbekistan.

The region has very contrast and diverse soils and climate characteristics. It is obvious that extensive use of land and water resources through application of unsustainable technologies made severe negative impact to the environment degradation, soil erosion and biodiversity loss. Therefore, the countries are convinced that the CA system in combination with other good agronomic practices can help to rehabilitate, maintain and improve soil health and fertility, increase crop productivity and farmers' income. The ecosystem services of CA and its impact to combat with climate change are clearly defined on improving water quality and carbon sequestration.

The lack of unified statistics and data collection system, and data does not allow calculating accurately the area under CA in the region. However, the estimated area under CA is 10-11 million hectares (ha) and the area of degraded land continuously growing. The population increase and raising demand for food, negative impact of unsustainable agricultural production practices to environment followed by land degradation, recurrent drought and heat stress due to climate change, and other factors are gradually leading to introduction and promotion of CA in all countries of the region. Despite this, there are still limitations for the widespread implementation of the CA system. Lack or insufficient access to special field equipment, higher fertilizers rate and herbicide application in the first years of transition to no-till technology, limited knowledge and skills of local people - farmers, agricultural and extension specialists, lack of evidence-based results of research work and many other factors still play a limiting role in the widespread adoption of CA. In addition to the dissemination of knowledge, techniques and examples of successful practices, the implementation of the CA in the region requires conducting research work and political support to increase the motivation and direct involvement of farmers. Training young specialists and farmers will also help to make a huge breakthrough in the development of CA in the region. There is also a need for changing the mindset of farmers, researchers, and policy makers.

Keywords: *Conservation Agriculture, mindset, adoption, promotion.*

Results of field trials on Conservation Agriculture in Lebanon

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Lebanon is a small country on the eastern side of the Mediterranean Sea, with a Mediterranean climate, 6 months of rain and 6 months of dry weather. In 2015/16, global Conservation Agriculture (CA) area covered some 180 M ha (12.5% of global cropland area) but CA adoption in Lebanon has been at a much lower rate than this, some 1,200 ha (less than 1% of total cropland). To promote CA in Lebanon, a series of field trials were started at the Agricultural Research and Education Center (AREC), Lebanese Agricultural Research Institution (LARI) and in many farmers' lands, in 2008 and continued several subsequent years with GIZ funding. The field experiments were conducted on rainfed wheat, barley and barley-vetch mixture, alfalfa, irrigated corn, and on olive orchards.

The results show that the application of CA in different agricultural regions in Lebanon gave similar results to that which were obtained on CA in other countries in the region and elsewhere. The adoption of CA led to the reduction in the cost of fuel, labor, and machinery required for land preparation. Also, it led to an increase in crop yield after 3 to 4 years. When discussing with farmers why not adopt CA at a faster and larger scale, it was apparent that soil and water conservation and regeneration of soil health were not the farmers' main concern, but rather the economic savings and higher returns. The results of the CA promotional programme were more successful for orchards than in field crop production. The introduction of hairy vetch as a cover crop between the olive and other orchard trees was successful and now is practiced in many apple and olive orchards, in addition to several vineyards.

The lack of knowledge about CA practices and systems as well as absence of affordable CA seeders are discouraging farmers from giving up plowing and initiate the process of transformation to establish CA systems. Although the adoption of CA in Lebanon is developing at a slower pace than in other countries in the region and outside, it is definitely progressing, albeit gradually. The potential of benefits that farmers may be able to achieve through the CA systems will encourage more farmers to adopt these CA practices and systems in the future. The lower cost of production and higher rate of return to investment are the main motivating factors.

The paper and oral presentation will share detailed data obtained by AREC and LARI experiments and promotion related to the adoption of CA systems in Lebanon and benefits harnessed by farmers.

Keywords: *Mediterranean climate, soil conservation, water conservation, orchards, vetch.*

Catalysing Conservation Agriculture uptake in the Eastern Gangetic Plains of South Asia

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Conservation Agriculture (CA) has been promoted for decades in South Asia, with an increasing focus as a solution to dense and persistent rural poverty in the Eastern Gangetic Plains (EGP). The EGP is distinct from the more agriculturally developed western Gangetic Plains (e.g., Punjab) and the adaptation, promotion and uptake of CA is different from what has occurred in other parts of South Asia and globally.

CA can still be considered in its infancy in the EGP. To ensure the timely progression to wider dissemination and adoption of CA, we undertook a rigorous, theoretically structured and in-depth qualitative assessment with more than 350 farmers and service providers across six locations in the Eastern Gangetic plains (Sunsari, Nepal; Purnea, Bihar, India; Coochbehar and Malda, West Bengal, India; and Rajshahi and Rangpur, Bangladesh). Purposive sampling along the CA adoption pathway was employed to solicit information on farmer learning, evaluation and decision making on CA in the context of their broader farming systems. This furthers work presented under the same methodology at the 7th WCCA which was implemented in Africa, affording further opportunities for regional comparisons.

Key learnings have emerged, from this work, that have substantial ramifications to future spread, scaling and impact from CA in the EGP. These primarily revolve around key drivers of farmer interest in CA (labour scarcity at planning and increased success using herbicides), yet the inability of the vast majority of farmers in the EGP to invest in mechanisation equipment. As yet, growing demand has not led to appreciable increases in zero tillage services, a reflection of a focus primarily on agronomic research at plot and farm level and only limited research on, and success in the promotion of, viable business models for zero tillage service provision.

Despite the potential scale bias, efforts must focus across the region on larger, more financially secure and risk-taking farmers who have the potential to invest in mechanisation equipment. These individuals, or those within farmer cooperatives, must be the backbone of future scaling efforts. Research must focus on ensuring profitable business models that entice investment in zero tillage equipment, particularly in the context of preceding investment in tillage equipment. Part of this also requires increased efforts to address seed gapping with maize, which has become more financially viable than wheat in the Rabi (winter) season. Our results also suggest that current entrepreneurs are focused more on scaling out to new geographies rather than scaling up within local communities, due to financial incentives of such expansion plans. The progress in increasing adoption is also variously increased (for increased subsidies and mandatory purchase of ZT equipment in West Bengal) to hampered (with government packaging of CA equipment in Bangladesh that makes individual machines unaffordable) and will require further rethinking. These and many more recommendations developed through this study will help in the further spread of CA across the region.

Keywords: *Farmer perspectives, participatory assessment, South Asia, Conservation Agriculture*

Scaling out of Conservation Agriculture for smallholders: lessons learnt

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Recent estimates put the area of CA globally at 180 million ha but adoption and uptake by smallholder farmers in Asia has been limited. In Bangladesh, we have identified, through research, multiple benefits by applying the CA for crop production on smallholder farms: labour savings, lower costs of production, increased profit, timely sowing. The relative value of the benefits varies among crop species, soil types and agro-climatic zones. The value of the various benefits to farmers may also vary from farm to farm. For a cash-poor farmer, the reduced cost of production may be the key benefit, while for a farmer with adequate farm labour, the labour savings may not be influential in the decision to adopt CA. In Bangladesh, the amount of retained crop stubble is often low due to other uses in farming systems but the minimum soil disturbance planting has still produced the same range of benefits, albeit with a lower relative response. Herbicides are now readily available and widely used in Bangladesh by farmers although diversity of herbicide types is still limited. In recent years there have been programmes to build farmer knowledge and confidence in CA systems and expand the availability of the planters and local service providers (LSP) to provide planting services for farmers on a custom hiring basis. However, Government programmes still provide incentives for farmers to till soils. The use of appropriate minimum soil disturbance planters is one of the pre-requisites to adopt CA smallholders farming. The Versatile Multi-crop Planter (VMP) is a unique multi-functional and multi-crop planter developed in Bangladesh with the capability for seed and fertilizer application in variable row spacing using CA. The nation-wide spread of 2-wheel tractors (2WT) and the development of the VMP, has provided a platform for implementing CA that decreases crop production costs and improves the fertility of soils, while maintaining or improving yield. Small contractors providing planting service for CA using VMP is a profitable enterprise that enables commercial scale out of smallscale CA in Bangladesh. To collect business performance data, we closely studied 50 VMPs that are operating commercially during 2012–2017. On average, each VMP covered 19 ha and served up to 75 farmers per year earning US$1,745 in 2017. The study estimated that farmers who adopted VMP and CA technologies have gained up to 38%, 8% and 6% more grain yield of lentil, mung bean and wheat, respectively, over conventional practice. The CA adopters obtained higher net return of US$366, US$93 and US$195 ha^{-1} for lentil, mung bean, and wheat, respectively, over conventional methods. Over 6,000 farmers hired/used VMP and practiced CA in 2017 to sow lentil, mustard, mung bean, sesame, jute, wheat, maize, rice, chickpea, etc. on more than 1,500 ha. In this paper, we will discuss lessons learnt on the key drivers for scaling out of CA in smallholders' rice-based intensive cropping systems of S Asia which might be useful for policy makers, researchers, university teachers, students, extensionists, service providers and farmers.

Keywords: *Smallholders, rice-based, adoption of Conservation Agriculture, weed management, intensive cropping*

A role of Conservation Agriculture practices under salt affected regions of Uzbekistan

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Salinity is becoming a major problem in Uzbekistan, which is increasing year after year, and thereby adversely affecting crop yields. About half (2.1 million ha) of the irrigated area in Uzbekistan is affected by secondary salinization: 31 percent is slightly saline, 18 moderately saline and 4.5 percent strongly saline. We have to tackle this problem scientifically by adopting best practices so that younger generations could also use available land resource more effectively. There are different options by which salinity problem could be managed; these include salt tolerant varieties, conservation tillage, and rice-wheat cropping system. CA is one of the most promising land use options that have been developed in our times. It is very clear that soil, crop and water management is very important for sustainable agriculture in Uzbekistan. Lot of work has been done to improve soil and water related aspects. Current research evidence from the irrigated conditions of Uzbekistan shows that CA practices are promising to combat salinity in the existing cropping systems. CA practices such as permanent no-till beds have shown their effectiveness in lowering the rate of land degradation caused by soil salinization. Site specific research is needed to assist farmers in responding to CA-based soil management and production system changes such as in nutrient requirements, and in pest, disease and weed dynamics, as well as in green manure cover crop options to be incorporated into crop rotations.

Keywords: *salinity, Conservation Agriculture, soil, irrigation and yield*

Conservation Agriculture for rice-based intensive cropping on smallholder farms in South Asia

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Although only a small percentage of crop land in Asia and Africa is managed under Conservation Agriculture (CA) systems, globally more small farms practice CA than large farms. Conservation Agriculture is knowledge and management intensive and it is a major paradigm shift for farmers affecting land management planning, as well as management skills and requires a willingness to learn and innovate constantly. We review the recent development of CA for rice-based smallholder farms in the Eastern Gangetic Plain (EGP) and the underpinning research on agronomy, weed control, soil properties and greenhouse gas emissions being tested to accelerate its adoption in Bangladesh. The studies are based mostly on minimum soil disturbance planting in strip planting (SP) mode, using the Versatile Multi-crop Planter (VMP), powered by a two-wheel tractor (2WT). One-pass SP with the VMP decreased fuel costs for crop establishment by up to 85% and labour requirements by up to 50%. We developed strip-based non-puddled rice (*Oryza sativa* L.) transplanting (NPT) in minimally-disturbed soil and found that rice grain yield increased (by up to 12%) after longer-term practice of CA. On farms, 75% of NPT rice crops had increased gross margin. For non-rice crops, relative yield increases ranged from 28% for lentil (*Lens culinaris*) to 6% for wheat (*Triticum aestivum*) on farms that adopted CA planting. Equivalent profit increases were from 47% for lentil to 560% for mustard (*Brassica juncea*). Moreover, VMP and CA adopting farms saved 34% of labour costs and lowered total cost by up to 10% for production of lentil, mustard, maize (*Zea mays*) and wheat. Effective weed control was obtained from the use of a range of pre-emergent and post-emergence herbicides and retention of increased crop residue. In summary, a substantial body of research has demonstrated the benefits of CA and mechanized planting for cost savings, yield increases in many cases, increased profit in most cases and substantial labour saving. Improvement in soil organic matter levels and total nitrogen have been demonstrated in long-term experiments together with ~30 % lower greenhouse gas emissions (mostly lower methane). From research and extension activities in smallholders' rice-based intensive cropping systems of South Asia, there is strong evidence for policy makers, researchers, university teachers, students, extensionists, service providers and farmers to engage in further development of CA.

Keywords: *Smallholders, rice-based, weed management, intensive cropping*

Tailoring the development and promotion of Conservation Agriculture to the unique characteristics of the smallholder farmer for enhanced adoption

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As the world population keeps growing, ensuring that food production keeps pace is one of the biggest challenges facing humanity. Large scale farming is seen by many people as the obvious answer to the above challenge and examples have been cited in the developed countries such as the USA, Europe and other places where the farming population has dropped with the few farmers working on very large areas of land to produce enough food to feed the entire population.

In Sub-Saharan Africa on the other hand, smallholder farming currently provides the bulk of the food needs for the majority of the people and will continue to be the major source of food supply for several years until big time farming takes over if at all possible within the next few decades. Millions of smallholder farmers across the region, however, are facing a serious soil degradation crisis and other problems that are gradually leading to food insecurity across the region. There is therefore the urgent need for the adoption of technologies that can help improve and sustain food production for the increasing human population.
There is ample evidence that Conservation Agriculture (CA) helps to achieve a more reliable harvest and reduced risks for farmers especially those in the smallholder category. For the smallholder farmers to be able to sustain food production and continue to feed the ever-growing human population, they need to be empowered to engage in the methods centered on CA principles and practices. This will require the tailoring of the development and promotion of CA to their unique characteristics such as limited access to land, information and operational funds.

This paper enumerates some of the characteristics of smallholder farming and outlines specific approaches needed to ensure effective implementation of CA at the smallholder farmer level so that their small land areas could be farmed more intensively, productively, profitably and sustainably in an environmentally friendly manner.

Keywords: *Conservation, agriculture, smallholder, farmer*

A systems approach to mainstream Conservation Agriculture in South Africa

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Introduction and purpose

The harmful impacts of accelerated soil degradation processes caused by tillage-based practices in South Africa, can be severe. To address these problems and essentially change the agricultural model or system, several stakeholders are participating in a systems approach with the vision to mainstream Conservation Agriculture (CA) in South Africa. The introduction of this systems approach will replace some traditional, ineffective linear R&D concepts and procedures in dealing with "wicked" problems and challenges, such as the development of CA in a wide range of local (on-farm) situations. This systems approach is emphasising the following important concepts and principles: farmer-centred innovation systems and platforms, experiential and discovery learning, learning-by-doing, critical thinking / reflection, experimentation and communicative action, interaction and facilitation of dialogue and the changing roles of key stakeholders. The key strategic objectives of this approach are: a) On-farm research, b) Awareness and access to information, c) Education and training, and d) Incentives and Market Based Mechanisms.

Results

The on-farm research strategy involved the establishment of collaborative- and farmer-managed (Mother and Baby) trials in various study areas to improve experiential learning, improve understanding and adaptation of technologies to local farmers and conditions, increase awareness among farming communities and facilitate farmer-to-farmer extension. The awareness and access to information strategy involved the organisation of frequent field days, conferences, cross-visits and publications (awareness materials) to demonstrate, share and discuss CA activities and results with key stakeholders. In the education and training strategy, formal and informal training events are implemented. Informal training is integrated with the on-farm innovation process. In formal training a number of local universities have started graduate and post-graduate courses. The Centre for Sustainable Agriculture, Rural Development and Extension at the University of Free State has included a CA module in their Honours course dealing with the following themes: Problems associated with industrial production systems; The principles of CA; CA research results in South Africa; CA R&D approach. As effective Incentives and Market Based Mechanisms, two venture capital companies were established based on the theoretical concept of an easement payment (collectively "Restore Africa Funds" or "RAFFs") to: a) facilitate and manage investments in the restoration of natural capital especially in conservation and regenerative (climate smart) agriculture under the banner of *heal the land, heal the people*, in Africa; b) achieved through private and commercial ventures in partnership with local and global development assistance, public sector contributions and R&D.

Conclusions

Farmer-led conservation or regenerative agriculture, with appropriate R&D, training and financial support, is arguably one of the best ways to combat soil degradation, while ameliorating the impacts of climate change, sequestering carbon, and contribute to food security. In this process, agriculture becomes a means towards healing the land and healing people.

Keywords: *Regenerative agriculture, farmer-centred, incentives, market-based approaches*

The adoption and spread of Conservation Agriculture in China

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Conservation Agriculture (CA), which is offering promising prospects for both enhanced yields and environmental services, was adopted by China to manage agro-ecosystems. Curernt studes in China shows that CA is effective in reducing energy and mineral nitrogen use and enhancing soil chemical and physical properties, so as to improve crops yields and agriculture productivity.

The development of CA in China can be processed into four stages. In the preliminary exploration stage (1960~1990), single component CA technologies (such as no tillage, subsoiling and straw cover) were tested. However, the CA system could not be extended due to the lack of suitable no-till seeders. In the systematic study stage (1991~2001), China Agriculture University (CAU) started systematic study of CA with the combination of agricultural machinery and agronomy. In 1999, Conservation Tillage Research Centre (CTRC) was set up at CAU by Chinese Ministry of Agriculture (MOA), specifically for CA. The study at this stage revealed the adaptability of CA in China and a series of medium/small size no-till seeders were developed for the spread of CA. In the demonstration and priority study stage (2002~2008), MOA began to demonstrate and extend CA in China, and organized the first national CA field meeting in Linfen, Shanxi Province. Consequently, the uptake of CA grew rapidly under the support of MOA in China. By the end of 2008, >220 national and >360 provincial demonstration counties within 15 provinces had been set up, respectively, covering more than 3 M ha. In the rapid developing stage (2009~Present), China State Council ratified the National Construction Programme of Conservation Agriculture in 2009. Since then, suitable CA machines and technical operations for different regions have been developed and disseminated, and technical support system for the extension of CA has been gradually strengthened. In 2018, CA was being practiced on more than 8 M ha, mainly located in Northeast ridge farming areas, North China Plain, Northwest oasis farming areas, farming-pastoral areas, Loess Plateau and south rice cropping areas. In 2020, in order to protect black earth in Northeast China, Chinese government launches a "National Action Plan of Conservation Agriculture for Black Earth in Northeast China (2020-2025)", and it is expected that CA will be used on 9.3 M ha in Northeast China in the next 5-6 years, covering 70% of total farmland.

Keywords: *no-till; stubble; technology; machine; development; experiences; prospect*

25 years of « Oberacker » for a climate-friendly and soil-conserving agriculture of the future

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The 25-year's studies of the long-term field experiment Oberacker in Switzerland reveal that Conservation Agriculture in line with a long-standing continuous no-tillage system is a suitable alternative to the conventional plow system.
Plowed topsoils do indeed create better germination and development conditions shortly after sowing, which is particularly beneficial for tuber and root crops. At the same time, however, the risk of compaction increases in the subsoil, especially under wet conditions. In contrast, higher nutrient availability in the topsoil, enhanced aeration of the subsoil and greater supply of plant available soil water under no-tillage result in higher yields for legumes and cereals. Cost accounting shows that no-tillage is still economical compared to other cropping systems as a result of increased yields and ecological contributions. It also contributes valuably to erosion control.

The Corg- and Ntot-contents under no-tillage are significantly higher in the topsoil layer than after plowing. Over the entire profile no higher C-sequestration was observed in no-tilled than in plowed soil.

Despite higher application rates in the no-tillage than in the plow system, neither more glyphosate nor more of the breakdown product AMPA was detected in the soil. Merely an accumulation was found in the uppermost 5 cm of the no-tilled soil. But no reduction in the amount and species diversity of earthworms and arbuscular mycorrhizal fungi could be observed – on the contrary: in all crops there are significantly more species under no-tillage (ø 18.5) as compared to plowing (ø 13.2). An important and simple figure for enforcement is the maximum carrying axle load. Loads >5 t mean that, especially in wet growing seasons, the number of
trafficable days without risk of subsoil compaction is counted.

Overall, the aim for the future is a low-input (relay) cropping system based on N- and P-recycled fertilizers with maximum energy and resource efficiency by means of a minimum use of auxiliary substances. This requires changes in the way how to drive on and till the soil. In order to preserve the functionality of our soils and to keep more of the environmental compartments intact, a holistic approach is needed that takes several concerns into account simultaneously: protecting the climate, conserving the soil, maintaining the landscape, reducing natural hazards, keeping waters clean and – last but not least – producing our food.

Keywords: *no-tillage, moldboard plowing, soil ecosystem services, yield, glyphosate substitution*

Long-term tillage effects on crop yields in a temperature humid climate

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A long-term tillage trial was started in 1978 at the Russell E. Larson Agricultural Research Center in Rock Springs, central Pennsylvania (40°44'N, 77°57'W). The climate is *dfb* (humid continental mild summer, wet all year) in the Köppen climate classification, with average annual precipitation of 950 mm and annual average temperature of 9 °C. The soil is primarily well drained Hagerstown silt loam (fine, mixed, mesic Typic Hapludalf, USDA classification) and Hublersburg silt loam (illitic, mesic Typic Hapludult). The trial was originally designed to evaluate fuel use of different tillage systems and plots are therefore large (13.7 x 230 m). Today, this research shows its value in comparing the effects of long-term no-till (NT) with reduced tillage (chisel/disk tillage) (CD), and moldboard plowing (MP) on crop yields and soil properties. During the first 26 years (1978-2003), the field was planted to continuous maize (*Zea mays*, L.). During the next 16 years (2004-2019) the field was planted to a three-year corn-soybean-wheat/leguminous cover crop rotation, starting with soybeans in 2004. Soil organic carbon content was measured in 2003 to a depth of 100 cm. Over the first 26 years, average maize yields were not significantly different between the three tillage systems, although during the first three years the crop yields in NT were lower than those in MP suggesting there was a transition period from intensive tillage to NT. During the final years of this period, however, MP yields were lower than those with NT, suggesting the effects of soil degradation started to be observed. Soil organic carbon content in the top 5 cm followed the trend NT>CD>MP. Soil organic carbon content at 5-20 cm followed the sequence CD>NT>MP, while at 20-100 cm there was no difference in soil organic carbon content between the tillage systems. Soil degradation effects of annual MP became even more pronounced in the diverse crop rotation years, as NT yields are now consistently higher than those achieved with MP. Mostly, there was no yield difference between CD and NT. This research shows the benefits of Conservation Agriculture for soil health and crop yields on well-drained soils in a humid temperate climate.

Keywords: *no-till, reduced tillage, conventional tillage, crop yield, Conservation Agriculture*

Conservation Agriculture in Central America and Peru

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This paper aims to appreciate the actual Conservation Agriculture (CA) adoption in Central America (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama) and Peru. Severe land degradation affects large proportions of the land areas of the countries. The estimated total area under different forms of CA in Central America is about 557,732 ha: El Salvador (1,950 ha), Guatemala (10,000 ha), Honduras (543,087 ha), Nicaragua (2,695 ha). The total area under CA systems in Peru is currently 200,540 ha. The CA principles apply to agricultural production systems' diversity resulting from a range of topography, soil types, and climates. These systems vary not only in the crops cultivated or the animals raised but also in the plot or farm sizes, types and intensities of management, the arrangement in the landscape, orientation for export or internal markets, agroecological conditions, and their location. In the region, CA annual cropping systems do not disturb the soil, leave stubble biomass on the surface, and include diversified crop rotations or associations, including cover crops and a varied mix of legumes, grasses, and other species. In the hillside areas in the region, there are traditional systems that follow the principles of CA. These include agroforestry with annual crops, cocoa and coffee plantations, pasture restoration with mixtures of gramineous and legumes plants, and controlled grazing to maintain proper soil cover and fodder supply (high Andean of Peru). There is also increasing adoption of fruit trees with cover crops and establishment of managed forests with various undergrowth strata to increase soil cover and to prevent erosion problems during the establishment phase (Quesungual system in Honduras). CA also provides governments opportunities to harmonize specific national objectives - notably better management of natural resources and the development of sustainable agriculture and livelihoods - with the primary purpose of benefiting rural families. Lack of or insufficient access to machinery for planting, fertilizing, and spraying pesticides limits CA's adoption and spread. Besides knowledge, technologies, and supplies, CA's adoption needs a favorable policy environment, targeted research, motivation, and participation of farmers and their communities. There is still a long way to go in the region, from the old approach of soil conservation in agricultural land based on physical structures to a situation of widespread adoption of CA systems.

Keywords*: no-till, soil health, machinery, green manure, agroforestry, Guaymango, Quesungual*

Current status of no-tillage adoption in Brazil

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Brazil is one of the most important agricultural producers and a pioneer on tropical technologies for enhancing environmental conservation. The adoption of no-tillage (NT) in annual crops, since the decade of 1970, has become the most important Conservation Agriculture system to ensure agricultural sustainability, enhancing soil conservation all over the country. The first census of area under NT was conducted in 2006 (2006 Brazilian Census of Agriculture from IBGE). This allowed a deeper understanding on NT distribution in Brazil. With the second census in 2017 (2017 Brazilian Census of Agriculture from IBGE), it became possible, for the first time, to evaluate in detail NT evolution in Brazil. The aim of this study is to characterize the spatial evolution of NT area between 2006 and 2017. The data was obtained from special tabs, elaborated under demand, through the partnership between IAPAR (Agronomic Institute of Paraná) and IBGE (Brazilian Institute of Geography and Statistics). The area under NT has increased in all Brazilian macroregions, with a national average of 84.9%, totalling 33,052,971 hectares in 2017. The highest increment (430.7%) was observed in the North. However, this was a reflex of the small area under no-tillage in 2006 (220,661 hectares), the smallest between all macroregions. The smallest increment was observed in the South (32,1%), the pioneer region in NT adoption, with the second largest area in 2017 (11,912,434 hectares). The Midwest presented the largest area under no-tillage in 2017 (13,726,367 hectares), an increment of 110.4% during the period under study. The Southeast and Northeast regions presented similar trends. They presented an increment of 45.9% and 54.4%, totalling 2,916,464 hectares and 3,326,725 hectares, respectively. The NT has been incorporated in the soybean`s production system in Brazil. Consequently, the expansion of soybean production was highly associated with NT expansion during the studied period, with a linear association of $R^2 = 0.98$. In other words, the soybean expansion was possible, among other factors, due to the use of NT. Despite NT expansion in Brazil, other conservation practices are still incipient. Most soybean production systems are based on less diversified crop rotations, which may limit the beneficial effects of Conservation Agriculture.

Keywords: *Conservation Agriculture, no-till farming, tropical agriculture, crop rotation, soybean*

Lessons learned from two long-term Conservation Agriculture experiments in Brazil and USA regarding soil functionality

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The scaling up of Conservation Agriculture (CA) relies on practical evidence of benefits, specific knowledge of how the system works, field training, and institutional and policy support. Some benefits of CA are realized in the short-term such as erosion control, conservation of soil moisture, decrease in soil temperature and weed control. Others, that are linked to ecological and sustainability functions require a certain period of time that can vary according to the soil and climate type, the range of improved agricultural practices applied, and level of land degradation at time when CA adoption process began. In order to achieve a high level of CA system organization and complexity, the system needs to gradually achieve intermediate phases of organization along an evolutionary pathway. Long-term experiments are crucial to understand changes that occur in soil quality in the medium to long-term. Restoration of soil organic carbon content has been associated with decrease in soil mechanical disturbance, promotion of biological diversity and increase in crop biomass input.

In CA systems, improvements in soil structure have been linked to well-developed root system of cover crops and crop rotation that stimulate soil fauna and microorganisms including fungi. In CA systems that achieve high level of organization, nutrient cycling and bioavailability, biological diversity, environmental buffer capacity, soil resilience, plant water availability, soil aeration and plant health are among the most important system properties that are observed. They also are characteristics that reflect system maturity. The interactions amongst the soil-plant-biological activity components can better explain the soil functionality of complex systems than the isolated indicators of each component. Achieving a high level of soil quality is a necessary goal in order to reduce temporal yield variability, to reduce dependence on external inputs, to provide environmental services, and to accomplish plant, animal and human health.

Two long-term experiments carried out in Brazil and USA with CA and complementary practices for more than three decades were revisited in order to understand the soil functionality in complex systems. The main lessons of these experiments were: a) frequent soil disturbance (conventional tillage) partially negated the positive effects of management improvement such as the adoption of cover crop and crop rotation (Brazil experiment) and organic fertilization (USA experiment); b) no-till without crop diversity and full soil biomass cover was not able to achieve the highest level of organization of the system even in the long-term; and c) the three interlinked principles of CA (continuous no or minimum mechanical soil disturbance, permanent soil biomass cover and crop diversification with rotation and/or association) when associated with complementary agricultural practices for a long period allow the restoration of depleted soil carbon not only in the shallow top layer but also at lower depths, supporting a diverse biological community that is coupled with a high level of organization and where the important emergent soil properties were also expressed.

The paper and the presentation will provide more details of the long-term experiments in Brazil and USA and the results obtained that explain the nature of the lessons learned.

Keywords: *scaling, adoption, organic carbon, cover crop, diversity*

Growth performance and correlation studies on Maize under different soil tillage conditions

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Depleting natural resources, declining profit and changing climate is the prime challenge before Indian Agriculture currently. Farmers throughout India are suffering from higher cost-lower income ratio. The scarcity of resources and dying soil quality are leading to environmental concerns as well as descending confidence of the farmers. This situation can be revived by sustainable agriculture practices along with conservation of resources. Maize is a very important cereal in North Eastern India with a good production promise and a wide scope of improvement through breeding. But, lack of availability of adaptive genotypes and standardizing suitable breeding strategy under Conservation Agriculture are the main constrains towards its sustainable future. In order to characterize the variation among the locally commercialized varieties of maize under Conservation Agriculture, five varieties were grown under three soil tillage conditions, i.e, Conventional Tillage (CT), Zero Tillage (ZT), and Reduced Tillage (RT). Their growth parameters like- height, number of leaves, leaf area index, root dry weight, total biomass etc were compared and correlated with their yield performance under the three systems. The best genotype based on the yield parameters was identified. The correlation study helped to understand the characters contributing most towards yield under different tillage along with their relations with the cultivation systems.

***Keywords**: Maize, Genotypes, Tillage, Yield, Correlation*

Long-term no-fire Conservation Agriculture diversifies production on a sandy acrisol in Acre State, Southwestern Brazilian Amazon

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Slash-and-burn agriculture (SBA) is still common in the Brazilian Amazon. Family farming in Juruá, Acre State, is also SBA-based with an aggravating prevalence of sandy soils in the region. In the search for a technological solution to the problem, no-fire Conservation Agriculture models (no-fire CA) were evaluated adopting soil tillage with a plow harrow (CT) and no-tillage (NT), the application of lime, phosphorus and potassium and the cultivation of plants of intercropping and/or rotation with cassava or maize crops. The SBA and no-fire CA systems were compared for 13 years on a sandy Acrisol in the rural area of Mâncio Lima municipality. The agroeconomic and environmental results of no-fire CA were positive compared to SBA. The total cost, with no-fire CA being 50% greater than SBA, was offset by increases in total income from the activity (327% NT / 204% CT), in the remuneration of labor (347% NT / 202% CT); in the daily rate paid to the small farmer (430% NT / 217% CT) and in the total productivity of the factors of production (181% NT / 100% CT). The net income was positive only in the NT, demonstrating its economic viability. The associated average productivity (cassava + maize from 2006 to 2019) at SBA was 7.6 t*ha^{-1}, while for no-fire CA it was 21 t*ha^{-1} (NT) and 20 t*ha^{-1} (CT), as a result of increasing technology input of 178% (NT) and 165% (CT). In addition, the NT avoided the emission of 1,536 t*ha^{-1} of carbon dioxide equivalent in 13 years due to the absence of fire and soil preparation. No-fire CA is a suite of technologies with proven agroeconomic feasibility and low carbon emission. From easy learning, technology can be transferred to farmers, technical assistance and rural extension professionals and students. The results hereby generated can support public policies to strengthen family farming. Family farmers from Juruá, especially residents of areas with sandy soils, are the target for technological solution. Nevertheless, this technology is also applicable to other scales of production in Acre and other states in the Brazilian Amazon.

Keywords: *Slash-and-burn agriculture, Cassava, Maize, Low carbon emission agriculture*

Smallholder agroecology training –3,000 success stories since 1997

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3.1 billion people in the developing world live in poverty, and 70% of those going hungry live in rural areas where degraded land could produce more food and sequester more carbon through regenerative agroecology practices. With little to lose and big potential gains, smallholder farmers are eager to make the transition to these practices that drawdown carbon out of the atmosphere into the soil and living plants.

Over the course of 23 years, Sustainable Harvest International has found that multi-year, on-farm training is key to the long-term success of smallholders adopting agroecology practices. Our proven model empowers low-income farmers to produce an abundance of diverse crops while stabilizing the climate, halting deforestation and increasing food sovereignty forever.

Outcomes of our program from 1997 – 2019 include the following:

- 3,000 families trained.
- 4 million trees planted.
- 25,000 acres converted to regenerative agroecology practices.
- 91% of families still using agroecology practices years after completing program.

Sustainable Harvest International has expressed its willingness to leverage those successes and years of experience by setting a vision to scale up our impact. Through regenerative agriculture, we will work directly with farmers, and partners who will replicate our model, to halt and reverse degradation of 8 million acres on 1 million farms and achieve food sovereignty for 5 million people. In so doing, we intend to help lead the way for a paradigm shift in the world's food systems.

Keywords: *smallholders, extension, training, regenerative, agroecology*

An operational definition of Conservation Agriculture to categorize the diversity of models in a given territory

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Conservation Agriculture (CA) is not a uniform agrarian system, but rather contains multiple models to fit the constraints and needs of farmers. Although the presence of a diversity of models in Wallonia has already been relayed several times, the models are not yet known and identified. Knowledge of these models is necessary to assess their economic, social and environmental potential.

To categorize the models present in a given territory, a typology based on the definition of CA must be constructed. But which definition of CA should be used as a reference? Three pillars are commonly accepted within the scientific community as the foundations of CA. Nevertheless, there is a lack of clear indications regarding the practical implementation of the pillars to enable the definition to be operational on the field. Moreover, the definitions diverge and contradict each other within the various scientific papers.

A literature review of the convergences and divergences is conducted among fourteen sources to construct a working definition of CA that can be used to establish a typology. The analysis of these sources revealed a definition of CA comprising the three fundamental pillars, combined with additional practices. While pillars distinguish CA from other farming systems, additional practices facilitate the adoption and the sustainability of a CA model.

This definition provides a comprehensive conceptual framework that is applicable and modifiable to all regions where CA is practiced. It has been adapted to respond to the local context. Typologies can be constructed from this operational definition of CA to study the diversity of CA practices.

Keywords: *Operational definition, Literature review, Pillars, Additional practices*

Effect of tillage and hydrogel application on the productivity of sunflower under rainfed conditions in Kashkadarya province of Uzbekistan

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It is well known that the sunflower plant appreciates warm dry climates, as found in many parts of Central Asia including Uzbekistan. Sunflower was grown mostly in irrigated conditions of Uzbekistan but not rainfed areas in the country. The objective of the study was hinged on possibility of growing sunflower under different tillage methods with and without hydrogel application in rainfed conditions of Uzbekistan.

Sunflower yields ranged under rainfed conditions from 0.60 to 1.1 t ha^{-1}, averaged over locations, with a mean around 0.87 t ha^{-1}. The highest yields were received in with no-till treatment without hydrogel (1.1 t ha^{-1}) while lowest yield (0.60 t ha^{-1}) was recorded with no-till treatment with hydrogel. Sunflower yield decreased consistently from without hydrogel treatment to with hydrogel application.

The results should be studied further in order to receive solid results. Results of cost benefit analysis showed that planting method affects profitability rate of sunflower under rainfed conditions in Uzbekistan. The highest profit was recorded with no-till planting without hydrogel application, while the lowest profit was obtained with no-till traditional tillage using hydrogel application. For the first time sunflower was grown in rainfed conditions of Uzbekistan using no-till and hydrogel application.

Keywords: *sunflower, no-till, hydrogel application, yield and rainfed conditions*

Graphical representation and monitoring of the agricultural sustainability on olive orchards and vineyards; the suitability of CA

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Agricultural sustainability is a crucial aspect for the protection of the capital natural and its future use. Hence, sustainability assessment of the farms and the identification of their potential improvements is crucial. The objective of this study was to evaluate agricultural sustainability through graphical-polygonal representations and alphanumeric data, on a permanent cropped land in Southern Spain. A mixed farm of vineyard and olive trees was selected as model farm for sustainability assessment based on the farming practices (BMPs), mainly centred on Conservation Agriculture (CA), that have been applied.

The monitoring assessment has been performed throughout 5 agricultural seasons on the farm by the INSPIA methodology. INSPIA methodology is based on the application of a set of 15 BMPs which are determined through 31 basic sustainability indicators, providing in the end, a final composite index of sustainability. Basic values of the indicators are in consequence of what farmers do in practice to farm their land. The greater the composite index, the greater the implementation of sustainable farming practices is reached, such as the ones flagged by CA: enhanced soil, water and air quality, improvement of the farmed environment for biodiversity, and thus, enhanced ecosystem services on which agricultural productivity relies.

Results on sustainability (alphanumeric and graphical findings, and indexes), are shown during that period, depicting the correspondent relationship among the implemented Conservation Agriculture practices and the indicators. The highest result of the composite index was reached when the groundcover was established, and the soil disturbance was minimized.

This research confirms the importance of CA practices, such as the groundcover establishment and the minimum or no-till management to upgrade agricultural sustainability on the permanent cropped lands in Southern Spain. While soil-tillage reductions of nearly 42% are measured, economic, social or environmental benefits emerge, such as increases in both organic matter content and in energy productivity of 66.6% and 3.7% respectively, among others.

Keywords: *Best Management Practices, sustainability indicators, groundcovers, indexes, sustainability graphical representation*

Weed dynamic in Conservation Agriculture: experiences from the Isite-BFC regional network of farmers and cropping system experiments on agroecology in France

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Conservation Agriculture (CA) relies on three fundamental pillars: diversified crop rotation, permanent soil cover and no soil disturbance. Weed control relies on few tools because pre-sowing tillage, pre-emergence herbicide spraying and in-crop mechanical weeding are not possible. This could lead to drastic changes in weed communities and quickly after the transition to CA, with fewer annual species (weed seeds remain on the soil surface, a condition deemed to be unfavourable to weed germination) and higher perennial species. However, the implementation of CA principles could be transcribed into a wide array of cropping systems because the objectives of farmers differ, and/or because systems are implemented in different production situations (e.g., associated or not to livestock, soil type, irrigation). Therefore, the Isite-BFC regional network gathers CA farmers and experimenters from cooperatives and research institute (INRAE) to share their experiences, detailed practices and weed surveys initiated since 2007 in some sites. Weed diversity was high in all systems compared to what is known from tillage-based agriculture. Weed community changes over time depending on the diversity of crop rotation tested and initial weeding pressure. Since CA is challenged by potential glyphosate ban in Europe, the application of glyphosate was stopped in 2018 in some sites and thus, cropping systems were redesigned accordingly to ensure weed management over the long run, economic profitability and multiperformance.

Keywords: *weed diversity, weed composition, glyphosate, famers' network, participative reserach*

Successful scaling approaches leading to autonomous adoption of Conservation Agriculture in West Bengal

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In West Bengal, India, the agricultural sector needs options that can address labour scarcity, reduce production costs and improve productivity. Conservation Agriculture-based technologies offer potential solutions for these issues. Since 2012, a network of actors comprised of research (local university, international research organisations), extension (Department of Agriculture) and farmers groups have been working together through participatory field trials, capacity development, supply chain and policy interactions to undertake research and development activities with the unified aim to take CA to scale across the state of West Bengal.

As a result of this, more than 70,000 farmers in the state are now using CA practices, with several important factors identified that have contributed to the scaling CA. First, the opportunity to strengthen links and build networks in the agricultural system that were limited before. For example, agricultural universities worked very closely with the state extension department, which was integral to fostering trust in academic results. An important part of this network was the farmers' groups (i.e., state sanctioned Farmers Groups, Farmer Producer Organisations and Self-Help Groups). These groups have played a crucial role in machinery provision and as an information channel for farmers. As emerging entrepreneurs, they have been linked to partner networks, and had access to technical expertise that has reduced risk and allowed them to capitalise on an opportunity to use more profitable and inclusive enterprises. Engagement of women and rural youth through farmers groups and alternative income generating activities makes the new system attractive to communities and government alike. These strong networks helped develop trust with communities, and coupled with over 200 participatory trials and ongoing technical backing from international research organisations, resulted in greater buy-in from multiple actors in the system and gave confidence to partners to channel demand to higher levels. A combination of proof of concept and increasing demand from farmers meant policy makers had something to see in the field that was also supported by locally produced, international standard science. Having dedicated, focal staff at every level from local (block and subdivision) and higher allowed for coordinated lobbying from different levels within the government system.

Convergence with government schemes was the ultimate aim for scaling and sustainability of CA use in West Bengal, and these outcomes are demonstrated in several ways. Now, it is compulsory that all new Custom Hiring Centres (CHC) include at least two CA machineries in their portfolio of five machines (minimum), in an attempt to promote CA technologies and avoid environmental hazards associated with straw and stubble management. At the local (block) level, extension staff are able to commit resources from state extension schemes to activities of their choosing, allowing these schemes to promote CA. This promotion of CA is supported by government research and extension staff assigned at district levels who have a commitment of both time and funds for technical backstopping, troubleshooting and adaptation as adoption spreads in both time and space. The approaches used here will continue to contribute to scaling and long-term sustainability of CA use in West Bengal, and provide key learnings more broadly for successful scaling.

Keywords: *Conservation Agriculture, West Bengal, policy convergence, agricultural transformation, policy*

Role of farmer cooperatives for participatory learning and scaling Conservation Agriculture: a case of Haryana, India

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Since the Green Revolution era, rice-wheat rotation has become a major production system in Haryana and Punjab states and contributing significantly in national food pool in India. However, continuous cultivation of this monotonous cropping system and excess soil tillage since last 5 decades poses the multiple challenges of declining ground water table and soil health, degrading natural resources with speedy climatic aberrations to the farmers. These challenges further intensified by the faulty practices such as, crop residue burning, traditional cultivation practices with excess tillage for wheat and puddling for rice and application of fertilizers and water without considering the temporal and spatial variability. During the recent past, the climate has been very disloyal with increased aberration, intensive and untimely rainfall and reduced number of rainy days, resulted into reduced crop productivity and farm profitability. Therefore, the farmers of this region are more vulnerable to climate change effects because of specialized single cropping system compared to other regions where diversity of crops are grown. Since the cause and affects of these challenges are complex and hence the solutions are not simple and needs local adaptions and inclusion of farmers wisdom in technology adaption and refinement. Considering this, farmers participatory research on Conservation Agriculture (CA)/ climate smart agriculture (CSA) and extension system was devised with creation of Farmers' Society networked with research and developmental institutions in Haryana, India. Initiated in 2010 at grassroots, this aimed to promote CA using philosophy of knowledge co-production where various stakeholders learned from each other. The aim of deploying CA based societies is to remove ill effects of climate and conventional agriculture practices and to create the knowledge hubs so that the farmers of nearby villages can share their problem and can get knowledge on the new tools and technologies. At society level, farmers' participatory research trials were conducted to enthuse and support fellow farmers demonstrating the new crops, cropping systems, tillage and crop establishment methods, precise water and nutrient management and also use of ICTs on their farms. This approach helps in speedy and wider adaptation of CA/CSA based technologies at grassroots level in the region. Adoption of CA/CSA based technologies enable farmers to insulate the climate change impact such as terminal heat in wheat and mitigating adverse effect of untimely intense rains in wheat and maize crop. Availability of new seeders (Happy Seeder) for wheat sowing reduces the rice residue burning in the region and helped in soil fertility improvement which resulted in higher system productivity (10-20%) and farm profitability (~25%) without deteriorating the environmental quality and natural resources. Through societies acts as custom hiring centers and visiting platforms where thousands of stakeholders visited to get newer knowledge and policies adapted to the specific agro-ecosystem. Providing knowledge on precise water, nutrient, herbicide and pesticide management practices will open new avenues for business creation to the small holders in the region.

Keywords: *Conservation Agriculture, participatory research, cooperative society, adaptation strategies*

Effect of fertilizer rate and tillage method on productivity of winter wheat in the Aral Sea Basin of Uzbekistan

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Conservation Agriculture (CA) proposes options for such changes through addressing a very broad variety of issues related to soil management concepts, water resources management and erosion control, mechanization and tillage, mulching, etc. Five nitrogen rates were evaluated in under two different tillage methods.

The rate of nitrogen had no significant effect on the yields in either of the two tillage systems. The increased fertilizer rates produced the greatest yield response. Most of the grain yield response was due to treatment no-till+nitrogen 120 kg/ha which produced an additional yield increase that was statistically significant across the four years. The highest yield was recorded (5003 kg ha^{-1}) in the treatment where nitrogen rate was 120 kg/ha in 2015 under no-till while the lowest yield was recorded (3733 kg ha^{-1}) in the treatment where nitrogen rate was 80 kg/ha in 2014 under no-till method.

Overall, no-till winter wheat had higher yield compared to conventional tillage method. On the basis of primary findings of this research it can be concluded that the year and fertilizer rate are one of the factors that has been implicated as critical in determining winter wheat productivity in the region under no-till. It should also be concluded that fertilizer use efficiency will be increased while fertilizer rate will be decreased in the no-till. Further investigations of the effect of fertilizer rate are needed to assess its effects in the longer term

Keywords: *no-till, fertilizer rate, winter wheat, yield*

The future of farming
Profitable and Sustainable Farming with Conservation Agriculture

8th World Congress on Conservation Agriculture

SUBTHEME 2

FARM AND ECOSYSTEM LEVEL BENEFITS OF CA SYSTEMS TO FARMERS, SOCIETY AND ENVIRONMENT

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The future of farming

Profitable and Sustainable Farming with Conservation Agriculture

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Farm and ecosystem level benefits of CA systems to farmers, society and environment

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The expanding global population, expected to reach 9.5 billion people by 2050, is exerting mounting pressure on the finite land area and resources for growing food. Extreme rainfall events and flooding have increased during the last century, and these trends are expected to continue, causing erosion, declining water quality, and negative impacts on transportation, agriculture, human health, and infrastructure. The objective of this review is to discuss the important role of carbon (C) and all of its attributes that make resource management critical for food security. The many attributes of C are critically important in transforming Conservation Agriculture (CA) systems into regenerative agricultural systems through the C cycle. Conservation Agriculture, C-based and C-focused, integrates system concepts based on three key principles: 1) continuous crop residue cover on the soil surface; 2) continuous minimum soil disturbance (no-tillage); and 3) diverse crop rotations and cover crop mixes with location-specific complementary practices, all important elements of CA. Enhanced C management enables interactive synergies between the biological, physical, and chemical properties and processes with multiple economic and environmental benefits. At the core of CA is the transformation toward soil health and systems management innovation with emphasis on regenerative C management. The important role of new diverse crop rotations and cover crop mixes providing opportunities for C input will make food production systems more resilient and increase water use efficiency. Benefits of soil C management for agricultural ecosystems are discussed starting with C capture in photosynthesis and following C flow through the system eventually back to the atmosphere. The long list of benefits provided by cover crop mixes, including different species and innovative cover crop management provides options for many soil types and geographic locations. The goal is to achieve “continuous living cover” and C input as much as biologically possible.

Keywords: *resilience, hydrology, biodiversity, soil carbon, soil structure*

Economy and biodiversity in Conservation Agriculture compared to conventional farming

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The purpose of the research is to investigate the differences between economics and biodiversity in three cultivation systems under Danish conditions - 1) Conservation Agriculture, 2) reduced tillage and 3) plowing. The experiment is part of the project "Grønne Marker og Stærke Rødder" (Green Fields and Strong Roots), which is carried out in a collaboration between the Department of Plant and Environmental Sciences at the University of Copenhagen and the consulting company Agrovi.

During three growing seasons, inputs are registered in form of man- and machinery hours, consumption of pesticides and fuel, as well as crop yields. Also, data regarding biodiversity are registered in the form of beetles, spiders and earthworms. Preliminary results show yield levels at plowed tillage and a reduced tillage systems can be achieved by Conservation Agriculture. At the same time, the registrations show significant savings in operating costs, especially in cereal crops which means the net result in Conservation Agriculture seems to be on average better, comparing the three cultivation systems. However, we have seen quite large fluctuations in yields, both between cultivation systems and each season, therefore further studies are needed.

There is a very clear tendency with regard to biodiversity; our research shows that biodiversity increases with decreasing tillage intensity. This applies to both beetles and spiders, but especially in relation to earthworms, the tillage intensity is of great importance. Reduced intensity of tillage leads to both more and larger earthworms, and especially in the absence of tillage, we have found large species of earthworms. These species play a significant role in the decomposition of crop residues and soil structure. We have also seen that a higher level of biodiversity seems to results in a more stable ecosystem in Conservation Agriculture. This means that infestation of pests to a certain extent is controlled by natural enemies and that the use of insecticides can be reduced or totally avoided.

Keywords: *Conservation Agriculture vs. plowed, resources, yields , economy, biodiversity*

Short term gains versus long-term sustainability – the need for long-term trials in Conservation Agriculture research

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Southern Africa is likely to be heavily affected by a changing climate and the brunt will have to be shouldered by smallholder farmers in rural areas. Long-term experiments on Conservation Agriculture (CA) technologies are rare in Africa and offer the opportunity to evaluate and assess the potential impact of a more variable climate and soil fertility decline on crop productivity. Here we assess the response of different CA practices, established in seven long-term experiments located in Zimbabwe, Zambia, Malawi and Mozambique on productivity and sustainability and use further data from long-term on-farm trials to evaluate the economic performance. Smallholder farmers, often living below the poverty line, are dependent on short-term gains from agriculture systems without taking into consideration loss in longer-term sustainability. We therefore aimed to identify cropping systems that may provide both, using long-term experiments of different age (4-15 years) as study objects. The results show that improved maize-legume systems under CA provide greater productivity, stability and climate resilience under the conditions of a variable climate. We also found that benefits accrue over time which highlight the need for longer-term investments in the promotion of CA systems. Finally, we found that short-term financial returns on investments are greater if more diverse maize-legume systems are practiced under CA due to reductions in farm labor for planting and weeding as well as greater yields in response to increased infiltration and soil moisture conservation. The results provide viable options for smallholder farmers to attain both short-term and longer-term benefits of CA which will lead to greater sustainability and adoption over time

Keywords: *Sustainable Intensification, climate-smart agriculture, no-tillage, Africa, climate change*

Agricultural sector burning: hidden impacts on soils, crop yields, human health, water and climate

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Open burning in agriculture – defined as all intentional burning in the agro-forestry sector, including stubble and pastureland burning and use of fire to clear fallow lands, but excluding prescribed burns on wildlands -- is a practice with deep historical roots. It can take place regularly with the misconception that it renews the soil, or sometimes to save time and effort. Burning, however, damages soil and decreases its productive capacity by destroying the organic matter and soil structure - vital for high yields. With each successive burn, soils become less fertile and water retentive, and more prone to erosion, while also destroying the straw - a potentially valuable resource for energy, animal feed or bedding. In addition, it produces greenhouse gases; and when the soot and smoke (black carbon, a short-lived climate pollutant or SLCP) from open burning travels through wind forces and is deposited to the cryosphere, it accelerates glacier melt by lowering reflected solar radiation. This then impacts water resources by speeding up glacier loss already well-underway through global warming, for example in the Andes, in a vicious cycle that then decreases availability for irrigation and drinking needs.

In contrast, alternative "no-burn" methods ultimately will improve crop yields and profits, while preventing emissions of GHGs and black carbon. Conservation Agriculture (low-till, no-till with cover crops and injected manure) can eliminate the need for the practice of open burning entirely, thereby improving human health, food security, and rural livelihoods through better access to clean drinking water and irrigation. These methods also provide some level of adaptation and resilience: the stubble roots preserve soil structure and slowly decompose, serving to fertilize the succeeding crop; and overall increasing soil organic matter. The leftover roots also provide resilience to both extreme droughts -- through preserving moisture content; and extreme rainfall events, by holding soil in place. Both these extremes have become of greater concern for farmers in a changing climate; and there is increasing evidence that such methods also fix greater amounts of carbon in the soil (ie negative emissions). Other no-burn methods also aid adaptation, such as the use of straw stubble for bio-energy or cookstove fuel to preserve local forest resources. Switching to Conservation Agriculture, however, remains the most sustainable of these potential alternatives.

Keywords: *open burning, fire, soil, conservation, health*

Soil health checkup of Brazilian Conservation Agriculture farming systems

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Brazil has around 35 M ha of cropland managed under Conservation Agriculture (CA) grain farming placing the country as one of the world's largest area. CA has many advantages in relation to intensive tillage-based farming by providing soil erosion control, organic matter restoration, saves labor, time and fuel and offers competitive yields. Documented effect of CA on soil health at the farm level is still relatively scarce. This study was carried out aiming to investigate the enzyme activity analysis as an indicator of CA soil health in main Brazilian agro-ecoregions. For that, seven fields located in main grain producing regions in South, Central-West and Northeast were selected. In each of them three environments (high, medium and low yield) were defined based on crop yield records and satellite images. The chemical soil analysis (SOM, P, K, Ca, Mg, S, Al, B, Cu, Zn, BS, CEC, pH) and physical analysis (soil texture, electrical conductivity - ECa) were performed. The activity of soil enzymes β-glucosidase and arylsulfatase was evaluated in 63 sampling points spread in four States. These enzyme activities have been recently proposed as key indicators of Brazilian soil health. One field with larger data base was selected for DNA characterization in order to more deeply understand soil health and its relationship with field crop yields. The results show that β-glucosidase and arylsulfatase activities have positive relationships with SOM, clay, silt, Ca content and CEC. Also, these enzyme activities had negative relationship with sand texture. The enzymes were sensitive to soil productive capacity within field. Tropical Brazilian soils usually are acid, with low activity clay, and dystrophic character. As a consequence, soil acidity correction, SOM restoration and soil fertility and CEC increase were important strategies to improve biological activity. In the study, SOM contents higher than 3.5% were associated with high β-glucosidase and arylsulfatase enzyme activities. However, around 37% of the data points had low SOM that were associate with low enzymes activity. The enzymes were also efficient indicators of soil biodiversity assessed by DNA characterization. Finally, the study concludes that following the three integrate principles of CA with focus on crop rotation and cover crop use, SOM restoration, alleviation of soil acidity, and increase in Ca content were key drivers in the restoration of soil health, with positive consequence for crop yield.

Keywords: *Agro-ecoregions, Soil Enzymes, Soil DNA, Soybean Yield, Soil Organic Matter*

Water smart agriculture improves soil health, productivity and climate resilience in the Central American Dry Corridor

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Soil and water resource degradation coupled with an increasingly extreme and variable climate threaten the food security and livelihoods of millions of smallholder farmers in the Dry Corridor of Central America. Water Smart Agriculture has the potential to increase farm productivity and climate resilience in the Dry Corridor, however, adoption rates of key practices of Conservation Agriculture (CA) remain low. The Water Smart Agriculture Program for Mesoamerica (ASA by its Spanish acronym) had brought together a network of local organizations and smallholder basic grains farmers across Nicaragua, El Salvador, Honduras, Guatemala and Oaxaca, Mexico that aim to evaluate and promote soil health-building practices. Conservation Agriculture and Integrated Soil Fertility Management including cover crops are being tested on 1400 on-farm trails across the region. Practices are adapted to local agroclimatic conditions, cropping systems and socioeconomic context and, together with farmers, are evaluated in direct comparison to conventional practice using a set of soil health, productivity and economic indicators. Preliminary results demonstrate that combined CA and soil fertility management result in improvements in soil health and translate into significantly increased productivity and economic benefits, often within the first season. Farmers face challenges such as trade-offs with residue use and access to cover crop seed, appropriate fertilizers and tools for hillside environments. The participation of farmers in on-farm trials and associated Farmer Field Schools has stimulated farmer-led problem-solving, farmer-to-farmer dissemination and spontaneous adoption. Farmer experimentation also builds critical innovation competencies that help farmers to continually evaluate, innovate and adapt their agricultural systems as the climate changes and new challenges arise. These results are extremely promising and serve as the foundation of a region-wide movement to provide critical support to increase water-use-efficiency and soil health services to 250,000 smallholder farmers.

Keywords: *Smallholder Agriculture; Conservation Agriculture; Soil Health; On-Farm Experimentation; Climate Resilience*

Benefits of Conservation Agriculture in watershed management: the case of Paraná Watershed 3, Brazil

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Conservation Agriculture (CA) addresses the causes of agricultural pollution by reducing the processes of soil disturbance, water runoff and transfer of soil particles, including microorganisms, nutrients and pesticides. CA leads to protection of water quality in a key compartment of the water cycle, the soil. Some watershed managers in the world have understood this and are developing actions integrating CA in the strategy for restoring the quality of water resources. The case of the Paraná Watershed 3, upstream of the Itaipu Dam in Brazil, illustrates the progress made by watershed management that has integrated CA in its agricultural land use plan.

To establish improved quality CA in Parana Watershed 3, FEBRAPDP (Brazilian No-Till Federation) participated in the 'Cultivating Good Water Programme' established by the Itaipu Dam Authority. The goal of the FEBRAPDP project was to improve the CA-based agricultural practices in the watershed to reduce soil erosion, water and nutrient losses, and water pollution while simultaneously improving the economic performance of farms. The project was built on a participatory approach involving farmers in meetings and field visits covering the extent of six small sub-watersheds. A set of indicators were chosen by the farmers and the technical group to form the axis of a multi-criteria analysis: crop rotation (including mulch), no-till effectiveness, soil and water conservation, crop fertilization, farmer's involvement in no-till. The indicators require neither costly measures nor external knowledge but are based on the observation and know-how of producers. They can be quantitatively or qualitatively assessed, comparing with a local benchmark. The aggregation by weighted sum of indicators results in a Participatory Quality Index for No-Till (PQI) which forms a self-assessment system in terms of the quality and effectiveness of CA.

The CA quality assessment methodology developed within the Cultivating Good Water Programme makes farmers more autonomous in their decision-making through self-assessment based on field observations and indirect assessments, helping them to reduce inputs (especially fertilizer) and improve their productivity in terms of use efficiency and biological output, and profit. This simultaneously contributes to reducing or minimizing the runoff and erosion of top soil and leaching of solids and pollutants such as nitrogen and phosphorus to watercourses, thus reducing eutrophication that generates greenhouse gases and higher drinking water treatment costs to the urban populations. It is also important to note that the greater infiltration in the soil provided by a well-managed CA system contributes very significantly to the recharge of aquifers and to the regulated flow of good quality water into the rivers of the Parana Watershed 3 that supply water to the Itaipu Dam.

The paper will elaborate on the participatory approach established by FEBRAPDP to improve the quality of CA in the watershed, the rationale for PQI and the results that have been obtained.

Keywords: *soil erosion, nutrient loss, water pollution, Cultivating Good Water, Itaipu Dam*

Initial impact of Conservation Agriculture on soil fertility

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Bidhan Chandra Krishi Viswavidyalaya (BCKV) has been engaged in research on different aspects of Conservation Agriculture (CA) with a few national and international partners and contributed significantly to its present knowledge pool. To strengthen the program and generate quality human resources for manning different activities of CA across the country a Centre of Advanced Agricultural Science and Technology (CAAST) is established at BCKV with financial assistance from the World Bank-Govt. of India under the ambit of ICAR-National Agricultural Higher Education Project.

To demonstrate, fine-tune and innovate location specific technologies on CA an experiment was set up in the year 2018 at the Balindi Farm (22.96°N, 88.50°E, 9.75 m msl), BCKV, West Bengal. The site had an average annual rainfall of ~1500 mm, and mean annual minimum and maximum temperatures of 12.5 and 36.2°C, respectively. Its soil was clay-loam. This study was undertaken to assess short-term effects of CA with rice-based cropping systems (i.e., rice-wheat, rice-potato and rice-cauliflower) on soil properties. The experiment was laid out in split plot design, where different intensity of tillage (zero tillage, reduced tillage and conventional tillage - based on energy used) was in main plots and a combination of rice residue and doses of NPK fertilizer was in sub-plots [0% residues+100% recommended dose of NPK (RNPK), 50% residues+100% RNPK, 50% residues+75% RNPK, 100% residues+75% RNPK and 100% residues+50% RNPK] with three replications to create a regime of CA practices. Average grain yield of rice was 3672 kg ha^{-1} and 50 and 100% of its straw yield was used as residue for the above treatments. Representative soil samples (0-0.20 m depth) were collected before start of the experiment in 2018 and after completion of one crop cycle i.e., harvest of wheat, potato and cauliflower in 2019 from each of the 135 (3×5×3×3) plots. Soils were analysed for pH, oxidizable organic C and extractable plant nutrients (N, P, K, S and Zn), which were subjected to analysis of variance to determine the statistical significance of tillage, residue+nutrient and tillage×residue+nutrient effects. Means were separated at $p<0.05$ using Duncan's multiple range test.

After one year of cropping soil properties varied [pH (7.3 to 8.1; mean 7.70), oxidizable organic C (0.25 to 1.54; mean 0.58%), available N (177.2 to 259; mean 222.9 kg ha^{-1}), P (15.8 to 54.9; mean 30.4 kg ha^{-1}), K (111.8 to 370; mean 194.3 kg ha^{-1}), S (17.5 to 211.2; mean 59.5 mg kg^{-1}) and Zn (0.2 to 2.4; mean 1.1 mg kg^{-1})]. On average, the effects of tillage and residue+nutrient treatments were non-significant and significant, respectively, but tillage × residue + nutrient interactions were non-significant for all the above soil fertility parameters and cropping systems (three) tested. A higher organic C, and available N, P, K and Zn were associated with 100% RNPK (both with or without residue) followed by 75% RNPK and 50% RNPK across the tillage and cropping systems studied. Results thus indicated that at the initial years of CA, effect of residue+fertilizer treatments override those of conservation tillages.

Keywords: *cropping system, soil tillage, crop residue, soil nutrient availability*

Status of Conservation Agriculture adoption in Syria

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Conservation Agriculture (CA) is widely adopted in the world, but relatively less so in countries of the West Asia region, including Syria, where the need for CA is high. CA was effectively introduced to Syria in 2006 by ICARDA supported by Australian funds and expertise. Successful work was based on conducting applied research, employing participatory extension and most importantly the fabrication of locally made affordable no-till seeders. Consolidated follow-up efforts with local partners led to a significant increase in the adoption of CA in Syria and to a lesser extent in Iraq.

Syrian crisis which began in early 2011 has severely affected all sectors of the economy, especially agriculture, as most farmers lost their assets or they were displaced. Most of the government funds and subsidies for agricultural development were reallocated into relief activities. As a result, farming has become difficult due to lack of inputs and security. Despite the absence of support from governmental institutions and development agencies, many farmers have kept practicing CA as it is an input-saving approach to sustainable production, especially under the situation fuel scarcity. However, as a result of the crisis, locally manufactured no-till seeders have become unavailable or unaffordable due to the disconnectedness of safe areas in the country and/or migration of local CA expertise.

During the past three years, attempts have been made by Syrian government, ICARDA, Aga Khan Foundation, UNDP, ACSAD and others to restore CA promotion campaigns, and national and international development agencies are already working individually and collaboratively to accelerate the adoption of CA in Syria. However, current situation in Syria calls for a different CA dissemination strategy which includes: inclusion of disconnected target areas; encouraging and supporting local workshops to manufacture affordable no-till seeders; and assisting small farmers to work in groups and make it possible for them to access no-till seeders and other inputs such as quality seeds, fertilizers and herbicides, and engage in participatory group training.

At the country level there is a need and a possibility to establish a national CA coordinated programme involving public institutions, development agencies and private sector. The paper will elaborate the ongoing efforts by various institutions to promote CA and to establish a nationally coordinated multi-stakeholder CA adoption and development programme under the oversight of the Syrian government.

Keywords: *West Asia, no-till seeders, input-saving, group training, nationally coordinated*

The contribution of accelerated adoption of Conservation Agriculture to the EverGreening the Earth Campaign

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Humankind is currently mobilizing to achieve The Race to Zero Net Emissions by mid-century. This is in line with the conclusion of the Intergovernmental Panel on Climate Change that there must be a very rapid shift from fossil fuels to renewable energy sources across the entire global economy, and that large quantities of carbon that has already been deposited in the atmosphere be captured and stored. In 2019, the Global EverGreening Alliance (evergreening.org) launched the *EverGreening the Earth 'Green Up to Cool Down' Campaign* to assure the drawdown of at least 20 billion tons of CO^2 annually by 2050, by accelerating the capture of CO^2 on the world's farmlands, forestlands, and rangelands. The Alliance is composed of 50 of the world's largest development and conservation NGOs, supported by major research organizations on landscape restoration.

The Campaign is a partner of the UN Decades for Ecosystems Restoration. Achieving the 20 billion tonne carbon sequestration goal by 2050 will enable the world to be well into negative emissions territory on an annual basis. This could stabilize the maximum global temperature increase at around 1.5C by mid-century, and begin to reduce it during the subsequent decades.

Six campaign target areas were identified for drawdown. The targets focus on nature-based evergreening practices that are cost-effective, livelihoods enhancing, and ecosystems-improving. These targets include: Accelerating the increase in tree cover on agricultural lands through agroforestry, increasing soil carbon through accelerated adoption of practices such as scaling up the incorporation of leguminous shrubs in agriculture, deploying evergreen energy generation for carbon capture and storage, restoring tree cover on degraded forestlands, particularly through assisted natural regeneration, and creating a healthier grass-tree balance with improved management systems on degraded pasturelands.

The target for Conservation Agriculture (CA) is to increase the global adoption of CA to 500 million hectares -- from the current level of around 180 million hectares. CA practices may increase soil carbon by modest to substantial levels, particularly through no tillage, mulch cover, crop diversification including crop rotation and associations and growing cover crops, and a number of other agroecological practices. Rates of carbon storage in CA landscapes can be further enhanced by the integration of trees and shrubs in CA systems.

The buildup of soil carbon is globally quite variable across CA systems and agroecological zones. The analyses that were used by the Campaign to estimate the annual increase in soil carbon with CA resulted in a projection of about 0.2 tons C per hectare per year overall. A more granular analysis is needed, based on a comprehensive review of the performance of CA systems and practices across farming conditions around the world. Thus, the EverGreening the Earth Campaign is creating a working group that *inter alia* is seeking to improve the projected contribution of CA to the global goal, and to provide judicious guidance to the plans for achieving the global CA target. Professionals with an interest in this topic are warmly invited to be in touch about participating in the working group.

***Keywords**: evergreening, carbon, Conservation, Agriculture, campaign*

Conservation Agriculture: can be an option for improving crop and water productivity with lower environmental footprints

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In rice-wheat (RW) system of north-western Indo-Gangetic Plains (NWIGP) the non-remarkable improvement in crop yields due to poor soil health, paucity of production resources *i.e.,* water, energy and labour along with climatic variability provides a pace towards adoption of Conservation Agriculture (CA) based best bet crop management practices in diversified maize-based cropping systems. In NWIGP maize-based production systems could be the potential alternatives to intensive RW system. Maize being a C_4 crop having adaptability to climate change and CA being an environment friendly technology, thus adoption of CA in diversified maize-based systems may leads to higher crop productivity, superior response to applied inputs, saving of water. The CA-based management practices in maize-based systems are also believed to provide mitigation co–benefits through reduced GHG emission and increased soil carbon sequestration. In a 11-year study of CA experiment established in 2008, we have assessed the performance of CA-based management practices [zero tilled permanent bed (PB) and zero tillage flat (ZT)] and conventional till flat (CT) in main plots in four diversified maize-based systems [maize-wheat-mungbean (MWMb), maize-chickpea-*Sesbania* green manure (MCS), maize-mustard-mungbean (MMuMb) and maize-maize-*Sesbania* (MMS)] in sub plots. The experimental design was split-plot with three replications. Significant ($P<0.05$) improvement in 11-year means system productivity (14.8-16.2%) of diversified maize-based cropping systems and soil carbon dynamics was observed under CA-based zero tillage (ZT) and permanent beds (PB). Among the tillage practices, conventional tillage (CT) based plots emitted highest annual GWP by 18.1 and 17.4%, compared to CA based ZT and PB plots, respectively during 5th and 6th year of experimentation. Therefore, the results of this study are unique and provide a new science-based evidence for the science and policy leaders. These evidences will be helpful to prioritize the appropriate combination of management practice in maize-based crop rotations to sustainably diversify the conventional rice-based systems of western Indo-Gangetic plains to address the sustainability thereat on water, soil and environmental quality of the food bowl of India.

Keywords: *rice-based system, water productivity, Indo-Gangetic Plains*

The follow is an opinion for Conservation Agriculture on winter wheat under dryland conditions in Central Turkey

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Fallow-winter wheat cropping system has been dominating the dryland farming in Central Turkey for more than a century. It is conducted using excessive tillage during the 15 months of the fallow period. Tillage is perceived by farmers to prepare the soil for seeding and especially increase soil water capture and accumulation under water stressed environments. However, increasing production costs, climate change, and degraded soils make it difficult to maintain the current practice of excessive tillage. In order to search for alternatives, an experiment was initiated in 2015 comparing conventional and Conservation Agriculture (CA) using several crop rotations, including fallow-wheat rotation. All crop yields under CA were significantly higher than the crop yields under conventional agriculture. The wheat yields after chickpea, lentil, Hungarian vetch and safflower varied significantly over the years and were often very low, hence did not provide acceptable returns for farmers. During the years of 2016 and 2018 with uneven distribution or low precipitation no wheat yield was obtained. However, it was always possible to obtain yield from wheat after fallow. Wheat yields under no-till fallow (chemical fallow) treatment were consistently highest in all years. Compared to tillage-follow treatment total production expenditures were 12.5% less in no-till follow treatment. Our results show that it may not be always possible to adhere to three critical components which define CA: (1) retaining full or as close as possible full ground cover, (2) minimum soil disturbance, and (3) maintaining diverse crop rotations. Contextual realities of low and erratic rainfall make it difficult for farmers to have diverse annual rotations. As such it may be advisable to promote no-till chemical fallow as one of the CA principles to reduce production costs and achieve acceptable wheat yield.

Keywords: *Conservation Agriculture, no-till, winter wheat, crop rotation, fallow*

The effect of legumes on soil fertility and nitrogen supply to field crops in conservative agriculture

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Intensive agriculture leads to a reduction in the humus and nutrients content in the soil and the predominant provision of mineral nutrition for field crops through the synthetic fertilizers applying. At the same time, the conditions of many natural plant species are deteriorating in agricultural ecosystems and greenhouse gases are increasing.

Long-term studies conducted at VNIIOU on sandy and coarse loamy Sod-podzolic soils of the Vladimir Region demonstrate the great potential of legumes as biological sources of nitrogen and effect of root residues.

Evaluating different legumes results shows that a total biomass of the above-ground and roots of perennial legumes amounted to 11.7-18.5tonne dry matter/ha, of which 40-56 per cent was root residues. On average, 6.3 t dry matter/ha/yr and 131kgN/ha/year was left in the soil with root residues of perennial legumes. Red Clover has the highest nitrogen-fixing capacity (263kgN/ha/ year), as well as perennial lupine and yellow melilot. Of the annual legumes, the largest amount of nitrogen was fixed by the annual yellow lupine but even this is only half compared with red clover.

In the non-Chernozem Zone of Russia, legumes are cultivated as cash crops, forage and as cover crop/ green manure. Generalization of the results of the Institute's long-term field experiments reveals that if the share of legumes in the crop rotation increases to 40 per cent, the yield of the rotation as a whole will increase by 1.6 times compared with the variant without fertilizers and by 1.5 times that of the variant receiving manure. The field experiments with different crop rotations shows that, with an increase in the share of perennial anal legumes (red clover) and perennial legumes-cereals grasses (red cover and timothy) in the rotation to 40 per cent the deficit-free balance of humus provided even without application of organic fertilizers. With an increase in the rotation rate of the share of perennial legume-cereal grasses up to 50%, the content of organic carbon increases by 0.029% per year in the soil during time of the crop rotation. At the same time, the content of easily decomposable components of organic matter in the soil increases by 4-5 times.

Lessons from biologic interactions and farming practices as well future directions for a properly biologic approach of agriculture are discussed.

Keywords: *legumes specoes, humus, nitrogen fixation, red clover, crop rotation, cover crop/rotattion effects on soil attributes*

Innovative fertilizers and fertilizer management: key for Conservation and Precision Agriculture based sustainable production systems and environment

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The improved yields driven by fertilizer applications account for roughly half of all food produced today. Fertilizers will continue to be vitally important—along with improved soil health, water management and crop genetics—for feeding a rapidly growing global population. Food production will have to double by 2050 with less resources while confronting five major challenges i.e., balancing high productivity with environmental impacts; achieving climate-smart and nutritious agriculture; equipping all farmers with the knowledge, capacity and authority to practice sustainable plant nutrition; and minimizing and reversing degradation of natural resources. Transformative management approaches and technology solutions will be required in the major agriculture-producing areas that provide the basis for future food and nutrition security. An integrated approach of Conservation and Precision Agriculture (CPA) based input management especially on plant nutrition and water management are the key to feed ever-increasing population and achieving climate –resilient sustainable production systems. The CPA based studies conducted across different agro-ecologies (rainfed and irrigated) of major production systems reveal that it improves crop productivity/yield, support sustainable cultivation, and improve smallholder security. Various crops including cereals, legumes, oilseeds, fiber, energy crops and vegetables can be successfully grown in CPA systems. However, it is vital that legume crops be included in cereal-based CPA systems as they improve soil properties and reduce the need for external synthetic N fertilizers. The incorporation of herbicide resistance strategies, including IPM; weed seed destruction; cover crops; and allelopathic crops (e.g., sorghum and sunflower) in crop rotations, are essential for controlling weeds, the biggest threat to the long-term sustainability of CPA systems. Use of CPA for vegetable crops is also important for sustaining the productivity of these systems globally. Our study in cereal-based system in South Asia revealed that yields of rice-wheat system increased in a range of 15- 27%, whereas the global warming potential intensity (GWPi) decreased. Positive economic returns and less use of water, labor, nitrogen, and fossil fuel energy per unit food produced were achieved. The CPA based crop diversification achieved 54% higher grain energy yield with a 104% increase in economic returns, 35% lower total water input, and a 43% lower GWPi. The CPA is most suitable for intensifying as well as diversifying wheat–rice rotations, but less so for rice–rice systems. This finding also highlights the need for characterizing areas suitable for CPA and subsequent technology targeting. But the literature review suggests that very few studies have been conducted on the innovative fertilizer management in CPA based system. Keeping in view that fertilizer application is one of the key drivers for agricultural and environmental sustainability. There is a need for dedicated approach to study the innovative fertilizer molecules and application methods under the CPA based systems.

Keywords: *Innovative Fertilizers, Conservation and Precision Agriculture, Global Warming Potential, Soil Health, Environmental Sustainability*

Impact of conventional soil tillage and raised- bed cultivation method on growth of winter wheat varieties

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Agriculture is an important part of the economy of the Republic of Azerbaijan and makes a significant contribution to ensuring food security for most of the population. Stable development of agriculture, increase production and the growth of the well-being of the population largely depend on the condition and fertility of the soil. However, over the past decades, agricultural land has been increasingly subject to degradation, which is steadily leading to a loss of fertility, and subsequently to a decrease in yield and production efficiency as a whole. In this regard, the impact of raised bed cultivation technology on the development of grain varieties, which contributes to the improvement of soil structure and fertility compared to traditional cultivation technology has been studied by us. The experiments were conducted at the Tartar regional experimental station of the Institute of Crop Husbandry Research work to study the effect of conventional soil tillage and raised bed cultivation on growth of winter wheat varieties "Azamatli 95", "Murov-2", "Tale-38" under different rate of fertilizer application. The effect of different tillage and sowing methods applied during the research on the following development characteristics of the plant was studied: seed germination percentage, number of productive tillers in the plant; the number of main stem leaves in the plant; plant height (cm) during the maturity phase; spike length (cm); the number of spikelets in the spike; the number of grains in the spike; the number of roots in the plant; root length (cm); dry weight of the root in the plant; weight of 1000 grains (g) and grain yield. Different effects of various soil cultivation methods on the development characteristics of winter wheat varieties were found. The most profitable option has proven itself in the technology of raised-bed cultivation and under $N_{120}P_{90}$ fertilizer application rate.

***Keywords**: tillage, raised-bed, conventional tillage, profitable, maturity phase*

Conservation Agriculture impacts in cereal-based cropping systems of South Asia: a meta-analysis

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Demand for staple crops in South Asia is expected to increase by 70% by 2030 and at the same time that resource degradation and climate-based production risks jeopardize current levels of productivity. As such, agriculture's contribution to meeting the Sustainable Development Goals (SDGs) requires a redoubled focus on innovations that are climate smart, regenerative, and broadly profitable. In the last decade, considerable attention has been given to Conservation Agriculture (CA) as a 'sustainable intensification' strategy, but there is a lack of evidence-based consensus on the merits of CA in the context of developing country agriculture. To assess the collective experience with CA in the cereal cropping systems of South Asia, a meta-analysis was conducted that aggregates data from 156 on-station and 1,197 on-farm trials. A total of 8,359 paired site-year comparisons is used to assess the performance of three core elements of CA (i.e., zero tillage, crop residue retention, and inclusion of a legume crop) in contrast to conventional 'best' agronomic practices. Results suggest significant, if not transformative, benefits when CA component practices are implemented either separately or in tandem. For example, zero tillage with residue retention had a mean yield advantage of 5.2%, irrigation water savings of 9.8%, reduction in costs of cultivation by 14.2% and increase net returns by 27.5%. From a more limited set of on-station trial data, evidence also suggests a reduction of 12-33% in the global warming potential with full CA adoption. Nevertheless, mean responses mask significant heterogeneity with more favourable responses observed on loamy soils and in maize-wheat systems, with negligible yield gains on sandy soils and 'others' cropping systems. However, cost savings and gross margin benefits were almost universally observed, with maximum benefits achieved in rice-wheat systems despite modest yield gains. Results suggest that CA and its component technologies provide real benefits in the cereal systems of South Asia, especially for its potential for increasing net returns, and there are opportunities for improved technology targeting to maximize expected benefits. Our results suggest that policy makers and development practitioners should continue to be appraised of the real but incremental potential of CA for contributing to the SDGs in South Asia.

Keywords: *zero-tillage, intensification, transformative, water savings, global warming*

Comparison and results of no-till versus Inversion practices in Nordic climate – conclusions after 14-year trial

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Koneviesti Magazine and Loimaa Novida agricultural school farm run a long-time trial site with several growing systems in comparable agronomic surroundings. This is the longest run such a trial site in Finland, now in 15th year. Including are several No- till practices, Mintill both at autumn and at spring and autumn Plough based practice. The purpose of this trial is to give farmers and researcher alike information of agronomic, economic and environmental situation of different growing methods.

Several ordinary measurements are recorded plus a few new ones. Environmental measurements are included – like runoff to waterways and emissions to atmosphere. Environmental recordings are based for sampling time to time, (due to limited resources).

A special attention is put on soil carbon balance. Unlike other finnish long-time measurements, Loimaa site can recently present data of whole soil profile (0 – 90 cm). Another new measurement is assessment of soil life – in terms of microscopic and other novel methods. The connection of plant nutrition versus grain nutritional quality is measured with XRF-technology, (gamma ray fluorisence). To make info from trial site useful for farmers also, we have adapted deep EC-soil scanning, NIR-based analyse of SOM and other agronomic measurement as part of husbandry policy. So far, we have been able to measure a positive carbon budget at Notill part of trial. A yearly accumulation has been positive by several hundred kilos C per annuum.

Other measurements have proved No- till to give constantly higher yields than counterpart methods, especially on dry seasons. Inputs for agchemicals has been less than expected. Usage is glyphosate has gone down and there is no need for routine applications anymore. Same applies for usage of fungicides which are not needed every year. Yields have not stagnated, rather increased year after year. We also develop our husbandry, covercrops will be the next area of interest. And finally we have collected economic data, which show how the different methods cope in economic terms. All basic data is published yearly in Koneviesti magazine. All measurements follow strict protocol and we have taken apart to UK ADAS YEN yield competition for 2 last years.

Conclusions so far are quite clear. If good rotational and agronomic standars is followed, No- till has been the best choice in all categories mentioned at the beginning of abstract.

Keywords: *Low fungisides, soil scanning, yield*

Soil moisture suction in no-till and tilled soils: analyzing long-term tensiometer measurements in the Swiss Central Plateau

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Fertile soils are crucial for human well-being, yet the intensification of agriculture and use of heavy machines increasingly threatens their quality. Agricultural practices with heavy machines expose soils to a high risk of irreversible subsoil compaction. Research has shown that from a sustainable land management perspective, soils should not be trafficked with heavy machines when soil conditions are wet (soil moisture suction <6 cbar at a soil depth of 35 cm). However, there is a lack of knowledge about the frequencies of wet soil conditions in Swiss agricultural soils and about potential influences of soil management systems on soil moisture. This study aims at closing these research gaps by analyzing the long-term (1996–2019) dataset of the Canton Bern including 13 different locations on six sites in the Swiss Central Plateau. Soil moisture suction data measured with five tensiometers per location at a soil depth of 35 cm and precipitation sums per site for three measurement days (md) per week are used. On every site, at least one permanent grassland and one crop rotation location are present. Furthermore, two tillage systems (no-till and mouldboard plough) and 11 different crops occur in the dataset. After data correction and validation, 22’947 md with available soil moisture suction data are analyzed. To put the results into a larger context, spade tests are performed at every location, and a climate and weather characterization of the years 1996–2019 is undertaken. Periods with wet soil conditions (<6 cbar at 35 cm soil depth) during the vegetation period from April to October range from 41 to 48% of the md for different locations (average over all sites), while site-specific differences range from 31 to 76% on permanent grassland locations. The duration of wet soil conditions can exceed three months in extreme cases. Furthermore, a seasonal curve in soil moisture suction is found and influences of the longer-term (≥3 months) weather conditions, as well as of single precipitation events on soil moisture suction fluxes are apparent. Differences in soil moisture suction fluxes are big between different sites and years: comparing a specific md over different sites and years shows that soil moisture suction values can cover the whole measurable range between 0 and 80 cbar. While the seasonal curve and the annual fluctuations likely originate from climate and weather influences, the differences between the sites cannot be attributed to a specific influence factor. Differences between permanent grassland and crop rotation locations can mostly be attributed to different crops’ seasonal evapotranspiration rates. Other systematic differences which hold for all sites and years cannot be identified. Differences between no-till and mouldboard plough are present, but non-systematic based on the analysis on one site. The spade tests show that tillage systems impact physical soil properties. In conclusion, the results point to a highly complex human-climate-soil-system. This study lays a valuable basis for future research, among others, by providing concrete recommendations for future study designs. Further research about soil moisture suction is needed to promote sustainable land management in Switzerland.

Keywords: *Soil Moisture, Tensiometer, Soil Compaction, Tillage Systems, Sustainable Land Management*

Mid and long term effects of Conservation Agriculture on soil organic matter, physical properties and biological activity in rainfed Mediterranean Soils

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In Morocco, a recent study of the soil fertility status at national level, based on the analysis of more than 36,000 samples, showed that the majority of these soils, under conventional agriculture, have low levels of organic matter (less than 2%). To reverse this degradation of organic matter, the use of Conservation Agriculture is a promising alternative. In this article, we will present the results of two sites under No Tillage (NT) on the mid and long term (16 and 32 years) in two clay soils (Vertisol) under different agroclimatic conditions (Sub humid and semi-arid) representing the rainfall cereal-based system. These result shows an increase in MO of up to 44% in the site in the long term up to 14% in the second site mainly in soil surface (0-20 cm). The analysis of the soil structural stability showed a significantly more stable aggregation under NT in the mid and long term compared to conventional tillage. The study highlighted that the soil compaction measured by the bulk density, which was higher at the start of the NT trial, was significantly reduced after 14 years under SD. This is explained by the soil biological activity which was quantified using enzymatic indicators and this activity was significantly higher under NT trial compared to conventional tillage.

Keywords: *Mid and long term, No tillage, soil organic matter, aggregate stability, biological activity*

LivinGro-A holistic approach to improving biodiversity and conservation in agricultural landscapes

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While above-ground biodiversity has been a topic of significant public interest over the last decades, soil biodiversity did not generate wide attention beyond the scientific and agronomic world. Syngenta's initiative called LIVINGRO™ takes a holistic approach to improving all dimensions of biodiversity related to agricultural activities in a given ecosystem.

Three-year pilots took off in Spain and Chile in 2020 and will start in Argentina, Mexico, and Germany this year. The aim is to generate robust, comprehensive scientific data that reliably measures how agricultural technologies and best farm management practices applied on crops grown in proximity to multifunctional areas consisting of indigenous annual flowering plants, can boost both sustainable food production and healthy, diverse ecosystems above and below ground, in and beyond the field. Together with scientists from public and private research organizations, Syngenta set off on a journey to study all insect orders from the surface and below ground. In addition, we also examine the soil microbiome and structure, as well as its ability to make nutrients bio-available for plants and to sequester carbon.

By taking a holistic view of biodiversity, including the soil microbiome, LIVINGRO™ has the potential to provide scalable measures for regenerative agriculture systems and improved food production sustainability in biodiverse, thriving, and healthy ecosystems, protecting our most precious agricultural resources, soil and water.

Keywords: *Biodiversity, conservation, regenerative agriculture, soil health, crop benefits*

Minimum tillage and no-tillage effects on VSA indicators at different pedoclimatic zones in Europe and China

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Under the H2020 project iSQAPER, 29 sites with min-till and 12 with no-till practices were identified across 7 and 5 pedoclimatic zones, respectively. These fields/plots were paired with nearby control fields/plots, sharing similar farming features but cultivated using topsoil inversion tillage. All plots were georeferenced and in 2016 a visual soil assessment (VSA), with a convenient score system (poor, moderate and good), of various components of soil quality was conducted on the soils of all fields/plots, complemented by measurements of soil organic matter, labile organic carbon content, pH and texture. Climate variables and indices (mean annual temperature, precipitation and potential evapotranspiration, aridity index, net primary production potential, and Gorczyński Continentality Index) were estimated using the software New_LocClim_1.10 for all locations.

No-till fields/plots have a statistically significant higher proportion of good scores ($p<0.05$, chi-square test) with respect to soil structure and consistency, soil porosity, soil stability (slake test), and susceptibility to wind and water erosion when compared to control fields/plots; the strength of the effect, given by Crámer's V for these VSA indicators, being V=0.85, 0.51, 0.43 and 0.43 respectively. The min-till group shows no statistically significant differences in VSA indicator scores with control fields/plots. Measured soil properties show no statistical difference between both conservation tillage groups and respective control groups.
Due to an insufficient number of no-till sites further statistical analysis was performed only for the min-till and control groups. Spearman's rank-correlation coefficients between VSA indicator scores and climate variables, within each group (min-till and control), show important differences between the two groups with respect to soil structure and consistency, porosity and colour. Correlation coefficients between VSA indicators scores and soil properties also show important differences between the two groups, especially the correlations of the VSA indicators soil

structure and consistency, porosity, colour, susceptibility to erosion, and surface ponding, with one or more measured soil properties.

We used Spearman's rank-correlation to detect potential interactions between climate variables and soil properties, by calculating the correlations with VSA indicator scores within min-till and control groups. The potential interactions detected are distinct between min-till and Control. Despite the small sample (n=29 per group and missing data for some variables reduced n further (e.g. for soil organic matter n=13)), exploratory analysis using Linear Discriminant Analysis, show that an important error reduction in the scoring classification, in comparison to a random classification (prediction of the VSA indicators' scores), can be achieved for most VSA indicators with few variables and/or interactions (e.g. presence of tillage pan, n=18, we achieved an error reduction of 83.3%, using penetration resistance and mean annual temperature as explanatory variables).

We argue that min-till practices effects on VSA indicators scores, although not statistically different from those with conventional tillage, may have, at particular locations, a less negative impact on soil quality and soil conservation than conventional topsoil inversion practices; we also argue that a dataset with a higher number of records would allow the development of equations to accurately predict the effect of conservation tillage (no-till and min-till) and conventional tillage practices (topsoil inversion) on VSA indicator scores.

Keywords: *soil quality; soil management; climate effect; VSA*

Tillage and crop rotation effects on soil carbon and selected soil physical properties in a Haplic Cambisol in Eastern Cape, South Africa

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Tillage and crop rotation influence soil quality and productivity hence the main aim of the study was to evaluate their effects on the soil bulk density, porosity and soil water content on an Oakleaf soil form. Conventional tillage (CT), no-till (NT) and crop rotations; maize -fallow-maize (MFM), maize-fallow-soybean (MFS); maize-wheat-maize (MWM) and maize-wheat-soybean (MWS) were evaluated during the 6th season of an on-going field trial. The field experiment was a 2 × 4 factorial, laid out in a randomised complete design. The crop residues were retained for the NT plots and incorporated for the CT plots after each cropping season. Significant interaction effects of the tillage and crop rotation were observed on the soil porosity ($P < 0.01$) and the soil water content ($P < 0.05$). The porosity for the MFM (45.28%) and the MWS (48.18%) was higher under the CT, whereas for the MWM (45.36%) and the MWS (46.85%) was higher under the NT. However, the greatest porosity was under the MWS. Whilst the NT significantly increased ($P < 0.05$) the soil water content compared to the CT; the greatest soil water content was observed when the NT was combined with the MWM rotations. The soil organic carbon (SOC) was increased more ($P < 0.05$) by the NT (1.25%) than the CT (1.06%), and the MFM consistently had the least SOC compared with the rest of the crop rotations, at all the sampling depths (0–5, 5–10 and 10–20 cm). The soil bulk density negatively correlated with the soil porosity and the soil water content, whereas the porosity positively correlated with the soil water content. The study concluded that the crop rotations, the MWM and the MWS under the NT coupled with the residue retention improved the soil porosity and the soil water content levels the most.

Keywords: *Conservation Agriculture; crop residue; retention*

Conservation Agriculture practices: an alternative to improve and stabilize crop yields and soil quality in rainfed Mediterranean region

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Crop yield in the rainfed Mediterranean environment, hot-spot for climate change, is highly affected by the rainfall variability, heat, and temperature extremes. With the declining rainfall amount, increasing rainfall variability and temperature extremes, and declining soil quality, crop production is affected, hence threatening food security in the region. Conservation Agriculture (CA) practices such as reduced tillage, soil cover, and crop rotation, are recognized as a set of adaptive agricultural systems in climate-sensitive regions. CA helps to conserve soil and water resources, enhance crop yield and stabilize crop production and improves soil health. Yield stability of major food crops, i.e., barley, wheat, chickpea, and lentil, grown under CA in variable rainfall conditions of the Mediterranean environment in Morocco, is not well understood. We have analysed the medium-term effect of CA in four major crops (barley, chickpea, lentil, and wheat) on grain yield, stability, and effect on soil quality while comparing the conventional tillage (CT) system (i,e. soil tillage, residue removal). The experiment was conducted in the International Center for Agriculture Research in the Dry Areas (ICARDA) research station in Morocco under CA and CT system for five growing seasons (2014/15-2018/19) contrasted in the rainfall amount, i.e., 480, 255, 276, 519 and 299 mm, respectively, and its distribution. The experimental station has clay soil. The commercial variety of each crop was used in the experiment and fields were uniformly managed for fertilizer, weeds, pests, and disease. On average, across the crops and years, grain yield was significantly higher under CA (by 19%; 0.29 t ha^{-1}) than in CT. Conservation Agriculture significantly increased the grain yield of chickpea by 18.8% and wheat by 42.7% than CT, while a similar yield was observed in barley and lentil between CA and CT. In chickpea and wheat, the relative yield stability of CA was higher than those of CT, indicating a transition to CA increase yield stability in wheat and chickpea. However, in barley and lentil, the relative stability of CA does not differ significantly from those of CT. Higher soil organic matter (higher by 11 and 7%), available phosphorus (higher by 13 and 3%), and exchangeable potassium (higher by 5 and 15%), in top 5cm and 30 cm soil profile, respectively under CA than in CT, indicating the adoption of CA practices leads to improve soil quality. All this evidence indicating that the adoption of CA technology provides i) higher and stable yield for wheat and chickpea and no yield penalty for barley and lentil and ii) improve soil quality in the rainfed Mediterranean environment in Morocco.

***Keywords**: yield stability, conservation tillage, soil quality, wheat, barley, chickpea, lentil*

Grain yields, nutrient availability and gross margins from Conservation Agriculture systems in two contrasting agro-ecologies of the Eastern Cape, South Africa

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Conservation Agriculture (CA) can arrest soil degradation, improve soil fertility and crop productivity. However, the ability of CA to provide the incentives in the short-term of practice is an issue of debate. This study investigated the short-term effects of tillage, crop rotation and residue management on soil organic carbon (SOC), soil nutrient availability (N, P, Ca, Na, Mg and K), crop yields and profitability at Phandulwazi and University of Fort Hare research farm (UFH) which are sub-humid and semi-arid, respectively. The experiment evaluated crop rotations: maize (*Zea mays* L.)-fallow-maize (MFM), maize-fallow-soybean (*Glycine max* L.)- (MFS); maize-wheat (*Triticum aestivum* L.)-maize (MWM) and maize-wheat-soybean (MWS) and residue managements: removal (R-) and retention (R+). There was no significant interaction of main effects with respect to the soil properties and crop grain yields with the exception of mineral N from the 5-10 cm soil depth at Phandulwazi. Residue retention was effective ($P<0.05$) in increasing SOC in the 0-5 cm depth at both sites. The mineral N by the crop rotations followed a trend: MWS>MFS>MFM>MWM, at both sites. Addition of soybean in rotations improved N-fertility compared to the cereal-only rotations. Residue retention significantly ($P<0.05$) increased Olsen P in 0-5 and 5-10 cm soil depths at UFH but not at Phandulwazi. Residue retention increased the bases across the sites compared to removal. Residue retention was consistent in significantly increasing crop grain yields than residue removal in seasons 2 to 5. After five cropping seasons, the greatest net benefits as well as increased profits were realised from the MWS crop rotation under NT with residue retention. Residue and inclusion of soybean in crop rotations are key in increasing crop productivity in the short-term.

***Keywords**: Crop rotation effects, residue management, no-tillage, smallholder farming*

Measurement of Carbon Flux in Nordic growing conditions comparison of different management practices

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The Finnish Conservation Agriculture Association FiCA has had a two-year 2019 - 2020 transmission of information project during which the association has measured carbon dioxide emissions and carbon sinks in the field from different cultivation methods and different soil types.

The project has been done because there is contradictory information in official research on climate emissions from the field, especially in peatlands. Measurements of the FiCA project show, that in the long-lasting no-till Conservation Agriculture, the carbon dioxide emissions of the field are reduced to a minimum. Then the fields become a carbon sink and a carbon store. This applies for equally to peatsoils and organic soils. These results are indicative and they need more accurate and longer-term measurements. This will be the subject of many studies in the future.

The traditional plowing method was in the measurements a major source of CO_2 emissions, especially in peatlands. Minimal tillage increased emissions, but its were quite small compared to plowing. Perennial grass also reduced peatsoil carbon emissions, but replanting grass by plowing method released its carbon dioxide. It is also possible to renew the grass with CA, so that the carbon bound by the grass is not released. Measurements of the FiCA project have been made from farmers fields, that have been in Conservation Agriculture for a long time. Measurements is also done from conventionally minimally tilled, plowed and tilled fields. The measurements have been done with a Vaisala carbon dioxide meter and with various transparent and opaque chambers. Plant assimilation use from the soil coming carbon dioxide and in addition reduce carbon dioxide from air -100–200 ppm during the day in the transparent chamber.

To reduce CO_2 emissions in peatlands, official research recommends restoration of peatlands by rewetting to swamp, raising groundwater levels, grass cultivation and afforestation. Conservation Agriculture makes it possible to retain peatlands and organic land in agricultural use and keep the carbon in the soil in which case these mentioned actions are not required.

The FiCA project has also measured the accumulation of organic carbon in the soil by annealing loss measurement. In long-term during 20 years CA, the amount of organic matter in farmers fields has increased by 1-1.5%. FiCA has also interviewed FiCA association farmers, how to succeed in no-till Conservation Agriculture. Interviews show that Conservation Agriculture has saved cost, increase yields, carbon to soil and weather resilience.

***Keywords**: Soil carbon sink and store, experience and information sharing and resilience.*

We will starve before we bake – global priorities are politically titled and funded

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While there is no doubt that the Earth has warmed over the last 40 years (see satellite graph). There is no doubt that the earth is rapidly losing its topsoil. No one with knowledge disputes this! Tillage washes our soils into oceans – never to be seen again.

While climate change is discussed almost nightly and is taught in schools globally, soil erosion is ignored. Climate change fills the scientific literature and funding for it is assured. Business entrepreneurs live on the opportunities it creates and politicians must talk about it – to get votes. Yet, in contrast, soil erosion is ignored.
If atmospheric CO_2 levels rose to 800 ppm most people would still have food, yet it would be warmer and possibly wetter. At the same time there is no news about the earth's capacity to regulate and compensate itself, through re-equilibration both biologically and chemically. Elevated CO_2 does increase crop yields, provided rainfall is constant, which it has mostly been in Australia for the last 100 years.
In contrast, the loss of soils due to extravagant tillage is a catastrophe here and now, and for at least 200 years. This need not be the case; we know no-tillage works, especially in drought areas. Tillage has huge consequences for the earth and its peoples (see image). We know that without soils we will starve! The practice of tillage is destructive to soils and its capacity to absorb and hold water. This is a serious environmental matter, right now!

Europe is losing soil a billion times faster than it is being formed, washing precious soils away at an alarming rate. Perhaps, of the 100 cm of the original soil, half is now lost and it continues in silence. No celebrity gives talks about this. Where are the political speeches on it? In 30 years' time we will look back and say "it was a crime against humanity" and we did it with tillage. We will have lost our most precious resource and we did not stop it – is this what we want? We won't get it back. The world must re-think – what will likely cause mass starvation?

No-tilled soils hold a secret that few know, a small secret power. It's called glomalin, a glue that holds soil together and it builds up over years of no-till and improves soil water infiltration, allowing soil to store more water to better cope with drought, and stops the soil from sealing over. Tillage smashes it and causes the rivers to bleed soil into oceans. Also no-till allows farmers to store carbon – the greatest C storage capacity on earth.

If global warming is what makes our young people suicidal, yet we can adapt. But, a loss of the earths topsoil is real, ongoing and it will likely cause the future wars. Let's have a conversation about what tools farmers need to help them adopt no-till and save our soils!

Keywords: *soil erosion, glomalin, no-till, topsoil.*

Impacts of post-sowing compaction on temporal variation of soil temperature for different wheat growth period in North China Plain

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Temporal changes induced by post-sowing compaction in soil temperature are not yet well understood, as they might significantly affect the soil–vegetation–atmosphere transfer system. Soil temperature temporal variation during the whole growing season is important because of its potential influence on the crop growth and yield. Therefore, on-farm field trials were conducted in Beijing of North China Plain to study the impact of post-sowing compaction treatments on temporal change of soil temperature from sowing to green stage during wheat growing season from October to February in the second year. Three different post-sowing compaction devices were used to test: (1) compaction wheel of rubber (CW), (2) compaction roller consisting of welded steel bars (CR) and (3) two kinds of compaction rollers (traditional roller behind compaction roller consisting of welded steel bars, soil was compacted twice in this treatment) (TCR). Soil temperature was progressively determined with soil temperature sensor to a depth of 60 cm from sowing to green stage. Five soil moisture sensors from each plot were inserted into soil surface of intra-row and inter-row, 20cm, 40cm, and 60cm to monitor soil temperature. Effects of the three compaction methods on temporal dynamics of soil temperature within different soil depth (0-60mm) in different growth period of wheat was measured with. soil temperature was not significant on the surface soil profile among three post-sowing compaction devices for both the intra- and inter-row at the sowing stage. After one month of sowing, for the intra-row surface soil, the highest temperature has been measured in CW treatment, and the temperature variation in a 24-hour cycle was smaller than that under CR and TCR treatment. the temperature under CR treatment was higher than that under TCR treatment one and two months after sowing and lower than that under TCR treatment three and four months after sowing in the night time; and the result in the daytime in contrast to that in the night time. The soil temperature in different soil depth was almost stable in 20-60cm soil depth in a 24-hour cycle, and the deeper the soil depth, the higher the soil temperature. This may be caused by the thermal insulation provided by vegetation, water, and surface soil layers, and the variation in soil temperature was lower at deeper soil than surface soil. Results of this study demonstrated that measuring temporal variation of soil temperature in different growth period will provide theoretical support data for soil and crop management.

Keywords: *Soil temperature; Post-sowing compaction; Different growth period*

Impact of Conservation Agriculture on major diseases of crops (wheat, mustard, potato, maize and cauliflower) grown with rice-based cropping systems

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Degradation of soil and depletion of its beneficial microbial population are common under intensive agriculture making it susceptible to diseases. It necessitates use of huge number of fungicides making farming costly and harmful to the environment. Conservation Agriculture (CA) has emerged as an alternative to such intensive conventional agriculture to conserve soil, improve soil microbial population and suppress diseases.

With these in mind, we evaluated the effects of CA on the disease dynamics of crops (wheat, mustard, potato, maize and cauliflower) grown in rice-based systems in the Gangetic Plains of West Bengal. The experiment was laid out in split plot design, where different intensity of tillage (zero tillage, reduced tillage and conventional tillage) was in main plots and a combination of rice residue and different doses of NPK fertilizers [0% rice residues+100% recommended dose of NPK (RNPK), 50% rice residues+100% RNPK, 50% rice residues+75% RNPK, 100% rice residues+75% RNPK and 100% rice residues+50% RNPK] was in sub-plots with three replications to create a regime of CA practices. On average, grain yield of previous rice was 3672 kg ha^{-1} and 50 and 100% of its straw yield was used as residue for the above treatments. There were five varieties each of wheat (DBW-39, DBW-107, HD-2967, DBW-38 and DBW-187), mustard (TBM-204, Bullet, B-9, ADV-414 and B-54) and maize (ADV-9293, PAC-751, ADV-757, ADV-759 and PAC-741) cultivated following rice with the above tillage-residue-nutrient treatments.

Results showed that in mustard, *Alternaria* leaf spot disease caused by *Alternaria brassicae* was minimum under reduced tillage with 50% rice residue+100% RNPK followed by conventional tillage with 100% residue+75% NPK. Among the five varieties of mustard, performance of Bullet was the best followed by TBM-204 and ADV-414 under the CA. In wheat, incidence of leaf blight disease was the least under zero tillage followed by reduced tillage. Among the residue-nutrient treatments, such incidence was minimum with 50% rice residue+100% RNPK. Among its five varieties tested, HD-2967 showed the highest resistance to leaf blight followed by DBW-107. Again, DBW-107 had the higher yield followed by DBW-187 under CA. In potato, occurrence of Phoma blight was the least under conventional tillage followed by zero and reduced tillage. Among the residue-nutrient treatments, 50% rice residue+100% RNPK had the least incidence. Occurrence of late blight disease was the highest in reduced tillage followed by zero tillage. It was minimum with 50% residue+75% RNPK across the tillage practices. In maize, southern corn leaf blight was the only major disease. Its occurrence was low under reduced tillage with 100% residue+75% RNPK followed by conventional tillage with 50% Residue+ 100% NPK combination. Among its five varieties, ADV-759 had the highest yield (15.1 Mg ha^{-1}) with least infestation of leaf blight across tillage and residue-nutrient treatments. *Alternaria* leaf spot was observed in cauliflower and its infection was minimum under zero tillage followed by reduced tillage. All these indicated that under zero and reduced tillage, application of 50% residue+100% RNPK for wheat, mustard and potato, 50% residue+75% RNPK for maize and 0% residue+100% RNPK for cauliflower were superior in respect of disease suppression.

Keywords: *cropping system, tillage operation, crop residue, plant disease*

Conservation Agriculture technologies increase production and productivity of cereal based farming system in Eastern Plains of Nepal

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This study was conducted to assess the impacts of conservation agricultural practices on crop productivity, profitability and ultimately sustainability of the cereal-based farming system of eastern plain region of Nepal. Majority of the farmers in this region are opting conventional agriculture practices which increases the cost of production, labor-intensive, decline in land and water productivity and ultimately to threat in sustainable intensification in the region. Sustainable and Resilient Farming System Intensification (SRFSI) has been adopted in responses to the concerns about the sustainability of the cereal-based farming systems (rice-wheat and rice-maize) in Sunsari and Dhanusha district. The study employed structured questionnaires and key informant surveys as the main data collection tools and project reports as secondary sources. Descriptive statistics like sum, average, percentages, and ratios were calculated to evaluate the socio-economic and production input data. Productivity was measured using production per unit area and profitability was measured in terms of gross return, gross margin, net return and benefit cost ratio. It has been found that there are several benefits like: cost of production, water consumption, lower labor requirement, lesser weed infestation under conservation agricultural practices compared to conventional farming system, like lower labor utilization (71 person days ha^{-1} compared to 106 ha^{-1}), lower input cost (NRs 78,395 ha^{-1} compared to 102,727 ha^{-1}), 50% less irrigation ponding time, and slight higher but not significant system productivity (8.11t ha^{-1} compared to 8.08 t ha^{-1} in rice-wheat and 13.1 t ha^{-1} compared to 11.75 t ha^{-1} in rice-maize) farming system through the adoption of Conservation Agriculture practices.

***Keywords**: Conservation Agriculture; EIGP; Farming system; Rice-maize; Rice-wheat*

Soil quality changes under long term Conservation Agriculture in Morocco (Region of Rabat- Merchouch)

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Conservation Agriculture (CA) is based on three linked principles low to no soil disturbance, with no-till (NT), mulching and crop diversification and rotation. Compared to conventional agriculture (CT), CA contributes to mitigating the impact of climate change by reducing carbon emissions and conserving natural resources. Indeed, CA enhances crop yields while simultaneously improves chemical, physical, hydrological and biochemical processes of soils. It increases the organic matter (SOC) content in the soil, saves 30-40% in terms of labour time, labour and fossil energy and facilitates water infiltration and significantly reduces runoff and erosion. In order to confirm such benefits, a long-term experiment was set up at the Merchouch experimental station of INRA is located 68 km south-east of Rabat in order to compare CA and CT in a Wheat-Chickpea rotation (Soft/bread wheat, variety Arrehane and chickpea, variety Farihane). Physical and chemical properties were measured at five depths (0-5, 5-10, 10-20, 20-40, and 40-60 cm). Generally, tillage system affected the physical and chemical properties of the soil, mainly in the surface layer (0-5 cm). After thirteen years of experimentation, the NT system showed significantly ($p<0.05$) higher dry bulk density, gravimetric moisture, organic carbon, and aggregate stability in three different depths than CT. For nutrients, a significant difference between NT and CT was found for P_2O_5 (p value = 0.0027) and total N (p value = 0). However, no significant difference between the two systems was observed for K_2O at all depths (p-value = 0.818). Our results indicate that NT improves soil fertility and sequesters organic carbon in a vertisol of a semi-arid Mediterranean region.

Keywords: *Conservation Agriculture, No-tillage system, Soil quality, Vertisol*

Is Conservation Agriculture 'female friendly'? learnings from the Eastern Gangetic Plains of South Asia

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Conservation Agriculture (CA) has proven benefits for poverty-stricken smallholder farmers in the Eastern Gangetic Plains (EGP) of South Asia, but there has been limited analysis of how gender implicates on CA adoption, roles, agency and impact. Using three interrelated data sources (in depth interviews of female decision makers; in depth interviews with female spouses of male decision makers; and a novel photo dairy/photo voice activity) across six locations in Nepal, Bihar, West Bengal and Bangladesh, we explore how gender dynamics influence CA uptake and benefits, with a particular focus on addressing the as yet clearly unexplored research question: is CA 'Female friendly'?

Answering this across the region is complicated by various cultural norms. In most locations, women have minimal involvement in agricultural decision making at household level (except some parts of West Bengal). Despite this, females were engaged in substantial farm activities that could be potentially influenced by the implementation of CA. Females farmers broadly identified that CA directly led to labour savings that were reallocated to other purposes, due mainly in part to less burden and drudgery in weeding activities. They also identified that with herbicide use, their husbands or male labourers were tasked with spraying allowing for more supervisory roles. Additional time was usually repurposed to both economic and non-economic activities, mainly: [1] spending time with children and domestic tasks; [2] attending community classes; [3] mushroom cultivation; [4] rice seed bed raising economic activities; [5] cattle breeding and poultry. Beyond labour, females identified that money was particularly saved at the early stages of crop production through zero tillage and where possible they allocated these financial resources to cattle.

In terms of agency and empowerment, females broadly identified that they had an ambition to step away from agricultural duties, which was facilitated through CA. In North Bengal and northern Bangladesh, females also expressed interest in machinery operation, but usually in the context of mechanical rice trans planters and two-wheel tractors and not with four-wheel tractors. However, this was hampered not by any perceived stigma, but a lack of training opportunities and a reliance on male spouses to obtain agricultural information. Conversely, there was an acknowledgement in the potential loss of agency with an increasing knowledge gap -particularly around herbicides and operation of machinery that could potentially lead to disempowerment. Females also highlighted concern with transitioning to maize and away from wheat using CA, as poor performance on a crucial cash crop would implicate on household budgets and support to children. Hence, females were likely to be negative towards zero tillage maize production.

Exploring if CA is 'female friendly' is complex, particularly noting the varying levels of agency and empowerment across the EGP. Overall, there was more positivity than negativity, particularly from the perspectives and lived experiences of females in this study. This highlights a need to review extension mechanism that engage with females and address some of the highlighted concerns to ensure equitable promotion, benefits and uptake across the region. Future research also needs to encompass intrahousehold (beyond female spouses and decision makers) and intracommunity (female labourers) perspectives to further understand the impact of CA adoption on women.

Keywords: *Gender; Equitable development; female friendly; female workload*

Greenhouse gas emissions missions in various cereal fertilization strategies in Conservation Agriculture in Mediterranean climates

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Fertilization is one of the most important agricultural activities whose main objective is to maintain and increase crop yields. Crops require quantities of nitrogen (N) necessary to meet the crops' nutritional demands. In this sense, it is very important to know the optimum levels of nutrients that allow to cover the nutritional needs of crops, maximizing their growth and development without increasing greenhouse gas (GHGs) emissions. Wheat (*Triticum*) is a winter cereal whose main nutritional element required is N. To produce a ton of grain 30 kg of N, 5 kg of phosphorus (P_2O_5) and 19 kg of potassium (K_2O) are needed. N availability below these levels during the crop cycle leads to smaller plants and reduced leaf growth. As consequence, there is a lower grain production and dry biomass content and, in turn, a lower quality of grain. In this sense, this work compared the GHGs emissions in Conservation Agriculture (CA) and Conventional Tillage (CT) under different types (urea, micro-complexes and mi-crogranulate) and doses of fertilizer. With this aim, the CO_2 emissions (CO_2 equivalents) have been analysed in two farms in the South of Spain, one of them located in the municipality of Córdoba city and the other in the Cabezas de San Juan (Seville). In both farms, in which the CA and CT management systems were carried out, we measured the CO_2 emissions through fuel consumption by cultivation operations and calculated the emissions originated by the agrochemicals applied during the crop cycle. Each farm was divided into twenty-four plots. According to the results, the CO2 emissions generated by the fuel used from the machinery were higher than those of CA (between 15% and 25%). Under CA, the total CO_2 emissions are lower than under CT (between 10% and 15%). Therefore, CA should be recommended as agricultural management system to reduce GHG emissions while improving soil and water quality.

Keywords: *Fertilizer, Nitrogen, No-Tillage, Climate change*

Profitability, work rate and fuel use in crops rotations in Conservation Agriculture vs conventional tillage in Mediterranean climate

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Agricultural systems based on intensive tillage for soil preparation and control of weeds lead to the degradation and loss of soil by erosion, contamination of groundwater by nitrates while decreasing the farms profitability. The adoption of model based on Conservation Agriculture (CA) provides similar and even higher yields by improving the structure and soil organic matter content, increasing its fertility. In turn, production costs are reduced by minimizing the use of cultivation operations. In this context, two farms located in Seville (south of Spain, Andalusia) have been analysed. In both farms have been established three management systems: conventional system plough based (CT), sustainable system 1 (S1) based on plough and rational strategy of inputs, and Conservation Agriculture system (S2), in which it has been carried out a rotation of cereal (Durum wheat), oilseed (sunflower) and legume (chickpea). The crops have been monitoring for two years. For the calculation of fuel consumption, it has been taken in account all machinery operations in each plot during the two agricultural seasons. Regarding the operations, it has been taken into account from harvest of the previous crop to the harvest. The results showed that S2 saves the 55% of fuel for the entire rotation compared to CT and the 51% compared to S1, detecting the greatest difference for the sunflower crop (64%). The work rate per hectare is similar for CT and S1 due to they used the same tillage operations. S2 requires the 49% less work time. All of this makes that CA a viable alternative to consider in comparison to the CT, in which a series of indicators (work rate, fuel use, operational and all mechanical operations costs) have been continuously monitoring to demonstrate the benefits that the CA contributes to the farm in an environmental level, economic and social.

Keywords: *, No-Tillage, work rate, sustainable system, reduction cost*

Agro-economic performance of mechanized Conservation Agriculture in Zambia

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Conservation Agriculture (CA) is depicted as a climate-resilient and sustainable practice capable of enhancing food security in sub-Saharan African (SSA) countries. However, its continued promotion and adoption has been predominantly on a non-mechanized small-scale basis. Despite the ample evidence of the positive benefits of CA, including enhanced yield, carbon sequestration and minimal soil degradation, its adoption remains low in Zambia. Improved mechanization results in increased agricultural productivity; yet, this potential has not been harnessed in Zambia, making CA labour intensive and unattractive to farmers. The objective of this study was to investigate the potential differences between mechanized conventional and conservation tillage practices on operation time, fuel consumption, labour costs, soil moisture retention, soil temperature and crop yield. On-farm mechanized CA experiment in a randomised complete block design with four replications was employed on a 15ha plot with two crops, maize and soyabeans. The three tillage treatments were: residue burning followed by disc harrowing, ripping tillage and no-till. The crops were rotated in two subsequent seasons. All operations were done using a 60hp 2-wheel tractor, a disc harrow, a two-tine ripper and a two-row planter. Soil measurements and the agro-economic factors were recorded for two farming seasons. The results showed that the yield of maize and soyabean under no-till and ripping tillage practises were not significantly different from the conventional burning and discing. There was a significant difference in soil moisture retention per cubit unit of soil between no-till (0.300±0.198 m^3/m^3) and disc-harrowed (0.168±0.011 m^3/m^3) plots at depths from 10-60 cm. Soil temperature in no-till plots was significantly lower compared to the disced plots at the depths 15 cm and 45 cm. For maize, there was a significant difference in operation time between both disc-harrowed and ripped and no-till plots, and a significant difference in fuel consumptions between disc-harrowed (18.67±1.25 l/ha) and ripped (14.46±1.82 l/ha) and no-till (8.90±1.52 l/ha) plots for the two seasons. There was no significant difference in the cost of labour between disc-harrowed (102.7±20.7 $/ha) and no-till (76.6±14.6 $/ha) plots. For soyabeans, operation time on no-till (2.50±0.28hr/ha) plots was significantly different from the ripped (3.99±0.54 hr/ha) and disc-harrowed (3.72±0.64 hr/ha) plots for the two seasons. Further, fuel consumption on no-till plots was significantly lower than both the ripped and disc-harrowed plots but not the labour. The high maize plant densities were not significantly different between the treatments for the two seasons. There was a significant difference between soyabean plant densities in the no-till and ripped plots compared to the disc-harrowed plots. These results indicate that MCA is economical and time-saving. Its yields are also viable compared to conventional farming. This research fills the gap on the potential of mechanized CA in the context of Zambia and its feasibility to incentivise policymakers to invest in appropriate and sustainable machinery and implements for improved small and medium-scale agricultural production.

Keywords: *Climate-smart Agriculture, Mechanized Conservation Agriculture, Soil moisture, Yield, Zambia*

Impact of nitrogen placement strategy on performance of maize under 12-year long-term Conservation Agriculture in north western Indo-Gangetic plains of India

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Nitrogen-N management under Conservation Agriculture-CA is a challenging issue. Residue retention on the soil surface hinders the effective placement of nitrogen. Subsurface placement of nitrogen can be potential options to increases the N use efficiency. The source and pattern of N accumulation by plant change as crop growth advances. So, to explore the potential of N sub surface point placement towards crop growth, N uptake and N remobilization, a field experiment was conducted with three tillage practice (Permanent raised bed: PB; Zero tilled flat: ZT; and conventional tilled flat: CT) and 3 N placement methods (NPM1: both the N split was surface band placed; NPM2: 1st split N was point placed and second split was surface band placed; NPM3: both the N split was point placed). The N accumulation till the end of vegetative stage was significantly higher in the CA based PB plots than CT among the tillage plots and in the NPM3 than NPM1 among the N placement plots. The accumulated biomass of maize in the PB and NPM3 plots acts as driving force for N accumulation, which increased the N remobilization by ~22%. Similarly, the N uptake during the reproductive stage was higher in the PB and NPM3 plots by ~10.5%. Only the long-term tillage practice could able to change the maize crop growth behaviour. The grain yield in the CT-NPM3 was similar to the CT-NPM2, whereas the NPM3 of CA based PB and ZT plots had significantly higher maize grain yield than NPM2 of CA. Although the economics of maize cultivation with point placement technology is favourable, the constraints like availability of machinery need to be addressed for its widespread adoption. The performance of CA based PB and ZT plots were statistically similar to each other.

Keywords: *soil surface, nitrogen management, zero till*

Conservation Agriculture (CA) has to move on

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After nearly five decades, zero tillage (no-till), the bedrock of CA, is *dejá vu* in Brazil. But CA is not just leaving the soil protected with residues or cover crops and planting/drilling crops through them, quality CA also requires a pluriannual rotation, frequently absent. It is also evolving by incorporating new compatible and sustainable technologies. Farmers, including organic farmers, are learning how to incorporate innovative biological and mechanical methods for disease, pest and weed controls, reducing pesticide and fertilizer use; the Farmer Responsibility Index underlines significant recent reductions in chemical hazards. As consumers demand greater food traceability, certification and benchmarking will continue to expand, while increasing complexities in soil, water, crop and livestock management are demanding higher skill levels and widespread use of specialized consultants. The success and longevity of the CA movement will depend on incorporating and promoting new compatible and sustainable technologies, such as biological controls, precision agriculture, controlled traffic farming, and drones for scouting and spot spraying. CA then provides land use intensification to reduce horizontal expansion, improved aquifer recharge, erosion control and other important environmental benefits, plus increased profit and lower food prices, with less negative environmental impacts. Historically, the environment has suffered, therefore, the above urgently requires more promulgation, backed by research. To expand the scope, and hence the definition, of CA, the following questions need to be addressed: (i) can CA become the umbrella definition for all these technologies; and, (ii) how do we adjust the concept to achieve this? One approach would be a CA base definition, with clarifying adjustments, and a list of approved compatible technologies. A challenge that needs to be addressed is from the novel label "Regenerative Agriculture" (RA), not yet scientifically defined but clearly based on CA principles. One approach would be to recognize CA as a *sine qua non* of agricultural sustainability, especially in the tropics, and the need to define additional science-based technologies that differentiate new labels from CA.

***Keywords**: Innovative technologies, agricultural sustainability, organic agriculture, Farmer Responsibility Index, Land Use Intensification, environmental impacts*

Effects of multifunctional margins implementation in annual crops on biodiversity

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Multifunctional margins implementation in annual crops is considered an important tool for increasing biodiversity in agricultural land. Increase biodiversity, in addition to its intrinsic value, provides ecosystem benefits, such as improvement in crop pollination, fight against pests and regulation of nutrients' cycle.
In order to know the effect of multifunctional margins implementation on biodiversity, the planting of 3 types of multifunctional margins, with different herbaceous composition for each of them was performed during the 2018-2019 agricultural campaign. With the purpose, not only to assess what floristic composition contributes to greater biodiversity, but also, what results it throws on a control margin of spontaneous flora. For this, the experience has been replicated in 4 farms located in the province of Seville (Spain).
In each farm, two plots have been established for each of the types of margins studied, with the intention of obtaining statistically significant data. For each plot, the Shannon biodiversity index, on the flora, on the arthropods that inhabit the plant species (aerial fauna) and on the arthropods that live on the soil (epigeal fauna), has been calculated.

For the evaluation of the results, various aspects have been taken into account to weigh the Shannon biodiversity index. As for the flora, the biodiversity of species that can serve as food for pollinating insects has been positively valued. While a negative value has been given to the presence of those that are potentially susceptible to invade the crop. Likewise, the biodiversity of pollinating insects within the aerial fauna has been valued to a greater degree than that of those who do not have this quality.

Taking into account these premises, a biodiversity value relative to each of the variables (flora, aerial fauna and epigeal fauna) has been obtained for each type of margin for all four farms, on a scale of 0 to 10. Subsequently, the average value of the three variables has been calculated, to obtain a global result that defines the qualities of the margin in terms of biodiversity.

The results reflect that the seeded multifunctional margins have a greater interest for their implantation, than those grown spontaneously. Specifically, the overall assessment of the four margins has been: Type 1 margin (7.16), Type 3 margin (7.04), Type 2 margin (6.85) and Control margin (6.24).

A particular study has also been carried out, taking into account only the Shannon biodiversity index for epigeal fauna in spring, with data on cultivated margins, control margin and crop. The results obtained for the four farms as a whole show a greater biodiversity of epigeal fauna in seeded margins (3.14) with respect to the control margin (2.99) and the one that owns the crop (2.73).

Keywords: *arthropods, auxiliary fauna, pollinators, biodiversity index, agri-environmental measures*

Emissions of greenhouse gases in rotation of crops with different crop management in Mediterranean climates

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The intensification of agricultural work, the burning of crops residues and the intensive use of inputs are increasing soil degradation. In addition, the effects of climate change are accelerating the process, generating strong impacts on food security and smallholders. Conventional tillage (CT) favours greenhouse gas (GHG) emissions: on the one hand, because the preparatory work (mouldboard, deep plough, disc harrow or rotating harrow) buries the remains of the plant and leaves the soil in optimal conditions for CO_2 losses; and, on the other, due to the number of work preparatory and the intensive use of inputs. Therefore, we face a triple challenge that constitutes food security, adaptation of food systems and people to climate change and emission mitigation (GHG) in agriculture. Conservation Agriculture (CA) promotes three fundamental pillars: crop rotation, maintenance of covered soil and minimal soil alteration. Through CA not only degradation is avoided, but also allows regeneration, improvement of biodiversity and productivity. For this study, two farms located in southern Spain have been monitored, both located in the province of Seville, in which a rotation of cereal-oilseeds-legume in three management systems has been established: conventional system (CT), sustainable system 1 (S1) and sustainable system 2 (S2). All crops have been monitored two years to study the rotation as a whole. For this, GHG emissions in the three systems in Mediterranean climates have been evaluated by analysed CO_2 emissions (CO_2 equivalents) according to the operations of each crop (use of machinery) and supplies (inputs) that are applied during the crop cycle. The results obtained between the different management systems have contributed to CA practice (S2) reducing GHG emissions between 15% and 18% compared to the conventional system and between 10% and 15% compared to the S1 system. Respect to CO_2 emissions, it is shown that the CA manages to favour air conservation, reducing air pollution by minimizing the mechanical operation of the soil that mitigates GHG emissions.

Keywords: *, No-Tillage, Climate change,Conservation Agriculture*

Perennial forage crops for improved soil nitrogen cycling in East African smallholder dairy systems

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Smallholder dairy farming is expanding rapidly in East Africa, posing challenges as well as opportunities to expand the use of Conservation Agriculture. Dairy cattle systems pose serious challenges for conserving soil resources due to high greenhouse gas emission intensities and land degradation. Perennial forages are gaining increased attention as a sustainable agricultural intensification strategy because they offer high-quality forage while alleviating some of the adverse environmental impacts associated with livestock. In particular, forage grasses that perform biological nitrification inhibition (BNI) may help to retain mineral nitrogen (N) in tropical soils that are at high risk for erosion and nutrient leaching. Dairy farmers are also interested in using leguminous forages as an intercrop with grasses and cereal crops to build soil fertility through N-rich leaf litter and root exudates. To understand whether perennial forage grasses and legumes can improve soil N cycling and fertility via plant-soil-microbe interactions, we collected soil samples from two replicated field trials in Rwanda. Each location included perennial forage grasses (*Brachiaria* cv. Mulato II and *Pennisetum purpureum*) grown alone or intercropped with the legume *Desmodium distortum*. As the farmer-preferred annual crop, maize was included as a baseline to compare against the perennial forage treatments. We quantified several N fractions and assayed for microbial activity. Bulk soil samples were collected before and after harvesting events over a period of six months that spanned both the rainy and dry seasons.

Preliminary results suggest that intercropping with legumes impacts soil microbial activity and N mineralization. At one study location, plots including *Brachiaria* cv. Mulato II resulted in lower ($p < 0.05$) levels of potential N loss through denitrification activity compared to treatments that did not contain *Brachiaria*. These results indicate that plant BNI effects extend to bulk soil processes that are directly tied to the retention of inorganic soil N. In the second location, *Brachiaria* treatments resulted in lower ($p < 0.05$) potential denitrification compared to *Pennisetum purpureum* but not maize treatments. Interestingly, while competition between perennial grasses and legumes resulted in reduced overall biomass compared to sole-cropped stands, legume presence did not stimulate potential N loss from microbial activity in all cases. While previous studies have identified a stimulatory effect of legumes on N loss through enhanced microbial activity, our results do not identify a trade-off between legume intercropping and N loss. Importantly, our preliminary analysis suggests that maize treatments are at a higher risk of N loss compared to perennial grasses when planted with *D. distortum*. Legume intercropping with BNI-competent grasses therefore merits further study as a management strategy to address the dual goals of maintaining plant productivity and limiting agriculture's environmental impact. We have shown that Conservation Agriculture practices can be used to sustainably manage soil resources; ongoing work will identify how farmer management and local conditions mediate the intended benefits of such strategies.

Keywords: *Nitrification, denitrification, tropical forage, soil fertility*

Soil quality changes after 20 years of conservation tillage

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Effects of conservation soil management on soil quality were studied in the long-term field experiment in Moškanjci, Slovenia, which was established in 1999 and shifted from conventional to organic farming in 2014. Long term conservation (minimum) tillage (MT), with reduced soil disturbances and improved residue management, resulted in stratification of soil organic carbon and nutrients with the highest concentrations in the very topsoil, as opposed to conventional tillage with mouldboard ploughing (CT), which maintained rather uniform distribution down to the ploughing depth. For instance, Corg content in the upper 10 cm layer was higher under conservation treatment (1.60% in 2011; 1.83% in 2017) than conventional (1.45% in 2011, 1.40% in 2017), while no significant differences between the treatments were found in the lower 10-20 cm layer at any sampling time. Similarly, also several other soil properties, such as aggregate stability and water holding capacity, were improved in the upper soil layer of MT in comparison to CT. Microbial biomass was also significantly higher in the topsoil of MT than CT. Furthermore, our results indicate an increase of microbial biomass after transition to organic agriculture in both tillage systems. Plant productivity, as an ultimate measure of soil fertility, was generally similar in both soil management systems, with smaller differences between cultures and years, however first year after transition to organic system, yield was highly reduced due to the high weed infestation, especially under MT treatments. Plant productivity, as an ultimate measure of soil fertility, was generally similar in both soil management systems, with smaller differences between cultures and years. However, in the first year after the transition to organic system, yield was highly reduced due to the high weed infestation, especially under MT treatments. This issue is addressed in our current research by studying the effectiveness of cover crops and specialized weeders and cultivators.
Observed soil quality improvement under MT supports introduction of conservation soil management into both, organic and conventional, agricultural systems as potential measures against erosion, drought, and nutrient losses. However, our results indicate that during the transition from conventional to organic system weed control is critical, particularly when conservation soil tillage is also implemented.

Keywords: *reduced tillage, organic agriculture, soil organic carbon, microbial biomass, microbial composition*

Should tillage be an evaluation factor in the breeding program for major cereal and legume crops?

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Conservation Agriculture (CA) based crop production is becoming more important in rainfed drylands due to its potential to minimize climatic risk, reduce soil erosion and improve soil quality and water availability. Due to minimum disturbance and crop residue retention, the soil environment for crop growth could differ between Conservation Agriculture and conventional practice. A limited research studies report the crop species and tillage (T), and genotype (G) by tillage interaction for the wheat, barley, lentil, and chickpea yield performance. It is also not well-understood whether tillage should be an evaluation factor in the breeding program in the Mediterranean rainfed conditions. A three-year (2015/16-2017/18) field study was conducted in the International Center for Agriculture Research in The Dry Areas (ICARDA) research field in Morocco to determine if significant crop species and tillage and genotype by tillage interaction existed on yield performance of wheat, barley, lentil, and chickpea. Thirteen advanced genotypes for each crop were planted in both conventional tillage (CT) and Conservation Agriculture (CA) systems. The strong inter-annual rainfall variation caused a significant difference in grain yield for all crops. Wheat and chickpea produced higher yield under CA than in CT, while lentil and barley performed equally in CA and CT. The G x T interaction was more frequent for chickpea than for wheat, lentil, and barley. For each crop species yield was mainly influenced by rainfall amount and distribution, and G x T was of little importance. The overall results suggest that a specific breeding program for CA in lentil, chickpea, wheat, and barley may not be efficient. However, the existence of some G x T interaction especially in dry years indicates that the selection of the traits which enhanced higher yield in CA especially in the low moisture condition could be important for the Mediterranean rainfed drylands. The existence of a trade-off between high yield and risk reduction in both tillage systems indicates that a breeding effort for the development of drought-tolerant and high-yielding genotypes is worth pursuing whatever the type of soil tillage. Thus, varieties with wider adaptability considering drought tolerance, higher yield with stability, and adoption of CA practices are important in the context of the Mediterranean rainfed environment. Integrating trade-off analysis between yield potential and stability in a rainfall gradient in both CT and CA in the national certification scheme of varieties may be more efficient than developing breeding programs for each type of tillage system.

***Keywords**: No-tillage, Genotype x tillage interaction, Rainfed, Wheat, Barley, Chickpea, Lentil*

LIFE+ Climagri: best agricultural practices for climate change: integrating strategies for mitigation and adaptation (Conservation Agriculture case study)

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If there is any sector that will strongly be affected by climate change, it is the agricultural sector, which is a consequence of the close relationship between agricultural activities and the climate. On the other hand, the agricultural sector is not only affected by climate change, but it is also a source of greenhouse gas emissions. Agriculture is responsible for 10% of the total Greenhouse Gases’ emissions in Europe. As a result, agriculture faces both the challenge of mitigating climate change and the need to adapt to the new scenarios that result from global warming, proposing solutions that contribute to this dual objective. On this basis, The LIFE+ Climagri project proposes a holistic approach to the problem of climate change in the agricultural sector, and more specifically in irrigated crops located in the Mediterranean Basin. The general objective pursued by the project is the establishment of agronomic management strategies for extensive crops that contribute jointly to the mitigation of climate change and the adaptation of crops to both present and future climatic conditions, and that serve to boost and develop environmental policies and laws in the EU and its Member States regarding climate change. To do so, ten Best Management Practices (BMPs) have been defined in the framework of the project, including Conservation Agriculture, among others. These BMPs have been implemented on a pilot scale in two farms located in the Guadalquivir Valley (Andalusia-Spain) and on a transnational scale in 13 farms located in Mediterranean countries (Portugal, Spain, Italy and Greece). On this pilot scale, two scenarios have been established, one with the current climatic conditions to test the BMPs in the present, and another reproducing the expected climatic conditions in the future, in order to study the impacts of climate change on the crop and anticipate the best adaptation strategies. To reproduce expected future climate conditions, a greenhouse was used to create areas with high temperature conditions and high CO_2 concentrations (450 ppm and 700 ppm).

After more than four years of project execution, results show that the plots with a greater number of implanted BMPs reduced CO_2 and N_2O emissions by 48% and 2 to 10% respectively, increased soil carbon sequestration by about 8% compared to conventionally managed plots, and saved 32% of energy consumption. In addition, on average, total costs of plots managed with BMPs, were reduced by 12.4% (€ 142 /ha) compared to plots using conventional management techniques without any BMP.

Based on the results obtained, the project has demonstrated the effectiveness of Conservation Agriculture practices in mitigating climate change and promoting the adaptation of crops to its effects at farm level. Therefore, these practices are very useful for their inclusion in those policies aiming at combating climate change that may arise under the Paris Agreement, the Sustainable Development Goals or the 4 per 1000 initiative, among others.

Keywords: *Best Management Practices, No-till, Carbon sequestration,Grennhouse gasses.*

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Sustainability assessment methodology for CA: The INSPIA model (alphanumeric data and graphical representations)

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The Initiative for Sustainable Productive Agriculture (INSPIA) project endorses best management practices (BMPs), mainly based on Conservation Agriculture (CA), to enhance the provision of ecosystem services through better stewardship of soil and water resources while ensuring high levels of productivity. This research presents the INSPIA methodology for the assessment of sustainability and for guiding farmers on strategic decision-making at the farm level, applicable to any kind of cropland (annual and permanent crops). The methodology is based on the application of 15 best management practices, which are evaluated through a set of 31 basic sustainability indicators that cover the economic, social and environmental sustainability dimensions. This set of sustainability indicators and BMPs were agreed by a panel of experts consisting of members of European universities and public research stations, representatives of non-profit making associations, members of public sector, technicians and farmers. The selection of sustainability indicators fulfils the three types of validation: design validation, output validation and end-use validation. Basic indicators are then grouped into 12 aggregated indicators, to build the final INSPIA composite index of sustainability. The INSPIA methodology provides farmers and advisers with a helpful tool to understand sustainability and which, to a certain extent, serves to improve performance toward sustainability. Results are presented through this methodology in three different graphical ways: a bar diagram with the whole set of basic indicator-values from 0 to 100; a pie chart representing the sustainability split in the aggregated indicators from 0 to 100; and a final sustainability index ranging from 0 to 100. In the medium and long term, the INSPIA methodology can help to monitor and assess agricultural and environmental policy implementation, as well as help improve its decision-making processes in the future.

Keywords: *Sustainable agriculture; Best management practices; sustainability indicators; composite index; strategic decision-making; sustainability graphics*

Impact of Conservation Agriculture on soil properties and maize grain yield in the semi-arid Laikipia County, Kenya

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Low and unreliable rainfall is a main constraint to maize production in the semi-arid parts of Kenya. Laikipia county lies between latitudes 0º 18" and 0º 51" North and between longitude 36º 11" and 37º 24' East covering an area of 9,462 km^2 and consists of mainly a Range Land Plateau whose altitude varies between 1,500 m above sea level at Ewaso Nyiro basin in the North and 2,611 m above sea level in the South between Mount Kenya and the Aberdare ranges. The county is located on the leeward side of Mount Kenya.

Participatory farmer experimentation with Conservation Agriculture (CA) was undertaken for six consecutive growing seasons between July 2013 and December 2016 to determine the effectiveness of CA in improving soil propeties and enhancing maize yields. The main CA practices tested included minimum soil disturbance, tyne furrow opening and seeding, legume (*Lablab purpureus*) cover crop and residue retention, all implemented under varying soil fertility regimes. The research design used was researcher-designed and farmer-managed. Participatory farmers' assessments and field days were carried out as a way of reaching out to the farming communities around the trial sites. The research findings obtained demonstrated that the use of CA impacts positively on soil properties and is a viable practice for enhancing maize yields in these moisture deficit parts of the country.

Initial soil characterization for the sites indicated that Laikipia soils are mainly Phaeozems and Vertisols with clayey/loamy texture. Soil chemical analysis carried out in the different CA and none-CA plots showed that after six consecutive seasons or three years of experimentation, CA practices impacted positively on a number of soil mineral components including phosphorus, potassium and calcium in the various trial sites in Laikipia county. Mid-season chlorophyll content assessment of the maize crop using the Soil Plant Analysis Development (SPAD) to measure the chlorophyll content showed that there was good response to fertilizer application as well as to the CA options implemented across the County. The lowest mean readings of 28.95 was recorded in plots of treatment T_1 (farmer practice) while T_6 (CA with mineral fertilization) gave the highest mean readings of 42.11, a confirmation that indeed, both fertilization and CA impacted positively in the overal maize plants' growth vigor as shown by the dark green leaves in the T_6 treatment that had more chlorophyll content hence more photosynthetic capacity while T_1 had light green or yellowish `leaves with less chlorophyll implying less photosynthetic capacity leading to less plant vigor. Maize grain yield data collected over the six cropping seasons showed that the use of CA resulted in a 2- to 3-fold increase in grain yields above the farmer practice where neither fertilizer nor CA were used. Mean maize grain yield in T_1 plots was 1.067 Mg ha^{-1} compared with T_6 plots that yielded 2.192 Mg ha^{-1}.

Keywords: *maize, minimum soil disturbance, Lablab purpureus, cover crop*

Effect of Conservation Agriculture practices on soil biological and physico-chemical properties of light black soil under peanut-wheat cropping system

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A field experiment was conducted at Research Farm of ICAR - Directorate of Groundnut Research, Junagadh in India, for four years during 2012-13 to 2016-17 to evaluate the effects of different tillage and residue management practices on soil biological, physical and chemical properties in peanut-wheat cropping system. The soil at the experimental site was clayey (55.7% clay), moderately calcareous (30.9 % $CaCO_3$), slightly alkaline (pH 8.2) with EC of 0.7dS/m, low in organic carbon (4 g kg^{-1}), available N (97.3 kg ha^{-1}), and available P_2O_5 (9.2 kg ha^{-1}) and medium in available K_2O (269 kg ha^{-1}). The treatments were three tillage practices: conventional tillage (CT), minimum tillage (MT) and zero tillage (ZT) in the main plots, and each soil tillage management had three residue management practices: no residue (NR), wheat residue (WR) and wheat residue + *Cassia tora* mulch in wheat (WC) in three subplots of each, and replicated thrice totaling 27 plots. The soil biological (enzymatic activities and soil microbial biomass carbon [SMBC]), physical (total aggregate percent, mean weight diameter [MWD], geometric mean diameter [GMD], porosity and infiltration), and chemical (soil organic carbon [SOC], cation exchange capacity [CEC], available N, P_2O_5, K_2O) parameters were studied following the standard procedures. Soil samples were taken after harvest of wheat in 2017 to measure physical and chemical parameters while moist samples were taken 30 days after sowing of peanut in each year to study enzymatic activities and SMBC. Porosity and infiltration rate were measured during wheat season in 2017. Data were statistically analyzed in split plot design using F-test procedure given by Gomez and Gomez (1984) and Tukey's test ($p \leq 0.05$) was used to differentiate the treatment means. The results indicated that dehydrogenase, alkaline phosphatase, and urease activities were similar in MT and ZT but significantly higher over CT in 0-15 cm depth. β glucocisade activities and SMBC were in the order ZT>MT>CT ($p<0.05$) in 0-15 cm depth. However, activities of all the enzymes and SMBC were significantly high with CT over ZT in 15-30 cm depth. Enzymatic activities and SMBC was found significantly high with WC over NR in both the depths.
Total aggregate percent, MWD, GMD, porosity and infiltration rate was found to be significantly high in ZT over CT in both the depths. Total aggregate percent (0-15 and 15-30 cm), GMD (15-30 cm), MWD (15-30 cm) porosity and infiltration rate was found to be at par under MT and ZT. Total aggregate percent, GMD, MWD, porosity, and infiltration rate were found to be significantly higher under WC while least values were found with NR.

Available NPK and CEC were high under ZT as compared to CT in both the depths ($p<0.05$). SOC was found high with ZT in 0-15 cm depth over CT, but in 15-30 cm depth SOC was high with CT as compared to ZT ($p<0.05$). SOC, CEC, and available NPK were significantly high with WC as compared to NR. Thus, the results of four years study indicate that zero/minimum tillage and wheat stubble retention and *Cassia tora* mulch may potentially be used to improve soil biological and physico-chemical properties in light black soils under peanut-wheat cropping system in Saurashtra region, India.

***Keywords**: zero/minimum tillage, peanut-wheat system, stubble mulch, soil quality*

Contribution of Conservation Agriculture for wheat productivity improvement in Eastern Indo-gangetic Plains of India

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Indo-Gangetic Plains (IGP) of South Asia characterized as small and fragmented farm holdings, poor input and output marketing infrastructure, poor access to new technologies, frequent climatic aberration (floods, drought and temperature) and a shorter wheat growing season compared to Western IGP. Ever increasing input, energy and labour costs, as well as poor access to mechanization and knowledge, forced farmers to opt for sub-optimal crop management practices, which leads to lower crop yield and farm profit. In recent years, the impact of climate change has also affected smallholder production systems in the region. The traditional method of wheat planting in eastern IGP is 2-3 tillage operations followed by broadcasting of wheat seed and again mixing the seed by a tillage operation. Temporary water stagnation in conventional tilled plots due to un-even topography leads to yellowing of wheat crop after the first irrigation is a common problem that causes less tillers and a declining crop yield. Since the year 2000, the state agriculture universities, ICAR, CGIAR institutes and several NGO's were promoting Conservation Agriculture practices (CA), especially zero tillage (ZT) in wheat. The benefits of the adoption of CA are higher crop yields, less production cost, less irrigation water and less labor requirement, while it also improves the soil health with less environmental impacts.

In recent years, these CA practices have been the prime focus of the policy planners of the region, which resulted in more investment of the state as well as the central government to promote these technologies. Introduction of CA changes the mindsets of the farmers, which leads to shifting the farmers from several tillage operation (3-4 tillage) to no tillage or reduced tillage (one tillage), broad casting to line sowing with a ZT drill and reduced crop residue burning. Bihar significantly increased the wheat productivity from 1.75 t/ha in 2004 to 2.99 t/ha in 2019 and the Bihar state received a national level award (Krishi Karman Award) two times for improving the wheat productivity in 2012-13 and 2017-18. This productivity gain was contributed to several factors, i.e., crop variety, quality seed and CA. A diagnostic survey of farmers from different districts of Bihar showed that CA increased wheat productivity by 20-25%. CA saves 7-10 days that were required for tillage operations and facilitate the early plating of wheat. On an average CA saves USD 50-60 / ha tillage cost, 25-30% irrigation water (during first irrigation), 40-50 L/ha fuel and 6-8 labor hours/ha. The co-benefits of CA are the improved soil physical structure, providing an aerobic environment, better root growth and reduced environmental pollution by reducing the diesel consumption for tillage and irrigation.

Keywords: *Conservation Agriculture, Zero tillage*

Carbon sequestration potential in the soil under two cropping systems and different irrigation systems

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Approximately more than 40% of the earth's surface is currently threatened by soil degradation, a process in which the loss of soil organic carbon (SOC) has a relevant role, and which is accelerated by climate change. It is generating strong impacts on food security and small farmers.

In soils dedicated to agricultural activities, quality and productivity can be improved by increasing the SOC changing the management practices that are used. Intensive agriculture has led to the loss of carbon in agricultural soils, between 30 and 50% in the last two decades. Developing models which simulate the carbon cycle have shown that the changes in soil management have provoked greater impact on this element than those caused by climate change. The problem of SOC decrease especially affects the Mediterranean basin, where cold and humidity in winter together with hot and dry summers with high temperatures accelerate the decomposition processes. These SOC losses are influenced by traditional, non-conservative agronomic practices that favour the decomposition of organic remains and erosive processes.

A 4-year study has been conducted in order to determine the mitigating capacity of agriculture against climate change. The capacity of the soil to sequester atmospheric carbon has been evaluated by increasing its SOC through the implementation of conservation management systems.

Several studies state that the carbon gain through Conservation Agriculture practises is related exclusively to the stratification of organic carbon in the soil profile. However, other works point out that the evolution of stratification ratio is a significant indicator of carbon sequestration in soils under Conservation Agriculture. On this basis, stratification ratios of 0-5/5-10, 0-5/10-20 and 0-5/20-40 cm in depth were calculated.

The obtained ratios were 1.22, 1.55 and 2.3 in the soil under conservationist practices, and 1.15, 1.39 and 2.2 in the traditional system. It must be highlighted that stratification was higher in Conservation Agriculture for each sampled depth.

Analysing organic carbon content at the end of the experiment, on average, soils managed with Conservation Agriculture techniques showed 13%, 7.8%, 3.2 % and 9% more SOC than soils under traditional management at depths of 0-5, 5-10, 10-20 and 20-40 cm respectively.

The coefficients of determination obtained between SOC and stratification ratios were R^2= 0.59; R^2=0.62 and R^2= 0.78 for the studied depths.

Keywords: *carbon sequestration, stratification ratio, Conservation Agriculture, climate change, no-till*

Camelina: a promising cash cover crop in North Italy

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Camelina [*Camelina sativa* (L.) Crantz] is an oilseed crop belonging to the *Brassicaceae* family, native to Europe and well adapted to arid and semi-arid climates (<350 mm annually). Camelina oil (~40%) has an excellent profile with a unique fatty acid composition, with high amounts of oleic (C18:1, 14.9–18.8 %), linoleic (C 18:2, 16–22.4 %) and linolenic (C18:3, 28–50.3 %) acids, that make it highly interesting for several foods, feed and industrial applications, including biofuels. Camelina is characterized by a very short cycle, low-input requirements, and high cold and drought stress tolerance. Camelina can be introduced into Mediterranean cropping systems as a cash cover crop in substitution to fallow or as an alternative to putting in rotation with winter cereals, thus promoting biodiversity and crop diversification. It can be harvested very early thus allowing double cropping with the typical main summer crops such as maize, sunflower, soybean, and sorghum. Moreover, camelina is well suited to Conservation Agriculture, thus enabling to enhance soil and water conservation. Optimizing soil tillage and seeding strategy are strictly necessary for maximizing oil yield, particularly for a new species such as camelina. A field trial was set in Bologna (North Italy, 44° 33' 32 m a.s.l) in autumn 2020. Different tillage techniques (no-tillage vs. minimum tillage), sowing dates (SD1=early October vs. SD2=late October) and methods (broadcasted vs. row-seeding) were compared. The camelina variety, Alba (by Camelina Company, Spain) was used. To evaluate the capacity of camelina to effectively cover soil, the 'Canopeo' web application (Oklahoma State University) was used at an interval of 15 days. Emergence rate was significantly different between sowing methods. Broadcasted plots showed an emergence rate of 96%, while a 39% reduction was observed in row seeded plots. Referring to soil coverage, higher values (+67%) were observed in S1 compared with S2. Soil tillage did not affect any parameter, thus confirming the high suitability of camelina for sod-seeding. In the coming months crop growth, phenology, capacity to compete against weed, N uptake, soil water infiltration at deeper layers, and seed yield will be surveyed in order to identify the best agronomic technique for camelina as a cash cover crop in Northern Italy.

***Keywords**: Cash cover crop, oilseed crop, sod-seeding, crop rotations*

Enhancing profitability of small holder farmers through Conservation Agriculture in Eastern India

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Bihar, situated in Indo-Gangetic Plains is one of the most populous states of India having predominantly an agrarian economy. Characterised by having more than 80 per cent of farm holding under marginal category the agriculture sector in the state is more vulnerable to the effect of different vagaries owing to complex, diverse and risk prone agro-climatic regions, production systems and farm typologies. Rice-Wheat cropping system is the predominant practice across the state of Bihar with about 57 per cent of area under wheat. Short winter span and terminal heat stress are the major factor for low productivity of the wheat in the eastern India including Bihar. An initiative was taken to promote conservation agricultural practices to study its impact on farm productivity and its ability to enhance income of small holders in Bihar. Zero Tillage Technology (ZTT) in wheat was chosen and the impact of its adoption was studied under two adopted villages (Birnodh & Barhari) of Bhagalpur district in Bihar. The results of study conducted over 3 years (2016-17 to 2018-19) has indicated that ZTT is gaining popularity amongst the farmers in the adopted villages for establishing wheat crop, for higher income and sustainability of the farming community. This technology allowed rice–wheat farmers for direct sowing of wheat soon after rice harvest without any preparatory tillage, so that wheat crop heads and fills grain before the onset of pre-monsoon hot weather and escaped terminal heat stress. This technology involved sowing with a specially-designed zero-till seed-cum-fertilizer drill/planter having inverted 'T' type furrow opener to make a narrow slit in the soil for placing seed and fertilizer. Wheat was sown by ZTT which helped in advancing sowing time (8-10 days), reduced cost of cultivation in terms of land preparation (Rs.3850/ha), saving in labours time (6-7 hrs/ha), fuel (44 l/ha), environmental pollution (60%) and water saving (33%) in comparison to conventional practice. Apart from recued cost of cultivation the soil health analysis also indicated considerable improvement in the population of beneficial soil micro biota over 3 years.

Keywords: *Adaptation, Eastern India, Environmental Pollution, Wheat and Zero Tillage Technology*

Benefits of conservation tillage for soil erosion control

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Soils are one of the most valuable resources on Earth, but endangered in their substance by human activity. Particularly, soil degradation by erosion causes severe environmental impacts, reduces productivity and thus impedes social and economic development. High soil erosion rates are usually associated with intensive agricultural practices and especially the advent of mechanisation in farming has accelerated sediment transport. Agriculture affects soil erosion not only by the mechanical processing of topsoils through tillage, but also by removing soil-protecting vegetation layers. Whereas tillage operations generally redistribute soil material within agricultural fields without further transport, they prepare and predispose the soil surface for further removal by climatic agents such as water and wind. Individual erosion events with rates of more than 100 Mg ha^{-1} yr^{-1} have been measured on agricultural land.

In this context, conservation tillage and particularly no-till farming are considered to be major improvements regarding soil erosion control. No-till practices reduce soil disturbances to the very moment of planting, maintain vegetation cover and thus effectively mitigate all forms of erosion caused by machinery and climate. Reduced erosion rates are widely observed after adoption of no-till and partly up to one order of magnitude lower than in conventional agriculture. At the same time, no-till is used very little in some regions of the world and reports on erosion rates under no-till for larger areas or whole countries are often scarce. In this context, it is noticeable that no-till systems are not widespread in larger parts of Asia, Africa or Central America, which are in turn mostly areas with erosion-prone soils and high annual rainfall. Furthermore, it has to be stated that even though no-till appears to be the best method to combat soil erosion, it might hamper other aspects of farm management. These problems are mainly related to weed control and thus declining crop yields with higher weed infestation, as weed abundance in no-till can be higher than in plough-based systems. This is particularly evident in organic farming systems, where herbicides are generally not foreseen and farmers are encouraged to periodically use ploughs. Nevertheless, there is great potential to introduce no-till in farming systems around the world for soil conservation. The further acceptance of such practices by farmers is one of the most important measures to successfully tackle the threat of soil erosion globally.

Keywords: *tillage erosion, water erosion, wind erosion, soil loss, erosion control*

Land degradation, climate change and farmers perspectives for promotion of Conservation Agricultural in the Kyrgyz Republic

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Mono-cropping and tillage-based farming systems, cultivation of soils in marginal areas and residue removal for fuel or fodder followed by climate change consequences enhances influence on a significant increase in the degradation of agricultural lands in the Kyrgyz Republic, which undoubtedly leads to significant economic losses and, accordingly, losses of agricultural producers, including losses from low crop yields, from decrease in pasture productivity and soil fertility losses. All these problems can become serious long-term socio-economic and environmental problems for all Central Asian countries, including Kyrgyz Republic, if it does not develop and implement important measures and decisions. has caused severe land degradation, soil erosion and loss of fertility in drylands No-till based farming system.

Conventional soil cultivation methods are used in the small-scale farming system in Kyrgyz Republic. Although, the smallholders produce more than 80% of total agricultural produce, the average crop yield remains low. It is related to the continued mono-cropping and low quality of inputs – seeds, fertilizers and plant protection means. The application of unsustainable approach has led to the environmental problems, including the degradation of soil. Moreover, climatic and natural anomalies, which have become more frequent in recent years, intensify this process. Therefore, further increase of production requires improving the farmers' capacity and knowledge on modern crop, water and soil management.

Existing practices of soil cultivation and pasture management require a fundamental revision in terms of the application of innovative technologies, conservation of natural resources and adaptation to climate change. One of these technologies is the Conservative Agriculture (CA) as a set of approaches for maintaining and conserving soil resources and rational use of water resources in the face of climate change.

Promotion of CA in the Kyrgyz Republic is still not given due attention from the Government, science and farmers. Although, today there are already positive results of introducing CA on pilot farms with a total area of more than 1000 hectares. Moreover, the draft national strategy on promotion of CA is formulated, some laws and regulations for agricultural soil conservation are adopted, and the extension materials and educational master's program at the Kyrgyz National Agrarian University has been developed. Local non-governmental organizations are actively promoting CA in to the farmers' fields.

Keywords: *mono-cropping, convetional cultivation, soil, crop, water, sustainable management*

Nitrogen fate in cereal cropping systems is affected by cover crops, N fertilization and tillage intensities -a case farm study

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Assessing sustainability of cropping systems in regards to their input use efficiency can be a useful tool to compare different systems with each other. In Denmark, especially Nitrogen Use Efficiency (NUE) is critical, due to high nitrate leaching losses and strict N fertilization regulations. These assessments should analyse the system over a longer time span, including non-cropping periods, where leaching losses mainly occur. A field trial experiment established on fields belonging to three different tillage systems is investigating the effect of different cover crops on leaching. The tillage systems comprise of conventional mouldboard ploughing (20 - 25cm), reduced tillage with harrowing (8-10 cm) and Conservation Agriculture with direct sowing. Reduced tillage and Conservation Agriculture (CA) practices have been in place for more than 10 years, representing a well-established system. Grain and straw yields form a cereal-based crop rotation were sampled in two years. Cover crops placed before and between the main crops were measured for biomass and nitrogen content in autumn. Nitrogen uptake of cereals and cover crops was compared to mineral nitrogen distribution in the soil profile, which was estimated from soil samples taken to 2 m depth in late autumn, early spring and after crop harvest. All cover crop mixtures reduced mineral nitrogen concentrations in the subsoil compared to the control treatment. Oil radish performed better than oats in catching mineral nitrogen in autumn. Adding legumes to the mixture did not affect nitrate leaching, but slightly increased mineralisation in spring. High yearly variability of cereal and cover crop nitrogen uptake had a greater effect on nitrate leaching dynamics than the tillage system. This study showed that leaching prevention comes down to the implementation of cover corps, not the tillage practice. Since cover crops are an intrinsic part of a CA system, it can be argued, that CA cropping systems can reduce nitrate leaching.

Keywords:*winter wheat, spring barley, system Nitrogen Use Efficiency, nitrogen uptake, nitrate leaching, cover crops*

Conservation tillage reduced soil erosion significantly – results from a long-term monitoring study in Switzerland

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The positive effects of conservation tillage have mostly been demonstrated using small test plots and experiments. The present study aims at confirming such observations on farmers' fields at catchment scale. In a 20-year monitoring programme between 1997 and 2017, accurate mapping of erosion damage was carried out in the Frienisberg region (Switzerland). The investigation area included 203 arable fields with a total area of 263 ha, i.e. the mean field size was 1.3 ha. Most of the farms were mixed farms, i.e. they grew crops and kept livestock. During 115 field inspections, 4060 plot years were examined and 2165 mapped erosion systems were recorded.

The Swiss agriculture policy system is based on a complex system of direct payments (subsidies). In addition, there are various cantonal and state subsidy programmes for conservation tillage. In the communities of the Frienisberg region, the share of reduced tillage with mulch from the previous crop rose from 1% of arable land in 1997 to 53% by 2015, and the share of no-till from 1% to 32%, so that a total of 85% of arable land was 2015 cultivated with conservation tillage. This high level of Conservation Agriculture application can be explained by the particularly high sensitivity of farmers to the topic of soil protection in the region; motivation through financial incentives, rising awareness among farmers, innovative farm contractors, knowledge transfer and good extension service of cantonal agencies. The significant decrease of soil loss from an average of 0.74 t ha^{-1} yr^{-1} during the first ten years period to 0.20 t ha^{-1} yr^{-1} during the second ten years can directly be linked to the increased use of conservation tillage. The majority of soil erosion (88%) took place on plough tilled land (PT), 9% on non-ploughed land with less than 30% surface residue cover (RT), 1% on mulch-tilled land with more than 30% surface residue cover (MT), and 2% on non-tilled or strip-tilled land with >30% soil cover (NT). At 0.07 and 0.12 t ha^{-1} yr^{-1}, respectively, the mean soil loss in MT and NT fields was an order of magnitude lower than that under PT (1.24 t ha^{-1} yr^{-1}).

The field measurements show that soil erosion can be significantly decreased by changes in soil tillage practices. This finding also underpins that conservation tillage can be a successful production system in real-life agriculture in Switzerland. In this respect, the Frienisberg region should be considered a case example of successful erosion control.

Keywords: *soil erosion, soil loss, conservation tillage, field measurements, long-term monitoring*

Impacts of cropping practices on the production of field crops (bread wheat and rapeseed) in the context of climate change in the Sais region of Morocco

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Morocco is severely affected by climate variability; the projections suggest that by 2050 aridification undergoes a further increase in temperature and a decrease in rainfall. Consequently, the future of agriculture and correspondingly that of the national economy could be compromised. Also, the fragility of its ecosystem, causing erosion and chronic water deficit, is influencing the productivity of cropping systems. This difficult situation and random, is aggravated by conventional agricultural practices that result in the deterioration of soil quality, fertility, structure and soil organic matter due to the soil disturbance which has potential negative consequences for yield. Conservation Agriculture (CA) presents several advantages in agronomic, environmental and socio-economic terms. It decreases soil disturbance, allows crop residue retention and crop diversification. It is an important approach to address declining soil fertility and the adverse effects of climate change in Morocco. Nonetheless, the aim of this work was the comparison and evaluation of the impact of four cropping systems (no-till, minimum-till, chisel plough and deep work) on agronomic parameters to increase the production of bread wheat, rapeseed and faba bean, on a semi-arid climate. In this context, a field experiment was conducted at the experimental station of Douyet of the National Institute of Agronomic Research of Meknes, Morocco. The experiment was according to the Split-plot design with three replications. The crop was attributed to the large blocks. While the tillage sequence has been assigned to the sub-blocks. The sowing date was 24-12-2019. The results showed that Conservation Agriculture has a positive effect when compared to conventional agricultural. The highest grain yields were obtained with no-till, especially in rapeseed compared to other cultural practices. The average yields were0.61 q/ha, 0.42 q/ha and 0.33 q/ha for no-till, chisel plough, minimum-till and deep work, respectively. Whereas, the non- germination was showed in disc plough. This decrease the grain yield due to late sowing and to drought stress caused by the decrease of rainfall during this cropping season, the annual rainfall was 135 mm. However, the results showed in faba bean have a high yield (10.14 q/ha) in cover crop comparing with no-till (7.98 q/ha), followed by chisel (7.32 q/ha) and the deep work (5.75 q/ha). On the other hand, the conventional tillage showed the highest yield in the bread wheat compared with other cultural practices (chisel plough, minimum-till and no-till) which had shown a similar yield.

Keywords: *Conservation Agricultural, cropping practices, bread wheat, faba bean, rapeseed, yield*

Conservation tillage enhances productivity and decreases soil nitrogen losses in a rainfed agroecosystem of the Loess Plateau, China

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Conservation tillage of dry farmland has been considered as a promising approach for mitigating the negative environmental effects of synthetic ammonia application and achieving agricultural cleaner production. However, accurate assessment of the nitrogen balance in dryland tillage system is still lacking. Based on a long-term (> 9 y) field tillage experiment (Yangling, Shaanxi Province, China (34°17'N, 108°04'E)) and in-situ observation, we assessed the effects of different tillage practices, including two conservation tillage methods (i.e., chisel plough tillage (CPT) and zero tillage (ZT)) and conventional ploughing tillage (PT) as the control, on soil nitrogen balance and crop productivity in the 2016–2017 and 2017–2018 growing seasons.

Total N inputs were 486.70 kg ha^{-1} and 485.9 kg ha^{-1} in the 2016–2017 and 2017–2018 growing seasons, respectively. We found that conservation tillage [i.e., chisel plow tillage (CPT) and zero tillage (ZT), which have the advantage of not involving soil turning, and hence result in low soil disturbance] can achieve a reduction of straw N removal by 8.4~39.8 kg N ha^{-1} y^{-1} (7.6%~ 32.7% decrease), mitigation of N_2O emissions by 2.24~4.76 kg N ha^{-1} y^{-1} (35.3%~61.2% decrease), a decline in N leaching by 5.1~38.7 kg N ha^{-1} y^{-1} (24.8%~157.9% decrease), and an increase of NH_3 volatilization by 9.9~34.1 kg N ha^{-1} y^{-1} (33.2%~104.9% increase) on averaging two winter wheat-summer maize rotation cycles. The sum of N losses was reduced by 0.6~37.8 kg N ha^{-1} y^{-1}, which corresponds to 0.4%~21.2% of the conventional tillage cropland total nitrogen loss. CPT achieved an increase in annual crop yields by 0.80~1.19 t ha^{-1} y^{-1} (5.9 %~8.1% increase).

The results also showed that CPT and ZT significantly increased accumulated soil total nitrogen by 69.5 and 188.1 kg N ha^{-1}, respectively, in the 0–100-cm soil layer, but PT decreased the soil total nitrogen by 24.3 kg N ha^{-1}. Taking N inputs and outputs together, CPT achieved a lower N surplus mainly due to increased crop N harvest and reduced N losses including gaseous emissions and hydrological leaching. Our findings suggest that long-term chisel plough tillage in dryland agroecosystems could serve as a promising soil management practice in increasing crop productivity and maintaining sustainability from soil nitrogen pool by enhancing N removal from crop biomass and decreasing N losses via N_2O emission and nitrate-N leaching.

Keywords: *Nitrogen balance, N_2O, NH_3, N loss, Conservation tillage*

Economic justifications for retention of crop residues on the field: a case from the mixed crop-livestock production systems of Morocco

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Conservation Agriculture involving direct seeding, crop rotation and residue retention is considered a panacea to several interrelated problems in agricultural production. However, in the mixed crop-livestock production systems of the dryland areas, crop residues have great significance as sources of animal feed – posing a major challenge in the uptake and adoption of CA. While the economic benefits and the drivers of adoption of zero tillage and rotation have been well documented, the literature on the economics and social implications of residue retention, especially in dryland areas, is still scarce. In this study, we used a multi-stage stratified sampling procedure to select a nationally representative random sample of 1,230 farm households cultivating 1,901 wheat fields in 21 major wheat-growing provinces constituting 80% of total wheat production in Morocco. The administrative units at each level were used for stratification. We administered a survey questionnaire to each sample household and collected data on socio-economic conditions of the farm households and detailed field-level information including management practices, quantities of inputs used, quantity of output obtained and other social and institutional factors that affect farmers' decision to adopt residue retention in both CA and conventional tillage (CT) systems. Adoption of residue retention in Morocco was purely demand-driven where farmers in each village were free to decide whether to adopt or not and therefore there was no randomization at village or individual levels. Therefore, endogeneity problems due to omitted variables and selection bias are expected to be present. Therefore, in this paper, we used area weighted averaging to estimate percentage of the sample fields on which residue was retained in the field and also applied the endogenous switching regression (ESR) model which is potent to correct for potential selection bias and endogeneity problem in econometric estimation to analyze the profitability of residue retention relative to the traditional practice of onsite grazing of the residue. To identify factors that positively or negatively influence farmers propensity and intensity of adoption, we used the double hurdle model which conceptualizes the adoption decision as a two-stage decision - first on whether or not to adopt; and on the second stage, for the farmers who decided to retain residue, on how much of their total wheat area to retain residue.

The sample showed that with the exception of only 180 fields where the complete package of reduced tillage, legume-based rotation, and retention of above 30% residue is practiced, either only two, only one or none of the three CA principles were practiced on the majority of the fields. Only 14% and 45.9% of farmers respectively retain at least 60% and at least 30% of crop residues on their fields. The ESR model results showed that relative to the complete removal of residue, these levels of residue retention respectively led to 400 kg/ha (44.6%) and 125.5 kg/ha (14.2%) higher yields, and 100% and 45% lower risk of obtaining below 500 kg/ha yield and 37% and 18% lower risk of obtaining below 1000 kg/ha yield in the subsequent wheat crop under wheat monocropping. Considering current residue and grain prices, retention of at least 60% and 30% of the residue required for successful implementation of CA covers the cost of alternative feed and still generates US$122.9/ha (44.3%) and US$27.7/ha (10%) higher income – all providing good economic justifications for residue retention. The policy implication of these results is that Morocco would benefit from investing on: 1) the development and/or import of alternative feed sources to reduce the tradeoffs due to the removal of residue thereby increasing the sustainability of soils through positive net addition of nutrients from manure; and 2) raising the awareness of farmers about the economic benefits of residue retention.

Keywords: *Residue retention, adoption, impact, drylands, Morocco*

Farm and household level socio-economic impacts of the adoption of minimum tillage in Central Asia

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Conservation Agriculture involving zero tillage, crop rotation and residue retention is considered a panacea to several interrelated problems in agricultural production. However, in the mixed crop-livestock production systems of the dryland areas, several factors including the tradeoffs between crop residues as mulch and animal feed, land fragmentation, low education level of farmers to understand and apply the complex system, financial liquidity problems, and absence of sufficient information on its socio-economic benefits are posing major challenges in the promotion of Conservation Agriculture. In Central Asia (CA), while there exist some documentation of the biophysical benefits of minimum and zero tillage, the literature on the economics of zero tillage (ZT) and minimum tillage (MT) is scanty. Using a nationally representative sample survey of 1838 wheat farmers in Uzbekistan and 609 wheat farmers in Tajikistan, this paper provides estimates of the adoption level of minimum tillage (MT) in CA. Using the instrumental variables approach (IV) which is potent in correcting for the inherent estimation problems of both overt and hidden biases and endogenous treatment, this paper provides empirical evidence on the socio-economic impacts of the adoption of MT.

Using wheat areas at the farm and the different administrative levels as weights for upward aggregation, the adoption level of MT in both countries is found to be only 10.5% (7.72% in Tajikistan and 10.3% in Uzbekistan). Model results show that after controlling for all confounding factors, adoption of the MT technology leads to 1040 kg/ha (28%) higher yields, US$172.7/ha (36%) higher gross margins, 16kg (26%) more consumption of wheat per capita per year and 80% reductions in the risk of obtaining yield levels below 1000 kg /ha. While the benefits per unit area and per household are fairly high, the low national average adoption levels have undermined the ability of MT to increase the national wheat production, reduce poverty and increase national food security in both countries. All these results provide socio-economic justifications for the efficacy of MT and that its wider adoption has the potential of improving the productivity, profitability, and sustainability of agricultural production in the region. However, the transformation of conventional tillage systems to zero or minimum tillage systems requires that policymakers fully understand the large economic, social, and environmental benefits that these systems offer. Given that farmers in the region are now becoming increasingly aware of the benefits of Conservation Agriculture in general and minimum tillage in particular as new and promising technology options, the governments of CA should provide both incentives and the needed extension services to encourage farmers to adopt the practices and to make the system attractive to the private sector to ensure timely and affordable service provision, especially for seeding under zero tillage.

Keywords: *Minimum tillage; Central Asia; socio-economic impacts; yield and gross margins; production risk management*

SUBTHEME 3

MAINSTREAMING OF CA WITH NATIONAL POLICY AND INSTITUTIONAL SUPPORT AND FOR GLOBAL GOVERNANCE TO SUPPORT NATIONAL AND INTERNATIONAL NEEDS AND COMMITMENTS

8WCCA
8th World Congress on
Conservation
Agriculture

The future of farming
Profitable and Sustainable Farming with Conservation Agriculture

8WCCA
8th World Congress on Conservation Agriculture

Mainstreaming of CA with national policy and institutional support and for global governance to support national and international needs and commitments

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Conservation Agriculture (CA) has been adopted by farmers in at least 78 countries around the world in response to land degradation from intensive tillage and monoculture production systems. Since pioneer farmers started the CA development journey five decades ago it has been refined into a sustainable production system with improved economics and multiple social and environmental co-benefits beyond stopping the immediate land degradation concerns.

In order to continue the widespread adoption of CA, drivers and levers for institutional and policy support need to be identified for the toolbox to mainstream CA for all conditions. A review of experiences in a wide range of countries allow the identification of commonalities and differences. Early farm initiatives received support from the private industry sector and in some countries, from innovative researchers. Extension services and government policies that supported organizations, innovative research and environmental concerns also catalyzed the emergence and spread of CA. An assemblage of private, public and civil sector developments will be considered from catalyst, barrier and synergies of integration contexts.

CA can have a bright future. The wide-ranging benefits of CA provide a basis for an important potential role of CA in meeting the objectives of the three UN Conventions established at the 1992 Earth Summit – conventions on biodiversity, climate change and desertification. CA practises are central to the climate smart agriculture concept and are a great representation of the "other effective area-based conservation measures" (OECMs) emergent in the new strategy for the convention on biological diversity CA also aligns well with the Sustainable Development Goals, the 4 per thousand initiative and the new European Green Deal, thus enabling agriculture to provide meaningful contributions.

The future may not be the same as the past, and we need to consider new policies and tools to mainstream CA in the years ahead. A glimpse of research institution issues, future digital drivers, policy types and tools will hopefully expand the toolboxes of CA practitioners to take advantage of future opportunities to grow CA.

The paper and oral presentation will elaborate: (a) several national level examples of CA mainstreaming processes that illustrate the kinds of policy and institutional support that is enabling the spread of CA to occur; and (b) how CA can contribute to global governance in meeting national and international needs and commitments.

Keywords: *pioneer, land degradation, barrier, synergies, biodiversity*

No-till in Conservation Agriculture: challenges and opportunities

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No-till within Conservation Agriculture systems (NT-CA), including crop residue retention and crop rotations has revolutionised agriculture in managing greater areas of land with reduced energy inputs, and improved erosion control, soil water storage, soil quality and, in many instances, yield and net farm income. These benefits have led to the identification of NT-CA as an important management practice to ensure sustainable future food security. However, while the development of NT-CA has seen much success, there are still significant agronomic, economic and/or social challenges associated with its use that limit adoption or lead to dis-adoption over the long-term. Here we appraise our existing knowledge of NT-CA to identify current challenges and opportunities for its use. Many users of NT-CA are increasingly devoting additional time and economic resources to dealing with herbicide-resistant weeds, increasing incidence of disease and pests, and soil compaction. In many regions, economic and institutional barriers also limit both the adoption and long-term success of the system, including i) insufficient access to required inputs (seed, fertiliser, seeding equipment); ii) a lack of access to suitable markets, and transportation/processing fascilities for certain crop rotations, and iii) a lack of research to identify management practices and crop rotations best suited to NT-CA in individual regions. In many farming communities, the principles of NT-CA systems also run counter to established land management and social practices, which limits its uptake. A combination of research in partnership with farmers and the private sector, education and good policy development is required for the continued success of NT-CA and promote greater uptake worldwide. In particular, the tailoring of NT-CA cropping systems according to individual locations and the introduction of flexibility in tillage management provides an opportunity to manage these challenges of NT-CA systems without significantly impacting on gains in soil health, envrionmental protection and yield stability.

Keywords: *no-till, Conservation Agriculture, food security*

Initiatives and experiences of Conservation Agriculture in Nepal

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Declining soil fertility, poor irrigation facilities, shortage of agricultural labour and ever-increasing production cost have affected the agricultural production function in Nepal. Therefore, in quest of alternative production systems, Conservation Agriculture (CA) practices consisting of zero or minimum tillage, residue retention and crop rotation have been compared with the conventional practices of repeated tillage, without residue and crop rotations in maize and rice-based cropping systems of Nepal. Considering the multiple benefits and widespread adoption of CA across the world, Nepal Agricultural Research Council, NARC started to work on CA under rice-based cropping system during the 1990s in close collaboration with the rice-wheat consortium. A couple of CA-based initiatives like Cereal Systems Initiatives for South Asia (CSISA) and Sustainable and Resilient Farming Systems Intensification (SRFSI) under rice-based systems have been implemented since the last few years in Terai. Furthermore, CIMMYT has also been working under various maize-based systems in the hills of Nepal. Different agricultural academic institutions are also having their postgraduate teaching and research programs on CA. Considering the above facts, a brief review of the past works on CA done by various organizations in Nepal was carried-out to find-out the benefits and bottlenecks of its technology development and promotion. The review revealed that individual crop and system yields were at par at early stages and superior after the third year onwards over conventional agriculture in Nepal. It not only allowed early planting of succeeding crops but also was more economical than conventional agriculture. More importantly, CA also improved the soil's organic matter and moisture contents, increased the infiltration rates and soil nutrient contents. Therefore, the findings of CA on soil, crop yields, economics and mitigate climate change effects are quite encouraging; however, its area coverage is quite low in Nepal. Therefore, further studies on system based technological, socio-economical and policy constraints to its adoption in Nepal need to be explored. Experiences of international CG centres and development institutions, national agricultural research system, universities, extension systems and non-governmental organizations working in research and development of CA should be taken into consideration. The recently established Conservation Agriculture and Systems Intensification (CASI) platform for Indo-Gangetic plains could be one of the useful initiatives in creating enabling environment for concentrated efforts of its member countries in developing and scaling out of CA based production systems.

Keywords: *tillage, residue, system yields, soil organic matter, economics, scaling out*

Conservation Agriculture in Southeast Asia – a case study from Timor-Leste

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This paper focuses on how Conservation Agriculture technologies (CA) can increase farmers' efficiency in crop production as well as their capacity to adapt to variable climatic conditions. A summary of the participatory adaptive research using the Farmer Field School (FFS) approach and an overview of the results obtained, constraints presented and opportunities for the future will be presented.
In Timor-Leste, "slash and burn" and the free grazing of livestock are contributing to soil erosion, a decrease in soil organic matter and the capacity of soil to retain moisture and nutrients. These factors, in turn, lead to low soil fertility and reduced crop productivity. Weather variability and climate change also affect crop productivity, especially with more frequent dry spells and less rainfall. Initial results demonstrated that subsistence Timorese farmers can produce maize and legumes more efficiently with crops that are better adapted to weather variability, particularly dry spells and reduced rainfall.

The most significant impact of adopting CA was found in crop yield. Compared to traditional farming in Timor-Leste, CA leads to higher productivity per unit of land (16% higher). Moreover, production costs are significantly lower if CA is adopted (33.5% lower). In fact, the amount of fuel needed for rolling is notably inferior to the amount needed for ploughing (68,5% less) and the total cost of farming equipment is reduced by 21.7%. In addition, labour time is reduced by 30.4% and productivity per unit of labour (P/uL) (kilograms of maize harvested over the number of days worked) is, therefore, greater (67% higher). Farmers reported to be spending less time in the field after the adoption of CA. With the time saved from working in the field, women conduct a series of other activities such as working in the house, providing more care for the children, looking after livestock, preparing and selling produces and investing in new businesses.

Due to the impact of El Niño, many farmers observed that keeping a layer of crop residue on the soil surface provided better condition for maize growth. The advantage of CA in such a critical weather event is serving as an entry point for farmers to realise the disadvantages of burning organic matter in crop fields, and that CA technology is more efficient than traditional practices, potentially making farming a more attractive option for young people who are migrating to cities because they are increasingly discouraged by the low productivity and labour intensive nature of traditional farming.

Keywords: *Conservation Agriculture, climate resilience, soil and water conservation, residue management, impact evaluation*

Arise African agriculture

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Africa is hungry and I have seen it! Yet it needs not be – they have good soils and rainfall. Interestingly, while Africa has embraced smart phones and smart cars, it has very little smart farming. Agriculture has many components to make it function efficiently but there is nothing that should stop Africa now. A history of witchcraft, control, revenge, jealousy and fear is giving way to increasing Christian values. Education is improving, democracy is becoming more real and the most important call is to feed their peoples and this can't be ignored anymore. The days of African dictatorships are numbered!

Given that Africa has 1.3 billion people and will likely double by 2050, the real question is "will Europe allow Africa to feed itself?" Europe cleared its forests some 400-600 years ago, but will it let Africa structure its trees in the landscape to ensure efficient smart farming? Rapidly changing values in the West towards humanism, liberal sexuality, gender fluidity, organics, anti-chemicals, anti-fertilisers, anti-glyphosate, anti-industrial agriculture, climate change panic, anti-animal farming, veganism, and anti-biotechnology are clear in Europe. Funds from Europe and their shared history have been an umbilical cord to Africa and there is a growing tension.

I believe that Africa's climate and land is more like Australias than Europes. Like Australia, Africa is; "A land of droughts and flooding rains." Africa must feed its children; it must stand on its own feet. Africa needs the modern no-till agriculture which has rescued Australia's farmers from the ravages of frequent drought, while maintaining its topsoil. Africa must make every drop of rainfall count and with no-tillage with residue retention they can do this. Such tools will bring Africa out of poverty, especially when done with integrity which most African countries are embracing. This paper will discuss some of the African agricultural logistical challenges and how they can be overcome.

Keywords: *food security, no-till, soil erosion, biotech*

The role of Conservation Agriculture in the European Common Agriculture Policy

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European Common Agriculture Policy (CAP) has been a factor highly influencing decision making by farmers and the way of farming. Historically, CAP was concentrated on the objectives of food provision, income support, affordable food and market regulation. In the last two decades, following intensification and overproduction, other objectives partially replaced the old ones and more attention was given to Rural Development, competitiveness of farming, environment and biodiversity. Amongst the proposed measures to achieve these objectives were mandatory minimum standards, agri-environmental or 'greening' measures schemes and, more recently, the so-called mission area on soil health and food, all of them to address today's hotspots of the CAP policy framework, i.e. climate action, efficient management of natural resources and the protection of biodiversity and landscapes.

The core strategies to tackle all these objectives in the recently defined CAP policy framework are summarized in documents and action plans named "European Green Deal", "Farm to Fork Strategy", European Mission on Soil Health and Food", and "Biodiversity Strategy". Despite referring positive and wishful approaches such as "Farming practices that remove CO_2 from the atmosphere … should be rewarded", these documents are mostly omissive when it comes to concrete when it comes to concrete measures and practices to be named and capable to address not only one but most of the objectives outlined concomitantly.

The simultaneous and continuous application of the principles of Conservation Agriculture (CA) has proven to be the most promising way forward to address effectively and efficiently the multiple challenges of food production, following a nature-based approach (minimum soil disturbance, permanent soil cover and species diversity). However, to make CA a mainstream approach towards sustainable agriculture, consumers, civil society and farmers must learn what is needed to achieve soil health and thus true and holistic sustainability of food production. We also must recognize that productive and resource-efficient agriculture must be able to trust on the availability of safe inputs to be used responsibly. Above all in Europe, the considerable income support to the farming sector should clearly linked to the verifiable delivery of ecosystem services. Finally, an unbiased, objective appreciation of all pros and cons of the different farming approaches is needed to assess their conformity with the whole set of goals established and to be achieved within the best compromise possible.

Keywords: *Agricultural Policy objectives, SDGs, Farm-to-Fork, CA deliverables, Productivity, Resource-efficiency*

Proposal of CA as a stand-alone action within the Slovenian rural development plan in 2021-2027

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We estimate that in Slovenia Conservation Agriculture (CA) is currently practised on just 2500 - 3000 ha corresponding to 1.5 % of all arable land. Compared to other world regions the adoption of CA in Europe and Slovenia is relatively slow. Having recognized the environmental challenges of agricultural land use, the European Commission set higher ambition on environmental and climate action in the proposals of the common agricultural policy (CAP) beyond 2020. The framework of the future CAP supports improved soil quality and protection, and increased carbon sequestration through better land use. In these terms, the Slovenian Association for Conservation Agriculture submitted a proposal to the Ministry of Agriculture, and to the other important stakeholders of a new, stand-alone, holistic policy action called Conservation Agriculture. Farmers would sign up for a new program voluntarily. The measure shall be implemented on the selected parcel without the possibility of transferring from one parcel to another during the contract period. The basis for entering the CA action is the approved action plan with predefined variegated crop rotation including cover crops, and agricultural operations. Farmers could use only appropriate equipment that minimizes soil disturbance or enables direct seeding to keep soil covered with pant residues even after sowing. Soil organic matter balance shall be modelled for the crop rotation period and kept positive or neutral for every field specifically. After five years the fields transformed into CA should have measurably higher soil organic matter content in the upper 10 cm of soil. All types of arable land such as annual crops' fields, and agricultural land under permanent crops such as orchards and vineyards could be included in the new measure. We anticipate that in five years, with proper financial support for the action, we can exponentially enlarge the area under CA from 1.5 % to 25 % of total arable land in Slovenia. Our proposal also provides an investment program, which is crucial in the time of transition from tillage-based agriculture to Conservation Agriculture and will enable better access to specialized equipment for sustainable farming.

Keywords: *Slovenia, agricultural policy, Conservation Agriculture, holistic action, sustainable agriculture*

Sustainable use of glyphosate in Conservation Agriculture

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About 95% of the food is produced directly or indirectly from soils, so achieving healthy soils is crucial for food security. Unfortunately, many threats pressure soil to be degraded, and tillage-based agriculture compromises the sustainability of agriculture, and therefore of safe food production.

It is well known that Conservation Agriculture protects and improves soil health, but to achieve the success of the system farmers need to face some challenges, and one of these is how to address weed management.

The adoption of the three principles of Conservation Agriculture (CA) is essential to introduce integrated weed management in farms. All three principles of CA help to reduce weed infestation density and pressure. But, the application of herbicides is a useful complementary tool necessary to and ensure crops profitability. In CA, the most used herbicide in integrated weed management strategies is glyphosate. CA facilitates the safe and minimum application of glyphosate per hectare. Therefore, glyphosate is the most widely used herbicide in CA.

However, the use of glyphosate is plenty controversial. It has been declared by the European Food Safety Authority (EFSA) as potentially carcinogenic. In contrast, studies carried out by the United States Environmental Protection Agency (EPA) ensures that there are no risks to human health when glyphosate is used according to the specifications of the label.

To understand more reliably the use of herbicides and specifically the use of glyphosate in European agriculture, the European Conservation Agriculture (ECAF), in collaboration with its National Associations, launched a survey in 2020. This survey asked farmers about soil management, use of herbicides and alternatives in case of herbicides ban. In all, 1677 responses were received from 21 European countries.

According to the results obtained, it can be observed that glyphosate is the most commonly used herbicide in European agriculture with 88% of the responses, independently of the soil management system: No-till, minimum tillage or conventional tillage, being mainly used for the control of weeds in preemergence. Likewise, no differences have been shown between the doses of use between conventional agriculture and No-till, overturning the belief that techniques included on CA use more glyphosate to control weeds in preemergence. Also, and asking about the perception of the effectiveness of this herbicide, more than 80% of the farmers surveyed think that glyphosate offers good weed control. Finally, the results show that in case of glyphosate will be banned, farmers do not find any viable and profitable alternative. In addition, if finally, the renewal of use of glyphosate won´t be approved in Europe, a large number of farmers who manage their crops under CA would return to tillage, with the negative consequences that it would have concerned soil health and GGH emission.

Therefore, integrated weed management, including the adoption of the three principles of CA, along with judicious use of glyphosate, helps improve the environment compared to tillage-based agriculture.

Keywords: *Integrated weed management, judiciuous use of herbicides, survey, alternatives to glyphosate*

Capacity development of agricultural mechanization hire service providers: opportunities for promoting Conservation Agriculture

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With climate breakdown and aggravated natural resource (especially soil) degradation, Conservation Agriculture (CA) offers exceptional potential over the coming years as a means to produce food sustainably for the planet's growing population while conserving natural resources and sequestering carbon at the same time. However, and especially in developing regions, CA implementation on the ground remains complex and the role of agricultural mechanization (especially for crop establishment and care) has been seen to be crucial. Consequently, over the past ten years, FAO has developed a program for the promotion of sustainable agricultural mechanization, in particular through support for private sector mechanization hire services provision.

This paper highlights the main results achieved after a program of capacity development for actors involved in agricultural mechanization hire services provision. This started with a training needs assessment and then organizing two regional workshops on sharing experiences of sustainable agricultural mechanization hire service provision practices in sub-Saharan African countries, one in Côte d'Ivoire with the participation of Benin, Burkina Faso, Côte d'Ivoire, Morocco and Senegal and one in Uganda with the participation of Ethiopia, Ghana, Kenya, Tanzania, Uganda and Zambia.

The exercise showed that there is great potential for developing agricultural mechanization hire services provision and different models were highlighted such as private enterprises of different types and sizes and cooperative use of shared equipment. Mechanization hire service providers, who are typically engaged in other activities such as crop production and processing and product commercialization, will play a crucial role, particularly in the promotion and dissemination of new practices such as CA. It was confirmed that, particularly for enterprises run by young people, there is openness to the introduction of new agricultural practices (such as CA) and information technologies which allow better monitoring of the use and management of equipment used for service provision.

Based on these considerations, a training manual for sustainable mechanization service providers was developed (by FAO and CIMMYT), including modules on management, technical issues and CA. It is aimed at trainers and its implementation is planned this year through a series of training sessions in English-speaking and French-speaking countries in collaboration with the African Conservation Tillage Network (ACT) in Kenya and the University Nazi Boni of Bobo Dioulasso in Burkina Faso.

In addition to the issue of developing the capacity of mechanization service providers, other factors must be taken into consideration, two of which are essential. The first relates to financing the acquisition of equipment and farming system transition to CA. As an example, in the case of Senegal the system of financing through the agricultural bank has encouraged private investment in agricultural mechanization and the creation of several hire service providers. The second point relates to the issue of the resistance of some producers to adopt CA and therefore reduce the demand for CA mechanization service providers. In this context, sensitization and extension activities need to be strengthened and sharply focussed.

Keywords: *Conservation Agriculture, sustainable mechanization, hire service provision*

LIFE Agromitiga: development of climate change mitigation strategies through carbon-smart agriculture

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In agricultural systems, one of the most relevant natural resources for fighting climate change is soil, thanks to its potential to capture CO_2 from the atmosphere. Proof of this is that soil, with three times more carbon than the atmosphere, is recognized as the second largest stock of Carbon (C) on the planet after the oceans, in addition to constituting one of the most important components of the biosphere, for its provision of ecosystem functions and services. Some agricultural practices, such as Conservation Agriculture, can increase carbon sequestration in soils. Therefore, this practice is considered by the 4per1000 initiative as one of the most effective practices to mitigate climate change. On this basis, LIFE Agromitiga, a European project financed by the EU LIFE Program, will promote a low-carbon agricultural system to battle climate change from the agricultural sector, through the use of Conservation Agriculture, providing validated results applicable to EU commitments on global climate alliances. To do so, LIFE Agromitiga will carry out the implementation of Conservation Agriculture practices at 3 scales (pilot, regional and transnational scale). Therefore, a Demonstration Farm Network will be established, which will include more than 35 farms, in countries such as Spain, Italy, Greece and Portugal, in which techniques such as no tillage and groundcovers will be monitored, as well as the amount of carbon that each practice would produce.

It is expected that, thanks to the implementation of LIFE Agromitiga project, a methodology for quantifying C footprint during the cultivation period of crops in different soil management systems will be developed. As a consequence of the proposed methodology, environmental policies in the EU on climate change and agriculture could be developed and promoted. Another result will be a report on how to increase the carbon sink in soils while reducing Greenhouse Gas emissions in the project area, which will be useful for international commitments like the Paris Agreement on Climate Change, the Sustainability Development Goals, among others. It is expected to increase the soil carbon sink by 1 Mg $ha^{-1}yr^{-1}$ in both annual and permanent crops. Therefore, a technological tool will be created, which will enable stakeholders, including farmers and technicians, to evaluate its practices regarding carbon sequestration in agricultural soils. Since Conservation Agriculture improves soil quality, leading to an optimized use of inputs (including Nitrogen fertilizers), resulting in lower emissions, energy savings and energy efficiencies superior to conventional agriculture, it is expected to achieve energy savings of around 30% in the crop rotations. Energy productivity is expected to increase by 50% and fuel consumption would drop by half.

Keywords: *Conservation Agriculture, No-till, Groundcovers, Carbon sequestration, energy saving*

Aknowledgements: *The LIFE Agromitiga project has received funding from the LIFE Programme of the European Union*

Multi-pronged theory of change drives successful Conservation Agriculture systems

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The American Farmland Trust (AFT) takes a comprehensive approach to Conservation Agriculture. Our mission reflects our multi-pronged theory of change in that we work with farmers and their partners to implement regenerative practices; we recognize that both protection of farm and ranchland and their transfer to new farmers is critical to the survival of Conservation Agriculture because without these lands, we will not have sufficient land for food, fiber and fuel production. We then "feed" these levers of change by taking learnings from our work and providing them to policy makers at the state and federal level to develop and implement policies that can incentivize and fund each of these actions that are necessary to support Conservation Agriculture. In this presentation, we will explore various examples of our work with farmers on adoption of regenerative agriculture practices and complementary work undertaken with a variety of AFT tools to quantify the economic and environmental outcomes from implementation of these practices thus illustrating to other farmers the benefits realized by investing in soil health. For example, through the use of AFT's Carbon Reduction Potential Evaluation Tool (CaRPE), a web-based interactive tool used to visualize and quantify greenhouse gas emission reductions from implementation of a suite of cropland and grazing land conservation management practices, we can work with farmers to run scenarios comparing practices, their estimated costs, and see where across a state or region the greatest impact can be achieved. Furthermore, through CaRPE's data and maps, policymakers and land managers can prioritize efforts for mitigating climate change from agriculture. We will talk about our work protecting farmland not only as a tool for meeting national and global food security demands and ensuring land is available for current and future generations of farmers, but also as a preferred methodology for offsetting greenhouse gas emissions when done in tandem with climate smart urban development. Research conducted in California as part of our Greener Fields project indicates that an acre of agricultural land in California emits 58-70 times less greenhouse gases than developed land and thus farmland protection is a critical tool in fighting climate change. And finally, we will discuss the critical role that the outcomes from our work can provide to enabling policy makers to develop relevant and much needed policies such as the role that AFT plays in the US Climate Alliance where we are working to ensure that agriculture is included in state climate action plans or our work with the Illinois Department of Agriculture to develop a crop insurance premium discount program for cover crops. In this innovative and impactful program, farmers who plant cover crops are offered a $5/acre discount on their crop insurance bill.

Keywords: *farmland protection, policy, regenerative practices, soil health, climate change*

Conservation Agriculture in Brazil: a comparison of no-tillage adoption between the South and Central-West regions according to classes of farm holdings size based on the 2017 Agricultural Census

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This paper analyses the adoption of No-Till System (NTS) by farmers comparing the two most important agricultural regions in Brazil based on data from 2017 Brazilian Agricultural Census (5.05 million farm holdings surveyed), considering size classes defined by the total land area of holdings, as NTS represents a key practice for Conservation Agriculture in tropical soils. The two regions have been selected as together they participate with around one half of country's total gross value of agriculture production (US$ 100 billion in year 2019) and also amount to more than three quarters (77.56%) of the 33.1 million hectares (ha) total area of NTS in Brazil, respectively 13.5 million ha in Central-West and 11.9 million ha in South region. Emerged from the analysis that the overall rate of adoption of NTS was substantially different between the regions, as in the Central-West 20.13% of the total number of farm holdings which used soil preparation declared to use NTS, a figure very close to the 20.11% Brazilian average, compared to 57.58% of holdings declaring to adopt NTS in the South region. In the latter, NTS was the predominant soil management adopted considering all size classes of holdings with area of more than 5 ha and, when considering all the classes of more than 50 ha, the rate of adoption was above 70 per cent in the South region. Conversely, the highest NTS rate of adoption estimated for Central-West region was 45.09%, for size classes above 2,500 ha. Regarding to the average area under NTS per class of farm holding size, there was close similarity between the two regions of study for the classes up to 500 ha, whereas for classes above 500 ha the average size of holdings was 139.56% bigger in the Central-West than in the South region. It is suggested for further study to research on the factors that influence the adoption of NTS and explain the differences identified between the regions and size classes of farm holdings, including farm typology, land tenure situation, characteristics of the farming systems, integration of cropping and livestock activities, type of technical assistance provided to farmers, and climatic, especially rainfall, regime.

Keywords: *soil management, best agricultural practices, soil and water conservation*

How will new agriculture technologies impact the future of CA?

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From my perspectives as a Farmer, Agronomist, and the Director of a large Agriculture Investment Firm, I am extremely fortunate to be able to witness, through all stages, many of the new breakthroughs in agriculture technology, not only in North America, but around the world. The farmland our investment firm owns in the USA is managed using CA practices (where possible) and the Ag Tech we invest in Globally often has the potential to directly impact our farms. In the past six years venture capital investment in new ag technologies has increased an incredible ten-fold! The $20 billion of new venture capital invested in ag tech in these recent years is expected to be very minor compared to these next six years. Partly because of this investment, there has recently been truly profound scientific advancements that have opened the door to countless additional new technologies that could help all farmers and consumers, but specifically they could improve and expand Conservation Ag as well. Technology, that in some cases should be accessible to most regardless of where they farm and yet cost less than the conventional options we have today, some of these emerging technologies are creating whole new categories of crop inputs/science. Technologies that will help *minimise soil disturbance*, lower pesticide use, improve nutrient use efficiency, allow for *greater biodiversity*, and facilitate the precise use of all crop inputs, just to name a few.

Drones, Satellite images, Robots, Autonomy, and even “Biologicals” are usually associated with new Ag Tech. These are important, but I intend to go beyond these categories in discussing exciting new ag tech and its relevance to Conservation Agriculture and to crop production in general. For example:

Designer Proteins – the potential now exists to replace most current pesticides with “natural” products that are more specific, less harmful, and non persistent.

Precise Fermentation – this process is now refined to the point of being able to create thousands of bio-based products at incredibly low cost, i.e., pennies an acre.

Inexpensive genetic testing – LAMP tests that facilitate fast, inexpensive, genetic testing, that leads to the creation of disease and insect traps that can operate in the field in real time! Genetic testing of a plant or soil for less than $5! Epigenetics creating a new non-gmo crop variety in 2 weeks!

Advanced AI Imaging – can now evaluate all soil properties inexpensively on the fly, including disease and microbe levels, ability to “see” pathogens from harvest through to retail as well.

Nutrient Availability – supercomputing has designed systems that can create N fertilizer without the need for a carbon-based energy system and are scalable from a small field to a large ag retailer system. Systems that will allow the reduction of P fertilizer by 75%. Microbes could play a role here as well.

Keywords: *Pathway Optimization, Robotics, Epigenetic*

The 4CE-MED project - Camelina: a cash cover crop enhancing water and soil conservation in Mediterranean dry-farming systems

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To increase food security and sustainability, ecologically sound, reliable and profitable farming systems should be identified and promoted. Conservation Agriculture (CA) is well documented for bringing environmental benefits; yet, it is surprisingly not widespread in the Mediterranean basin, mostly due to the lack of technical knowledge including specific machinery. Within the framework of the EU PRIMA joint program, the 4CE-MED project (May 2020 - October 2023) aims at developing innovative, diversified and resilient cropping systems suitable for the Mediterranean climate, adopting a participatory approach (national platforms of stakeholders) to serve as main basis for identifying the urgent needs of smallholder farmers. The project consortium includes eleven partners of seven countries (four EU and three non-EU countries). Local socio-economic barriers will be analyzed to understand major constraints in the deployment of specific CA systems. In particular, 4CE-MED focuses on camelina [*Camelina sativa* (L.) Crantz] as a cash cover crop under CA. Cash cover crops are defined as crops able to reach seed maturity before the establishment of the main crop, thus providing additional sources of income for farmers. Among alternative species, camelina, belonging to *Brassicaceae* family, was selected because of its considerable resilience and a likely expected suitability for CA systems. Moreover, camelina can be a multipurpose crop able to source oil (~40%) and protein (~28%), and also straw, for a number of food, feed, and non-food applications. In each participating country (Italy, Greece, Spain, France, Tunisia, Morocco, and Algeria), field and plot trials have been undertaken aimed to investigate different camelina genotypes under diverse climatic conditions. Site-specific crop rotations will be evaluated in term of productivity, profitability and environmental benefits. In addition, field visits and training courses will be organized to allow farmers and stakeholders to become familiar with these likely innovative and sustainable cropping solutions. The ultimate goal of 4CE-MED project will be to transfer its results to farmers, farmers', cooperatives, industries, and policy makers by developing a collaborative network of stakeholders, who will adopt, modify and improve the locally 4CE-MED solutions.

Keywords: *Mediterranean, Conservation Agriculture, Sustainability, Cover Crops, Smallholder Farmers*

We should defend glyphosate – because it´s safe, cheap & effective

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The benefit of glyphosate to stop soil erosion through no-tillage and to improve soil quality and health is undisputable. It has increased soil biological activity with increased storage of soil carbon and with a 40 year history. The evidence that glyphosate causes non-Hodgkin's lymphoma (NHL) is very, very doubtful. The longitudinal study in the USA of 57,000 farmers and farm workers with a 20 year use of glyphosate shows no difference in NHL incidence compared with those who have not used it. I believe that their target is not glyphosate but biotechnology (GM) and they are happy to take out glyphosate as well.

Indeed for 25 years a network of activist scientists hostile to biotechnology, has been trying to remove biotech from agriculture. They include; Australia's Dr Judy Carman, India's Dr Vanda Shiva, USA's Dr Don Huber and Jeffry Smith, France's Dr Giles Seralini and many more. The continued growth of GM crops has likely forced this group to change their tactics. Since most of their publications have been widely discredited and GM acreage with Roundup Ready technology has increased.
The success of Californian Court cases against glyphosate was a deliberate strategy. The hundreds of millions of dollars awarded to contract gardeners, on small wages, who contracted NHL is baffling. Or perhaps even strategic and much of the monies goes to the lawyers? I know USA farmers are keen to have a similar case held out in the rural Midwest where more sensible judgements are likely as all the evidence could be presented. A current court case to be held in Australia in 2020 is likely to be more partial.

In the past four years, regulatory authorities in the EU, Korea, Japan, Australia, New Zealand, Canada and the USA have reaffirmed that exposure to glyphosate does not cause cancer. More than 800 scientific studies and reviews, including independent safety assessments, affirm that glyphosate does not cause cancer. The study found no connection between cancer and glyphosate.

So how did the IARC come to the conclusion that glyphosate probably causes cancer? I have read several activists' papers and their methodology is conveniently obtuse or misleading. Prof Bruce Chassy says "*the experiments were improperly designed and poorly executed, and the analysis and conclusions faulty*." When anyone criticises their scientific approach they send defamation letters – I have received three such notices.

I emailed Kurt Straif of the IARC in Sept 2015 asking if could he tell me what the evidence was for their classification, his response was evasive. Prof Chassy then responded to Kurt and myself, saying; "*Given the paucity of evidence supporting this conclusion, and the evidence contrary, many experts question IARC's classification.... please explain?*

Keywords: *glyphosate, sustainability, food production, fraud*

Next steps for taking directly seeded rice (DSR) to scale in the Eastern Gangetic Plains of India

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Directly sown rice (DSR) addresses some of the major drivers of change in the agricultural systems of the Eastern Indo-Gangetic Plains. Because of this, DSR have been the focus of targeted interactions, particularly in central Bihar where promotion has centred around districts with suitable agro ecological conditions (ex. areas with reduced weed pressure such as lowlands, assured early irrigation to control inundation and to avoid stand mortality before the chance of heavy monsoonal rains increase), adequate machinery, and high potential for productivity increases and production risk reduction through DSR. Agronomic results highlight an increased average yield of 0.34t/ha against transplanted rice under normal conditions, and an increase to 0.8t/ha when aided with one supplemental irrigation.

Despite this, supply and demand have not synced. By strengthening the service economy over the last 10 years, more than 5,000 Bihari farmers are now using DSR for the establishment of rice across regions through service providers. Yet only 10% of service providers are engaged in providing DSR services, and the scaling up of DSR has been slower than expected. This study applies an in-depth analysis through five stakeholder typologies namely: DSR service provider, DSR dis-adopter (i.e. stopped usage), DSR farmer, Zero Tillage (ZT) wheat service provider and lastly, the ZT wheat farmer to explore the various dimensions of DSR adoption from farmers, as well as the experiences, challenges and opportunities faced by DSR service providers.

The results highlight the emergence of trends in farmer perspectives on DSR, as well as issues with demand for and viability of DSR services. Key themes emerged in the skill level of service providers, both for seeding and in weed management due to a more complex weed flora. There is also an increasing number of rotovator owners and operators and investment in tillage machinery that is counter to DSR service provision. In many cases, there exists an expectation of support from the department of agriculture, KVK and NGOs for operation, service and awareness creation of machine that service providers see as outside their scope. These learnings and more provide an important point of reflection for future scaling efforts on DSR.

Keywords: *Direct Seeded Rice; Service provision; Lived Experience and Perspectives*

Soil biological response to cover crop termination methods with two levels of water availability

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The use of winter cover crops (CC) in annual rotations promotes the sustainability of agro-ecosystems by improving soil health. However, the benefits can be reduced or disappear depending on the CC termination method. Incorporating CC by tillage or glyphosate use are common to terminate CC, whereas roller crimping is emerging as a new promising technique. However, the reduced effectiveness of the roller crimper in certain conditions may call for its combination with glyphosate. The objective of this work was to evaluate the effect of different methods of terminating CC on the abundance of different groups of microorganisms and other microbiological parameters. Four methods to terminate CC (a mixture of barley and vetch) were evaluated (INC mowing and incorporation of CC residues; GLY glyphosate; ROL roller crimper; and RGL combination of roller crimper with glyphosate) and a control without CC (CON), with different water levels (high H and low L). Treatments were distributed in randomized blocks with five replicates, using microcosms with an alkaline soil, poor in organic matter. Sampling was conducted in the succeeding main crop (maize) at pre-emergence and 57 days after sowing (DAS). Abundance of microorganism groups (total bacteria, archaea and fungi, and Glomeromycota) were determined by qPCR. In addition, the length of extrarradical hyphae and mycorrhizal colonization in maize were determined.

We found that CC termination methods and its interaction with water level differentially affected the microorganism groups at both maize pre-emergence and 57 DAS. At maize pre-emergence, GLY decreased the bacteria abundance under both water levels, especially under high water level. By contrast, at this level, bacteria were stimulated by INC. The archaea abundance was less sensitive to water level and was favoured by the roller crimper, with or without glyphosate. Total fungi and Glomeromycota were favoured by RGL, regardless of the water level. At 57 DAS, the biological response of soil changed with respect to pre-emergence. Thus, the negative effect of GLY on total bacteria abundance disappeared at 57 DAS. Abundances of total bacteria, total archaea, total fungi, Glomeromycota, length of extrarradical hyphae and mycorrhizal colonization were enhanced by INC in both water levels. Therefore, the time elapsed since CC termination increased the benefits of incorporating CC residues regardless of the water level. By contrast, the positive or negative effects of glyphosate, roller crimper and its combination on certain microorganism groups were highly dependent on water level. Overall, we found that the time since CC termination and the water availability modulates the biological response of soil to CC termination methods. Further research is therefore needed to investigate the impacts on a variety of environmental conditions to better understand the processes involved.

Keywords: *glyphosate, roller crimper, qPCR, maize, soil health*

A private Conservation Agriculture label by farmers and a professional movie to reconcile farmers with citizens

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Farmers practicing Conservation Agriculture in France are still a little minority (2 to 4 %), like in most other European countries. Despite improved results of their farms versus conventional agriculture, proven by all data when properly and honestly assessed, they are facing many obstacles. Among them, the worst is the political management of agriculture by politicians, who follow public opinion and are influenced by diverse lobbies. Traditional farmers unions, unable to deal with this phenomenon, are now the target of anti-farmers activists (“Agri bashing”).

APAD (Association pour la Promotion d’une Agriculture Durable), a French farmers association specialized in CA, has now a rapid growth, due to its attractivity for farmers (thousand farmers and fifteen local groups). But it also faces the opposition of intellectual elites of media, politics, NGO’s and leading academics, for whom only organic agriculture is acceptable. However, APAD farmers have seen that a productive dialog is possible, even on pesticides or glyphosate use, every they give honest and transparent explanations of results and practices on their farms. Despite the great success of numerous meetings of citizens on CA farms, the impact is still too low to recover recognition of the public.

APAD has made a professional scientific study with a University specialist of the food chain, about perception by citizens/consumers of agriculture, environment, and CA.The findings show that citizens do not like traditional farmers anymore, hate pesticides, like “nature”, trust no one (food industry, politicians, media, NGO, scientists), but do not praise organic so much as expected. They are looking for nature and farmers they can trust. After having been introduced to CA, a large majority recognizes that they like it, and may even accept some level of pesticides, if farmers explain their effort to improve.

Based on these findings, APAD has launched a private label, owned by farmers, based on a process of progress, with an internal audit of candidates by a peer review process, led by the most experimented farmers. The first indications after one year and 200 labelled farms, are indicating a high level of interest of media and public for this process where farmers are bringing themselves their reality to citizens without any intermediate or filter. APAD wishes to mutualize with sister associations all experiences about productive dialog with citizens, to reconciliate farmers with citizens, and humans with nature.

Keywords: *farmers associations, recognition by citizens, label, consumer study*

Legacy effects of cover crops mixtures differently affect soil microorganism groups

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Cover crops (CC) can promote arbuscular mycorrhizal fungi (AMF) compared to fallow, and can affect other soil organisms with key soil functions. However, benefits on soil health may depend on CC species and its combinations. This research quantifies the legacy effects of CC species (monocultures and mixtures) in rotation with two different main crops on selected plant and soil biological attributes. We established microcosms experiment with five replicas and low inputs (fertilizer and water) conditions. Three CC in monoculture (two legumes and one grass) and in two mixtures of one legume with one grass, in addition to a control without CC were evaluated in combination with two different main crops (MC); maize (C4 plant) or wheat (C3 plant). The experiment was carried out in a greenhouse after two rotation cycles with CC and MC. Plant and soil were sampled in the main crop of the second cycle. The mycorrhizal colonization, the length of extra radical hyphae, the total abundance of bacteria, archaea, fungi and glomeromycota in the soil, the plant biomass aboveground and the shoot P were measured. We found a strong interaction between CC treatments and succeeding main crops. All CC increased the mycorrizhal colonization compared to non-CC in wheat and maize, especially the CC with barley+vetch in maize. The hyphae length was increased by ~50% in the barley+melilotus in wheat in addition to improve the shoot P compared to the control. The abundance of total bacteria and glomeromycota was increased by all CC in wheat. On the other hand, in maize, all CC with barley showed the lowest abundances of total bacteria, total fungi and glomeromycota. Choice of CC species and species mixture and its interactions with the succeeding main crop can have large effects on soil microorganisms, at least at short time, with potential impact on soil key functions and agronomic aspects. Further research is needed to understand these interactions, especially concerning the mixtures, in a way that give support on the decisions of which CC is more appropriate in each case.

Keywords: *maize, wheat, bacteria, fungi, mycorrhization*

Effectiveness of Conservation Agriculture in meeting the environmental objectives of the European Common Agricultural Policy

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In recent years, the European Union's Common Agricultural Policy (CAP) has increasingly focused on the environmental challenges facing the agricultural sector, such as climate change, pollution, soil degradation, among others. Through the successive reforms, these challenges have been increasingly present both in Pillar I of the CAP, which focuses on the commitments that farmers must make to have access to income support, and in Pillar II, which specifically provides for voluntary measures aimed at achieving certain environmental objectives. The Rural Development Programmes (RDP) compiles the voluntary measures of each Member State of the European Union, which in the case of Spain have been transposed into regional legislation. Conservation Agriculture has been contemplated in the RDP of some regions in Spain, as is the case of Andalusia. Thus, agricultural practices such as No-till and Groundcovers have been contemplated in some agri-environmental schemes like "Sustainable management systems in rainfed annual crops" and "Sustainable management systems in olive groves" during the period 2014-2020.

This work has aimed to determine the results achieved in Andalusia as a result of the application of the practices promoted by these agri-environmental schemes. To this end, a sustainability assessment has been carried out in a network of 8 demonstration farms located in Andalusia. The study has a focus on wheat (*Triticum durum*) and olive groves (*Olea europaea*) and the management practices evaluated have been Conservation Agriculture (No-till in the case of wheat and Groundcovers in the case of olive groves) and conventional tillage in both wheat and olive groves. The sustainability assessment has been based on the INSPIA methodology. This methodology is based on the calculation of 31 basic indicators, providing a final composite index of sustainability, bringing together the environmental, economic and social areas. The greater the implementation of sustainable farming practices, the higher the value of the composite index.

The results have shown that the sustainability index, in the farms under Conservation Agriculture, was between 11% and 32% higher than in the farms under conventional farming. Moreover, the overall sustainability index in the farms under Conservation Agriculture increased on average by 17% after four seasons.

Keywords: *Sustainability indicators, Sustainable agriculture, No-till, Groundcovers, INSPIA*

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Promoting CA-based knowledge and innovation systems and information sharing and communication

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Undoubtedly, the world is undergoing dramatic transition due to the confluence of 5 fundamental disruptive forces: climate change, demographics, communication/digitalization, data/technology, and rurality/urbanization. These forces are amplifying each other, intensifying land challenges in magnitude, scale, and influence, breaking the environmental and socio-economic trends. In addition, limited global land and biomass resources accompanied by growing demands for food, feed, fibers and fuels requires reshaping and transforming the agriculture and food sector. In fact, the shift to new paradigms and from these challenges has been maturing in science and society for years. Among pertinent transforming options, Conservation Agriculture (CA) was found to alleviate impacts of these forces. Worldwide CA is adopted in more than 180 million hectares in all continents and in most edaphic and social situations. In other terms, countries and their farming communities and institution should leverage on successful results to scale-up implementation towards sustainable food systems. However, still each of the CA principles poses different constraints and opportunities to farmers. Hence, for further expansion dynamics and producing monumental change in CA dissemination, it is necessary to improve comprehension, use and appropriation of CA principles and to ease knowledge and innovation access, acquisition, and development (Findlater et al., 2019). CA transition may be facilitated by several information sharing and research-based knowledge communication channels and initiatives (co-learning platforms, farmer networks) with support from private sector, civil society groups and other financial structures and incentive measures (e.g., price premiums, access to credit, regulation). Given the extensive heterogeneity of farms and societies around the world, stakeholders should use imaginative advancements to accomplish a genuinely necessary edge from CA systems.

Keywords: *Conservation Agriculture, Innovation and Knowledge Sharing Framework, Agricultural Information and Innovation System, Communication Pathways*

The future of farming
Profitable and Sustainable Farming with Conservation Agriculture

8 WCCA

8th World Congress on Conservation Agriculture

SUBTHEME 4

PROMOTING CA-BASED KNOWLEDGE AND INNOVATION SYSTEMS AND INFORMATION SHARING AND COMMUNICATION

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The future of farming

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Next steps for Conservation Agriculture

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The greatest problems for expanding the adoption of CA principles worldwide are (i) lack of consistent policies or private programmes for payment of environmental services (PES), (ii) access to certification schemes that would qualify for PSE as in (i) above, (iii) lack of information on long term benefits, especially for cover crops, (iv) competition from new denominations that claim sustainability, but do not have a scientifically defined code of practice or independent verification. On PES, there is a forgotten enunciation in the Declaration of Madrid (First World Congress on Conservation Agriculture, Madrid, 2001 - FAO/ECAF), absolutely crucial to this debate: "....the conservation of natural resources is the co-responsibility, past, present and future, of all sectors of society, in the proportion that they consume products resulting from the exploitation of these resources", and concluded: "It follows that the environmental services provided by farmers practising Conservation Agriculture should be recognized and recompensed by society". This important section of the 1st. WCCA declaration was not emphasized in the subsequent promulgation of CA. Thus, there is an urgent need to link CA with PES. Today's CA concepts from the FAO website deal only with the agronomic definition of CA omit the social co-responsibility for conservation and need to be tightened and made uniform. In many countries, independent evaluation in certification is necessary to qualify for PES. The conundrum with certification is its rigidity and, consequently, it is difficult, and often initially costly, for farmers. Here, a stepwise approach to certification could resolve this, giving time for adjustments and dilution of investments over time. As an example, the Round Table on Responsible Soy (RTRS) has a widely respected, comprehensive, certification scheme, recognized by the European Commission, that includes zero de-forestation, best practices including CA, social and legal commitments. The drawback is that it is only for soya (and shortly maize). Extending this to a whole farm exercise, covering all farm products, would be much faster than to start from scratch. On competition from new denominations that, *de facto,* practice CA but with no scientific code of practice or independent verification, these would not normally qualify for PES. To encompass such new denominations, it would be necessary to obtain evidence that these are based on CA principles and additional social indicators, as required. This could qualify them for PES under such certification. On the technology side, the rapid growth of biological control for pests and diseases and mechanical, laser, or robotic weeders is attracting organic farmers to CA, since soil cultivation is not sustainable in terms of carbon balance. There is thus a need for a CA organic certification, or promulgation of a recommended code of practice for this mode. Overall, CA is contributing greatly to reducing global warming and responding to world population demand for ever more food. It is up to the technical sector to develop a simple and efficient whole farm certification tool that facilitates PES and consolidates CA. There is a trade-off between the risk of fraud and facility, or cost, of execution. This needs to be equated.

***Keywords**: CA principles, payment of environmental services, agricultural sustainability, biological control, organic agriculture, Round Table of Responsible Soy*

Promoting Conservation Agriculture with smallholder farmers in Tipitapa, Nicaragua

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Conservation Agriculture (CA) has become an important method globally but it has not yet become a priority for impoverished smallholder farmers in Nicaragua. This is the case for 80% of poor rural households in this country that continue to depend on subsistence agriculture in a setting where natural resources are limited, land has been over-farmed and population density is high. For this reason, American Nicaraguan Foundation manages an experimental farm located in Tipitapa, municipality of Managua, where we have built a fully sustainable eco-system including bio-digesters, pig raising, demonstration plots and soil testing. There, we have a training program for 440 small farmers to improve their capacities, quality of the soil and the use CA methods.

At the beginning of the project in 2017, the soil analysis showed the deficient existing levels of pH (6.5), organic material (2.23), Nitrogen (0.11), Phosphorus (10.31) and Potassium (1.71). For experimental purposes two demonstrations plots were established. The production plot was divided into four subcategories to train the smallholder farmers in the use of no-till agricultural techniques, use of biol as a natural fertilizer, crop rotation and cover crop. Biol refers to the pig manure composting produced in the biodigesters and it is composed of 70% water, 15% organic material and 15% mineral fixtures. Maize, sorghum, red beans and Canavalia beans are the crops planted in the demonstration plot because of the similarity of their cycles. The other plot remained untouched without biol or crops, just for comparisons purposes.

After three years of crop rotation and the use of CA techniques, Nitrogen increased 2,745% to 3.13 and Potassium 222% to 1.71. Also, pH increased to 7, organic material (6.93), and Phosphorus (10.31). Contrary, the other plot did not reflect any significant change from the initial levels.

Keywords: *subsistence agriculture, Tipitapa, training programs, no-till agriculture techniques*

Development of innovative strategies to avoid use of glyphosate in conservation tillage systems - Smart weed control

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Within the framework of a three-year EIP-Agri-Project, the operational group of “Smart weed control” investigates alternatives to chemical weed control in conservation tillage or even no-till systems. Therefore, different strategies are tested in a three-year crop rotation with the aim to suppress weeds. The use of herbicides (glyphosate) is compared to new developments such as electro physical weed control (Electroherb/Zasso) and other innovative solutions just like mechanical or biological (companion plants, cover crops, under sowing crops) methods.

The studies thereby focus on conservation and improvement of the soil ecosystem, resource efficiency and climate protection. Evaluation of the different methods tested follows both economic and ecological aspects assessed in terms of sustainability. To reach the project goals successfully, modern measurement methods such as geo-reference-based sampling, drones, multi-spectral cameras, thermal cameras, soil scanner and satellite data are used.

The variants are evaluated both from an economic and ecological aspects and

Hence, this innovative project is a smart farming approach, which combines both soil fertility aspects and innovative digital measurement technology. This allows for testing different combinations of methods and, with the help of the results, for developing a model for decision support in practical use.

Thereby, this innovation project contributes to a both competitive, sustainable and resource-friendly agriculture and food sector. This knowledge transfer helps sensitize the farming community and promote the cooperation between farmers, scientists, consultants, companies of agriculture and food sector and consumers.

***Keywords**: Glyphosate, EIP-Agri, Tillage, No-till, Smart Farming, Conservation Agriculture*

Water smart agriculture competencies framework for smallholder farmers in Central America

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The large-scale adoption of restorative land and water management practices in smallholder agriculture has the potential to significantly increase productivity, adaptation to climate change and food security in Central America. However, after decades of agricultural development interventions, critical skills for land management remain a limiting factor. The Water Smart Agriculture Program for Mesoamerica (ASA by its Spanish acronym) is building capacity at multiple levels, from farmer field schools to professional training programs to universities, as part of a strategy to take ASA practices including Conservation Agriculture (CA) to scale in Central America and southern Mexico.

ASA and local partner institutions have placed soil management capacity building at the center of a strategy to reach 250,000 Central American smallholder farmers in a period of 6-years with critical Conservation Agriculture support services. The ASA program is evaluating the effectiveness of soil management capacity building initiatives at various levels, including: 1) Training of farmers through Farmer Field Schools facilitated by lead farmers/promoters and supported by extensionists; 2) Strengthening the extension system for ASA practices through training of trainers and institutional change to better target smallholders; 3) Curriculum strengthening in agricultural education programs to include critical ASA content; and 4) a regional master's program in Integrated Soil Management in Tropical Environments, which includes ASA content. These initiatives are guided by the ASA Competency Framework that identifies the skills, knowledge, attitudes, values and behaviors necessary for the effective implementation of ASA practice in the field by farmers, extensionists and experts. The model includes, Conservation Agriculture Management in Rainfed Systems as a key competency.

We will present the ASA Competency Framework, the innovative methodology we are using to monitor and evaluate the impact of capacity building on behavior change and practice, and results of competency evaluations of extension workers and farmers.

Keywords: *Soil Management, Education; Scaling; Farmer Field Schools; Extension*

The role of SLM knowledge in evidence – based decision – making for LDN

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Sustainable land management (SLM), in its many forms, is crucial for the prevention and reduction of land degradation (LD), and the restoration of degraded land and hence in attaining land degradation neutrality (LDN). LDN represents a paradigm shift in land management policies and practices. It is a unique approach, that counterbalances the expected loss of productive land with the recovery of degraded areas. The amount and quality of land resources, necessary to support ecosystem functions and services and enhance food security, remains stable or increases within specified temporal and spatial scales and ecosystems. It strategically places the measures to conserve, sustainably manage and restore land in the context of land use planning.

To attain LDN it is essential to have access to relevant knowledge for decision-making and be informed about the wide range of sustainable agricultural practices, as can be found with Conservation Agriculture under different ago-ecological and climatic conditions. One key source of data covering SLM, worldwide, is the World Overview of Conservation Approaches and Technologies (WOCAT). WOCAT is unique in being a global network of SLM specialists dedicated to combating LD and supporting knowledge sharing about SLM. It promotes the assessment, sharing and use of knowledge to support adaptation, innovation and up-scaling of SLM. WOCAT has developed a well-accepted framework and standardised tools for documentation, monitoring, evaluation and dissemination of SLM knowledge, covering all steps from data collection with several questionnaires, to the Global SLM Database and to evidence-based decision support. WOCAT has a vital role to play in providing the evidence required to base decisions.

One important and potential SLM measure is Conservation Agriculture. With its concern of conserving, improving, and making more efficient use of natural resources through integrated management of soil, water and biological resources. It is a way to combine profitable agricultural production with environmental concerns and sustainability. The three fundamental principles behind the CA concept are: i) minimum soil disturbance, ii) permanent soil cover, and iii) crop rotation. Each of the principles can serve as an entry point to degradation; however, only the simultaneous application of all three results in full benefits. CA covers a wide range of agricultural practices and works in a variety of agro-ecological zones and farming systems: high or low rainfall areas; in degraded soils; multiple cropping systems; and in systems with labour shortages or low external-input agriculture.

The wide range of CA related technologies and approaches, documented in the WOCAT Global SLM Database, will be presented together with examples of dissemination and mainstreaming activities.

Keywords: *WOCAT, Sustainable Land Management, Land Degradation Neutrality*

Reverte – restoring degraded pasturelands in Cerrado Biome

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The Cerrado ecoregion in Brazil is one of Latin America's largest dryland landscapes, comprised of shrubland, savannah, as well as large spaces of open plain. The soil there is known to be some of the least fertile in the world, impacted by a history of ranching for beef production, leading to the degradation up to 18 million hectares of soil. This degraded soil either lies barren or has been incorporated into pasture with low productivity.

Last year (2020) Syngenta and The Nature Conservancy launched the Reverte program, putting in place tools to enable local farmers to restore degraded land.

Reverte is an initiative to influence the sustainable agriculture expansion in Cerrado biome. It aims to enable growers or cattle holders to make the investment needed to bring degraded pastureland back into cultivation, together with the inputs and guidance that are needed to guarantee the investment's pay back.

Reverte facilitates the adoption of integrated land and pasture management practices and sustainable technologies, guided to expand in degraded pasture lands, that are currently producing less than its potential and are offering less ecosystem services than possible (because of soil conditions degradation). The focus is to optimize the land use, improving efficiency and sustainability of agricultural cultivation expansion on degraded pasturelands.

This is a holistic approach to enable growers and cattle holders to make the investment needed to bring degraded pasture land back into cultivation, considering the best agriculture practices that need to be implemented to have the best win-win scenario of productivity, conservation, and to guarantee the investment's pay back.

We are integrating different tools such as financing, seed varieties adapted to local conditions and soils, agronomic practices that enhance soil conditions and digital tools to allow growers control and monitor their improvements on soil conditions.

In the first five years of implementation, there is a potential to reach one million hectares – and that is basically with a combination of Syngenta's technology and other production systems (integrated systems, crop rotation, cover cropping, etc.).

Reverte will start in 3 main regions in the Cerrado (in Mato Grosso, Goiás and Maranhão), where we aim to increase governance and disclose best agriculture practices for sustainable expansion of agriculture into degraded pasture lands.

We will engage with producers and rural associations in the territories, to foster integrated systems of production, respecting the current stakeholders in the territory, and supporting on the transition to a more efficient land use and soil recovery.

In order to have access to the agricultural inputs and guidance that are part of Syngenta's commercial offer in Reverte, a grower/producer must ensure that their area is in compliance with the program's environmental criteria, (i.e., the Forestry Code is being duly followed) and get the financial approval by the involved banking entities. Also, during the entire time a grower stays on the program, he must follow the Reverte agronomic protocols.

Keywords: *Regenerative Agriculture, degraded pasturelands, Reverte, Cerrado, soil degradation*

Soil protection and carbon sequestration through seeded groundcovers, spontaneous vegetation and pruning remains mulch in olive orchard

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Olive orchard is well-adapted to Mediterranean conditions so this crop has economic, social and environmental importance in this area. Woody crops are considered lands with scarce soil protection as canopies provide less than 30% of soil cover and, in many cases, olive trees are placed in marginal areas with steep slope what eases erosion processes. In addition, some agricultural practices like intense tillage or bare soil favour soil loss. Groundcovers have been proven to be efficient controlling erosion in olive orchard, furthermore, they have the ability to fix atmospheric carbon and improve soil organic carbon (SOC). Among different types of groundcovers are found spontaneous, seeded or pruning remains mulch.

A four-season study with four experimental fields was performed to assess the protection provided and the carbon sequestration potential of seeded species from different families of plants and the spontaneous vegetation of the area. The seeded groundcovers were a grass (*Brachypodium distachyon*), a crucifer (*Sinapis alba*) and a legume, hairy vetch (*Vicia villosa*), each of them was sown in a different field and compared with the specific natural flora. In the fourth field, mulching system with scattered pruning remains from olive trees were tested and compared to the natural vegetation of the area. The dose of pruning remains was established from the average of pruning weight obtained per tree, the distance between two trees and a strip of 2 m (chopping machine width). Soil coverage during the decomposition period and carbon fixation in soil were measured in all types of groundcovers considered.

The seeded groundcovers showed higher soil cover than spontaneous vegetation throughout the study period. Brachypodium was the species that provided a higher and long-lasting protection level with values over 75% at the end of the decomposition period of the four seasons. In all fields, the seeded specie was more protecting than spontaneous. The pruning remains mulch maintained the soil cover quite high until the fourth season where the value was lower of 30% at the end of the season since there was not a new application of pruning remains during four years.

Regarding carbon sequestration, pruning remains reached the greatest annual rate of 3.5 Mg C ha^{-1}. However, it covered lower (2 m) strip surface than living groundcovers (3.5-4 m). Brachypodium increased SOC 1.9 Mg C ha^{-1} annually in the field with the highest clay content. Sinapis obtained an average fixation of 1.8 Mg C ha^{-1} per season and vetch improved SOC 1.1 Mg C ha^{-1} y^{-1}. Instead, spontaneous vegetation provided lower sequestration rate in the four fields, the values ranged between -0.2 and 1.7 Mg C ha^{-1} y^{-1}. Among the experimental fields, those where the soil clay content was higher and initial SOC was lower gave better increments.

The use of groundcovers in olive orchard is highly recommendable because they can protect the soil and mitigate climate change through SOC sequestration. The treatments where farmers had a role, such as seeded groundcovers and pruning remains, worked better than spontaneous vegetation, which is the most used groundcover.

Keywords: *Brachypodium distachyon; Sinapis alba; Vicia villosa; Soil cover*

Happy seeder: a promising conservation agricultural technology for sustainability of rice-wheat cropping system in Haryana

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Rice-wheat system of Indo-Gangetic plains (IGP) of South Asia provides the bulk of food and supports livelihoods of millions of rural poor. There has been a significant increase in grain production of rice and wheat during the past four decades. Over time, there has been a progressive increase in rice crop residue production as well. But, in the absence of scalable and economically viable alternatives for managing rice residues coupled with shorter planting window and growing labour shortages and energy prices, the farmers in the region have chosen the ´Burning Way' of managing the rice residues which led to the significant increase in farm fires. This has resulted in multiple problems of soil health deterioration, air pollution-induced human health issues, loss of biodiversity, diminishing farm profits etc. The happy seeder, a planter capable of direct seeding in the presence of heavy crops residues load (up 11 t/ha) have shown promise to address this issue. However, investments for its large-scale adoption needs robust evidence base and increased capacity of stakeholders under a diversity of farming situations. Farmers participatory validation trials were conducted continuously for ten years (2009-10 through 2018-19) in five districts (Karnal, Kaithal, Panipat, Hisar, Fatehabad) of Haryana. The paired comparisons were made for key performance indicators (grain yield, net economic returns, labour and energy use) between happy seeder (no-till direct drilling) and conventional tillage based wheat crop establishment in rotation with rice. The results (n=415) showed that use of happy seeder for direct seeding (no-till in the presence of surface residues) of wheat resulted in 6.55±2.52% higher grain yield, US$ 152±32 higher net economic returns with 79±3.5% lower labour and 70±2.2% less energy use compared to conventional tillage-based wheat crop establishment. The science-based hard evidence generated from real farm situations across larger geography has helped extension agents, farmers, service providers, developmental departments and Governments for promoting no-till wheat using happy seeder technology in North-West India.

Keywords: *no-till, net economic returns, energy, labour, grain yield*

Enabling smallholder farmers to sustainably improve their food, energy and water nexus while achieving environmental and economic benefits in the EGP: Conservation Agriculture-based sustainable intensification for smallholder systems

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Traditional rice-based crop production in the Eastern Gangetic Plains (EGP) region of South Asia are energy, water and labor intensive and inefficient, with relatively low productivity and profitability. Additionally, crop management in these systems typically does not consider the emission of CO_2-equivalent greenhouse gases, which is often relatively high. The EGP is currently a highly impoverished region, but it has natural resources sufficient to become a leading food-producing region in South Asia. Conservation Agriculture-based sustainable intensification (CASI) crop management practices improve crop productivity and profitability while reducing energy, water and labor requirements, and greenhouse gas emissions. The introduction of CASI practices within villages and districts of the EGP provides opportunities for farming households to sustainably diversify and/or intensify their crop production. it also enables the micro-entrepreneurship and employment opportunities within rural communities.

In over 400 on-farm experiments we compared the performance of traditional and improved management practices in rice-based cropping systems. We found that CASI management practices improved crop grain yields by up to 10%, reduced labor demand by up to 50%, while increasing water productivity (up to 19%) and energy productivity (up to 26%). Combined, these results reduced the cost of crop production under CASI by up to 22% compared to traditional practice, and increased gross margins in general by 12% to 32%. Concurrently, CO_2-equivalent emissions from CASI management were lower than those from traditional management by between 10% to 17%.

The method of implementing and testing CASI management practices was important: this participatory research was embedded within existing farmer support groups, which served as hubs to support collaborative participatory research and to connect farmers and researchers with other important stakeholders as needed. An actively enabling policy environment was necessary to support CASI uptake and to facilitate outscaling at scale outside research areas.

Keywords: *economic benefits, environmental benefits, greenhouse gas emission reduction, productivity benefits, profitability benefits*

The development of straw retention technology for Conservation Agriculture in China

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Conservation Agriculture is the effective technology to help address challenges of feeding a growing and more demanding population and soil degradation in the world. Crop straw retention technology is one of three principles of Conservation Agriculture (no-till, crop rotation and crop straw retention), which can reduce soil bulk density, increase soil organic matter, improve the large diameter size content of aggregate and structure and fertility of soil, provided the good soil environment for crop yield increase and prevented open burning of crop straw. The crop straw retention machine is the main agricultural machinery equipment to accomplish crop straw retention process. In the operating process, crop straw is firstly chopped and collected by high-speed rotation chopping knives. Then, the chopped straw is inhaled by negative pressure occurred in the machine inlet by high-speed rotation chopping knives. Further, by multiple comprehensive effects, such as chopped, teared and rubbed, the crop straw is chopped, of which length is satisfied the quality criterion. Finally, the chopped straw is spread to field by the airflow and centrifugal force. The straw chopping quality and spreading uniformity are important factors to evaluate operating performance of straw retention, and directly affect the no-tillage or reduce till seeding quality, seed germination and growth, thus impacting crop yield. According to the power provided source, the retention machine is divided to powered by tractor and combined harvester. Furtermore, to reduce straw plugging in no-till or reduce-till planting process, straw chopping device combined with no-tii / reduce-till seeder; to increased the decomposition of straw, straw retention machine combines with tillage and cultivation machine to form straw mixed or buried machine. However, because of poor straw chopping quality, bad spreading uniformity and high energy consumption, widespread application of crop straw retention machine is limited. In the future, the chopped straw simulation model, specific air flow field distribution in chopper room, and the effect of machine parameter on straw chopping and spreading quality should be the main research points to address above limited factors of crop straw retention technology.

Keywords: *Conservation Agriculture, crop straw retention, crop yield, chopping quality, spreading uniformity*

Learnings from the first Conservation Agriculture focused MOOC

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Massive Open Online Courses (MOOCs) are a disruptive innovation that emerged through the education sector in developed countries after 2012. MOOCs have continued to evolve and change, now becoming a facilitated learning tool that has the potential to reach vast populations as part of a two-way learning and sharing process. To date, this has mostly been used for academic and classroom teaching and interaction.

More recently, researchers at Bihar Agricultural University (BAU), India, have been working to catalyse the benefits of MOOCs at a wider scale with a focus on farming communities across the developing world. This was first attempted with a MOOC focused on agricultural start ups that had 5,886 enrolments and 1950 completions (33% - while the average student completion for MOOCs is less than 10%). This was achieved through novel mechanisms such as nudging though social media and cultivating a vibrant discussion on the platform.

In Early 2020, the first Conservation Agriculture focused MOOC was implemented by BAU, in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT). Topic covered principles of CA, CA machinery, CA agronomic management, common CA challenges and constraints, advantages of CA and CA business models for successful service provision. Course content was delivered in both Hindi and English. The MOOC had varied participation from farmers to researchers, small entrepreneurs and policy makers, and others.

This study provides an analysis and learnings of this novel CA based MOOC. The includes a comprehensive analysis of enrolment statistics, content evaluations and active engagement with course content and learnings. Further to this, a pre and post informational needs assessment of enrolled participants was undertaken. This highlights key CA information gaps that are common to the populations who participated and remaining gaps that future MOOCs should address. Further to this, a novel randomised control trial was implemented to assess different engagement mechanisms within MOOCs, to increased active participation and completion. Such findings will ensure future extension and learning activities (both MOOC and other) are relevant and impactful, with a particular focus on addressing an information gap within local farming communities that are not able to access traditional extension services. MOOC specific learnings will also provide key pathways to nudge and increased active participation and completion.

Keywords: *MOOC; Extension; Knowledge Gap; Farmer Education; Training*

Conservation Agriculture adoption in Central Asia: present and future prospects

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The development of agriculture sector is one of the government priorities because the Central Asia region is suitable for production of a large variety of crops. Cotton and cereals are the main crops. Kazakhstan is a major producer and exporter of wheat, while Uzbekistan is a major global producer of cotton. Since 1990s, there has been a considerable expansion of areas under wheat in Turkmenistan and Uzbekistan, and substantial reduction in Kazakhstan (over 2 M ha). Over the past three decades, diversification of crops was limited in Central Asia because of the prevailing mono-cropping practices in the agricultural sector. Legumes (alfalfa and beans), maize and vegetable production decreased sharply. Despite some successes in the expansion of the area under fruit tree crops, there are still shortages of fruits and grapes.

Sustainable crop production is constrained by variable and uncertain rainfall, cold winters, hot dry summers and soil salinity in many parts of the world including Central Asia. Soil degradation continues in conventional production systems, largely due to tillage and poor biomass management but also because of poor understanding about how to secure ecological sustainability. Thus, to achieve the future needs of increased and sustainable agricultural production in Central Asia, it is necessary to understand and apply Conservation Agriculture (CA) practices, such as no-till, crop biomass retention as soil mulch cover, crop diversification, in combination with other good agricultural practices of integrated crop, soil, nutrient, water, pest and energy management. Research on soil-climatic conditions and biological properties of varieties is an important part of integrated crop management for the development of good quality CA systems in the region for irrigated as well as rainfed conditions. The latest agricultural policies in Central Asian countries are becoming increasingly aligned to the promotion of sustainable and environment friendly crop production systems based on CA. The extended abstract will elaborate on the present status of adoption and spread of CA systems in Central Asia, and the future prospects for mainstreaming CA.

Keywords: *Degradation, no-till, crop biomass, crop diversification*

Crop residue management and pathway to Conservation Agriculture: a case study in alluvial agro-ecosystem of West Bengal, India

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Alluvial agro-ecosystem pertaining to Indo-Gangetic plains (IGP) of India has always been the 'food-bowl' of the country, feeding millions of its population. In the last seven decades, the foodgrain production in the country has increased almost six folds and similarly crop residue generation as well. This huge amount of residue often lacks proper disposal and ends up getting burnt on the field. This has got a serious impact on factors of production operating with the system dynamics and its productive behaviour. The burning kept our soils starved with organic carbon and beneficial microbes, only to deteriorate the soil health and its inherent productivity. On contrary, these residues, if properly managed, are a rich source of carbon, nitrogen and other beneficial nutrients. Retention and incorporation of crop residue into the soil is one of the main principles of Conservation Agriculture. The confirmed impacts are improvement of soil health with added benefits of essential nutrients, activation of soil microorganisms and better retention of soil moisture. Alluvial plains of West Bengal under the IGP are the most productive region of the state with high cropping intensity and impacted soil health. Conservation Agriculture, especially crop residue management, could be a promising solution to upkeep the soil health with sustained production. This paper highlights the crop residue management in selected villages in the alluvial plains of West Bengal. The crop residue management includes the source of residue generation, their disposal manner and percentile status on the use of these crop residues. A score of 75 respondents, who have been following differential level of Conservation Agriculture, both in cognitive and non-cognitive way, has been selected following both purposive and non-random snowballing method. The results revealed that farm size is substantially correlated to the mode of disposal of crop residues. Principle Component Analysis (PCA) has been administered to understand the propensity of conglomeration of different exogenous variables into identifiable factors. A total of five factors have been identified, which cumulatively contributes to 68.21% of the total variance in the dataset.

Keywords: *Conservation Agriculture, crop residue management, farm size, natural resource management, soil health*

The role of farmers implementing and disseminating sustainable soils management systems: challenges and drivers, view of farmers associations

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For a long time, many scientific studies and several initiatives of intergovernmental /governmental agencies (GSP = Global Soil Partnership) of FAO, the 4per1000 Initiative, the Climate Smart Agriculture, are well documenting:

- Status and threats on soils: erosion, compaction, loss of SOM and biodiversity,
- Technical solutions to improve practices and farming systems.

Conservation Agriculture (CA) systems are more and more known by farmers, experts, decision-makers and stakeholders. Their positive impacts are well documented and more and more recognized internationally, on food security, climate, biodiversity, water management (i.e., all Ecosystem Services).

Awareness is raising globally about the urgency of action, often in link with climate emergency, soil degradation, and loss of biodiversity.Beyond the growing general acceptation of the principles of CA by the “international scientific community”, in principle, two questions remain unanswered by experts and stakeholders, in first-line policymakers:

- the technical question: how to implement, in practice, the on-farm transition to CA while continuing to produce in a viable way and enable farmers to live and produce,
- the sociological question: how to engage farmers to change their practices into CA is still a mystery for most no-farmers persons.

Several studies led by sociologists tried to get an answer. Without results: innovative farmers are a minority, thus not easy to identify, they are reluctant to be treated as objects of study. They do not trust unknown persons, especially when having faced criticism about CA.However, policymakers need to understand the sociological aspects of farmers decision processes, their reaction to challenges, drivers and policies.These questions of obstacles and drivers to adoption are also vital for farmers associations who want to disseminate and grow.

Several CA farmers associations have got success in the technical implementation of CA on farms, and on dissemination, especially when they benefit from the support of expert scientists in the subject. They are leading the change of their colleagues on their farms, locally, but also around the world, thanks to modern ways of communication and the globalization of knowledge and know-how.Many CA associations have formed the Global Conservation Agriculture Network (GCAN) to advocate for CA in Climate Conferences, starting in COP21 in Paris Dec. 2015. GCAN is supported by the experts and scientists of the CA global community, led by the CA-COP of FAO (CA Community of Practices).

Several of them around the world have mutualized their experiences and made interesting findings concerning:

- understanding challenges farmers are facing
- their drivers for changes
- the keys to success

They propose a method to their colleagues and partners of the CA global community, a joint venture to scientists, official bodies and the private sector. The objective is to accelerate CA implementation by farmers on the ground, to make rapidly agriculture the essential part of the solutions to the multiple challenges the global society is now facing.

Farmers are not a problem for anyone, but the essential actors of the solution.

Keywords: *farmers associations, sociology of change, Sustainable Soil Management, Conservation Agriculture, policies, ecosystem management, food security, carbon sequestration*

Assessment of economic impacts of Conservation Agriculture and precision agriculture technologies on a winter wheat crop

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The adoption of sustainable cultivation practices in modern agriculture such as Conservation Agriculture (CA) and Precision agriculture (PA) is absolutely necessary not only for sustaining crop productivity but also for reducing costs and ensuring economic viability of the farms. The scope of the present study was to compare the economic impacts when integrating CA and PA techniques on a winter wheat crop. During the 2017-18 winter growing period, a pilot field was established on a farmer's field in central Greece testing No-tillage (NT), Sustainable rotation with legumes (SR) and Variable rate fertilization (VRF) and comparing them with traditional practices including ploughing, rotation with maize and constant rate fertilization. Three treatments including different levels of implementation of the sustainable practices: "NT", "NT+SR", "NT+SR+VRF" were compared with a reference method "R" containing all the traditional practices.

All field operations and inputs were recorded analytically in timesheets. Final yield was measured with a combine harvester provided with a yield monitor. The data were analysed for estimation of production costs, gross and net profits for each treatment. The investment cost of the equipment was also taken into account. For that scope, the FarmEcon tool (Cavalaris et al., 2015), a computational model giving the opportunity for a holistic economic analysis of agricultural farms was used.
Two alternative scenarios were examined. The first one was considering the actual farm size of the collaborating farmer, which was 20ha and which is representative of the small farms in Greece and the second one, an hypothetical large farm of 300ha but with the same crops and structure.

The results shown that no-tillage had a clear positive effect on winter wheat yield. The average yield in the traditional R plot was 3.38t/ha while NT yielded 3.73t/ha. The combination of no-tillage with a legume rotation in the NT+SR method provided a further yield increase at 4.26t/ha. The best results were obtained with the combination of all the three sustainable practices in the NT+SR+VFR method which gave 4.37t/ha.

The economic analysis revealed important margins for cost reduction for both the small size, 20ha farm as also for the large 300ha farm when sustainable methods are implemented. Compared with R, cost reduction for NT and NT+SR was 170€/ha for the small farm and 195€/ha for the large. The cost reduction comes from abolishing soil tillage and from the lower depreciation of the machinery (only for the big farm). The addition of VRF at NT+SR+VRF method provided a further reduction of 15€/ha and 31€/ha for the small and big farm respectively, coming from savings at the fertilizer use.

The net income is estimated negative for all the cases of the small farm and positive for the sustainable methods at the big farm (still negative for R). The negative result is owed to the high depreciation costs of the farm equipment, a factor that is often dismissed by the farmers. For the big farm, the net income was -85€/ha for the reference method R, 191€/ha for NT, 338€/ha for NT+SR and 346€/ha for NT+SR+VFR.

Keywords: *Conservation Agriculture, Precision agriculture, no-tillage, economic analysis*

Fine-tuning nitrogen fertiliser norms for wheat under Conservation Agriculture in South Africa

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Current N norms for wheat are derived from N response trials under conventional tillage and wheat monoculture, as well as adoption from research that originated mainly from Western Australia. Development of scientifically sound N norms for wheat the Western Cape is required. The aim of this study was to evaluate N requirement for wheat and to determine optimal N top dress rates under CA.

Cropping systems included were dryland wheat (*Triticum aestivum* L.) after canola (*Brassica napus* L.), medics (*Medicago spp*) or lupine (*Lupinus spp*) or after lucerne (*Medicago sativa*). Randomised block design with eight N top dress rates and four replicates. The N top dress treatments comprised of different N rates (0, 25, 50, 75, 105, 135 and 165 kg N ha^{-1}). Grain yield and quality were recorded. Linear and segmented linear models were fitted to normalised data.

At Darling (medium deep sandy soil) the control yield was 1282 kg ha^{-1} for the canola-wheat rotation and 1347 kg ha^{-1} for medics-wheat. Yields increased by 0.87% kg^{-1} of N applied between N rates of 0 and 34.56 kg ha^{-1}, thereafter slowed to 0.11% kg^{-1} of N applied. At Porterville (deep reddish coloured clay loam soil) the yield of the control was 1997 kg ha^{-1} for canola-wheat and 2591 kg ha^{-1} for medics-wheat. Yield increased at a rate of 0.16% kg^{-1} of N applied between N rates of 0 and 72.92 kg ha^{-1}, thereafter the yield declined at a rate of 0.07% kg^{-1} of N applied. At Tygerhoek (shallow sandy loam shale derived soil) the control yield was 3060 kg ha^{-1}. Yield increased at a rate of 0.55% kg^{-1} of N applied between N application rates of 0 and 59.72 kg ha^{-1}, thereafter yield declined with a rate of 0.05% kg^{-1} of N applied.
Results shows that biologically optimum yields can be reached at lower total N application rates than currently prescribed. Determining site specific economically optimum N application rates are in process.

Keywords: *Conservation Agriculture, fertiliser, nitrogen, wheat*

ENGAGED: System design of direct seedings under permanent cover crop without glyphosate

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Direct seeding under permanent cover crop (SDCV) corresponds to sow a crop in a multiyear vegetal cover crop (often clover) without soil perturbation. It is an emblematic technique of Conservation Agriculture whose agronomic and environmental interests are multiple because of the special attention paid to soils. However, the issue of weed control and permanent cover crop control is central to SDCV culture systems. The use of non-selective herbicide such as glyphosate is the most common technical lever for weed and cover crop management. Glyphosate is in the hot seat since the President of France announced its banning from 2023. It becomes necessary to find alternatives for the sustainability of these systems.

The CASDAR Project "ENGAGED" (2018-2022) aims to build glyphosate-free SDCV growing systems with low herbicide use. The ENGAGED Project is based on three main actions:

- Tracking farmers innovations
- To monitor the development dynamics of weed species on plots of farmers testing conducted in SDCV without glyphosate.
- Constructing crop system prototypes through co-design workshops with farmers from different groups, particularly Economic and Environmental Interest Groups (EEIGs).

The progress of the project allows us today to identify the tracks worked by farmers and evaluate their feasibility. The field-tested strategies on the farm plots integrate all the components of the technical itinerary (sowing density, fertilization, herbicide). The results presented come from data collected over two years (2018-2019 and 2019-2020) in a network of plots located in the northwest of France. The first year was designed in order to test chemical alternatives to glyphosate without restriction on quantity of the other herbicides. The efficiency of a spring mulching, an electric weeding before the sowing, a more intense fertilization and a double sowing density were evaluated the second year of the experiment. The observations made tend to show that the electric weeding is effective in controlling the weed flora, but has too little effect on legume cover. Furthermore, the double sowing density seems to compensate the loss of plant observed on the glyphosate-free plots, where the cover was poorly regulated, but the results are not conclusive enough to conclude to an effect of the mulching of the cover and of the intensified fertilization. A third testing year will complete these first conclusions.

Keywords: *Direct Seeding, Permanent CoverCrop, Glyphosate, Low Herbicide, Weeds Control, co-design, farmers innovation tracking*

Conservation Agriculture implementation trials on Denmark

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Interest in adaption of Conservation Agriculture in Denmark is high during recent years. The interest is largely caused by on farm field trials that have shown that grain crops, legumes and oil seed rape can reliable be established by direct drilling techniques.

In the Danish project OptiTill different brands of drill were demonstrated in the years 2013 until 2015 in large-scale field plots both in tilled and in non-disturbed soil. Yields measurements using plot harvesters showed differences between plots but no general tendency of neither lower nor higher yield from plots drilled in undisturbed soils compared to yields from tilled plots.

Getting used to the look of no-till soils takes time

Field walks were popular in the three demonstration fields. Farmers participated from all parts of Denmark even with visitors from Norway and Sweden. We made a survey among farmers. Concerning establishment of crops, the farmers clearly judged the tilled plots to be much better established compared to the direct drilled plots. Counting the plants showed similar number of plants; but plants in black soils look more viable than plants established among residues. During recent years, many farmers have now seen many no-till fields and these farmers are aware that crop can be highly viable even though they do not grow in black soil.

True on-farm trials

The OptiTill project was followed up by the Carbonfarm project where growing systems are compared in a more structured way with randomised and replicated trials on two farms. The trails are managed with machinery used on the farms. Conservation Agriculture is compared with plots that have been tilled either with inversion or with non-inversion tillage. Starting in 2018 results from three seasons show minor deviations between growing systems and between the two host farms. As an average between farms and seasons, there are no difference in yields between growing systems. Measurements have been made on soil parameters including carbon content in different soils layers. The trials look so promising that additional funding have been granted to continue the trails for additional four growing seasons.
In the Carbonfarm project two organic farmers host field trials as well. Methods to enable no-till organic farming practises are being developed and tested on the farms. Methods includes intensive use of cover crops, aquatillage and mowing between rows.

Keywords: *OptiTill project, no-till, Carbonfarm project, cover crops*

Perceptions on soil macrofauna in the agricultural field

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Soil is responsible for one quarter of the biodiversity on our planet. The soil fauna is divided in groups according body size: microfauna, mesofauna and macrofauna, and each contribute to soil functions and the soil food web. Soil management directly the soil fauna, and knowledge of the role of these animals in soils is important for their proper conservation and for sustainable agriculture. In the present study, we evaluated the social perceptions concerning soil macrofauna among farmers and professionals working in agriculture. A questionnaire was applied in the years of 2008 and 2018 in the National No-Tillage Meetings in Brazil. A total of 12 questions identified the profile of those interviewed, soil management practices and their perceptions regarding soil macrofauna. A total of 171 people answered the questionnaire (87 in 2008 and 84 in 2018), including 33% farmers in 2008 and 31% in 2018. From the list of nine organisms (Oligochaeta – earthworms, Hemiptera – stinkbugs, Formicidae – ants, Diplopoda – centipedes, Araneae – spiders, Isoptera – termites, Coleoptera – beetles, Chilopoda – millipedes and Gastropoda – slugs) only earthworms, spiders and centipedes were not generally considered pests. When asked if they observed an increase in pest incidence, 61% of the interviewees noticed an increase in 2008 and 73% in 2018. This increase was related mostly to the excessive use of pesticides and monocultures in both years, though the number of people relating these practices increased in 2018 (31% and 52%, respectively). Most respondents considered earthworms (93-100%) and spiders (45-64%), to be beneficial animals. The management practices considered to enhance soil biodiversity were mainly green manures, crop rotation, integrated pest management and the use of no-tillage (all >65% in 2008), although the number of responses including these practices decreased slightly 10 years later. In both years <29% of the respondents considered that maintaining native vegetation fragments was important to improve soil biodiversity. When asked about soil health indicators, >80% mentioned the presence of many organisms (although most animals had been considered by many respondents to be pests earlier!), while roughly half mentioned the presence of many earthworms and soil aggregation. The fact that the number of responses mentioning increases in pest incidence increased, and the responses mentioning for good practices decreased after 10 years is worrisome, and highlights the need to further capacity building and dissemination of information regarding the importance and function of soil biodiversity and soil animals to society.

Keywords: *Bioindicators, soil quality, soil macrofauna*

From farmer to farmer: a need to change the way we see soil biology and plant health, monitored by biological and chemical analyses

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The soil–plant interaction is a highly complex system, where one depends on the other. We, farmers, have disturbed this system by using tillage and chemicals for years in order to have high yields. Sadly, we know now that this has led to a soil depletion and to a food production which is poor in nutrients. We are in the need of change today. Our goal is to have healthy soils in order to produce healthy plants and therefore healthy food. The challenge, for a farmer, is to define where to start the change in order to get the best results, what to do and how to monitor it.
With all tillage operations and chemicals used in agriculture today, we got into a vicious circle. The challenge is to get into a virtuous circle again: a plant that feeds the soil and a soil that feeds the plant. Only then farmers will be able to produce better.

That is how we got interested in Conservation Agriculture. We started for 15 years to use cover crops and no-till. These are the first keys to improve the soil: food and no disturbance for soil biology. In order to monitor the impacts of our actions, we use chemical (Kinsey–Albrecht) and biological soil analyses (chromatography and microscopy). All of this led to the use of plant analyses: get balanced plants to get healthy plants that are able to be resistant, productive (quality and quantity) and a source of energy for soil biology.

A lot of information is available, but most of it is theory or not yet spread out. On the field, on larger scales (farm scale), improvement takes time and we go step by step, being dependent on weather conditions that are more and more difficult.
Our goal, as farmer and consultant, is to combine all informations available and the great ideas, and try to put together a system that works out for farmers and that we can spread out. Little by little, the work done by E. Ingham, C. Jones, J. Kempf, N. Kinsey–Albrecht, E. Pfeiffer, D. Reicosky and a lot of others in different countries, gave us tools to build a system that improves soil and plant health. Analysing and comparing soils from farmers all over France and the Swiss long-term field trial "Oberacker" provided us more practical insight. Using the data base from fields under no-till for more than 25 years is a strength. This system has still to progress and to be spread out. However, we start to see improvements in our soils, in terms of structure and biology quality, and in our plant production with less N and less fungicides.

***Keywords**: Conservation Agriculture, plant health, soil health, cover crops, soil biology*

Overcoming the physical and mental barriers for upscaling Conservation Agriculture in the Mediterranean

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ConServeTerra is a new PRIMA funded project which will start in mid-2020. The overall objective of ConServeTerra is to facilitate wider adoption of CA principles in the Mediterranean region by tackling the mental, cultural and contextual realities surrounding farmers' soil management decisions. ConServeTerra will approach the issue from two angles: First it will analyse and map the mental and cultural attitudes towards soil and its management, while simultaneously using educational tools (i.e., rainwater simulator) to improve farmers' appreciation and understanding of soils. Secondly, selected pragmatic application of CA principles (e.g., strategic and reduced tillage, appropriate stubble grazing, and legumes) will be investigated. Accordingly, ConServeTerra will adopt a more pragmatic and ecological approach to CA based on site-specific biophysical, socio-economic cultural and mental factor considerations. These ecologically based systems restrict the use of expensive fertilizers and pesticides and are more flexible with the tillage intensity, which is a vital strategy in controlling weeds for low-input smallholder farmers. The reality of stubble grazing in the Mediterranean region necessitates the establishment of optimal stubble management options under CA. For organic and low-input smallholder farmers, tillage is the single most effective tool for weed control and N-mineralization. Therefore strict promotion of no-tillage is at odds with the realities of this group of farmers in the Mediterranean with limited access to inputs. A pragmatic approach of reducing tillage intensity, while diversifying rotations with pulses and legume based forages may be more effective considering the Mediterranean context. Data produced through high-input-system experiments on legume cultivation under CA have little relevance and transferability for Mediterranean low-input smallholder farmers. Pragmatic application of CA principles present a great potential to increase water use efficiency, improve food security and economic well-being of communities in the Mediterranean region.

Keywords: *CA in Mediterranean, smallholders CA, pragmatic CA, crop-livestock integration, mental models*

The first twenty years-the development and adoption of a climate smart grain production system for the Swartland region of the Western Cape Province, South Africa

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A long-term crop rotation trial was launched by the Western Cape Department of Agriculture at Langgewens Research Farm (33.276821552S 18.703171288E) near Moorreesburg in the Swartland region of the Western Cape, in 1996. The aim was to determine the short- and long-term effects of eight of the most feasible crop and crop/pasture rotation systems identified for the Swartland on: crop yields, weed control, disease suppression, soil production potential, sheep production, and economically sustainable land-use in the Swartland. The initial project continued for 20 years and was terminated in its original form, in 2015, as planned. An integral part of this research was also the development of Canola as an alternative crop for the Western Cape. After 20 years, an impact study was undertaken by an independent company to investigate the impact (social and economic) this trial has had on the greater Swartland region at the end of the 20 years.

The effects of crop rotation on wheat yield over the 20-year period shows that wheat monoculture, being the norm at the time of inception of the trial, has become inefficient as part of an efficient production system, with the lowest wheat yield over the period. A general trend was that the systems including the legume pasture, Medic (primarily a mixture of *Medicago truncatula* and *Medicago polymorpha)* showed the highest wheat yields and biggest percentage improvement in overall wheat yield. Implementing crop rotation had an overall 30% improvement on average wheat yield over the period when compared to a wheat monoculture system. Wheat yield data showed that there was a 15% overall improvement in wheat yield with the implementation of no-tillage. Carbon percentage increased over the range, from a low of 18% to the highest of 34%. The pasture cropping systems showed a slightly higher improvement of 2% Carbon over the cash cropping systems. These results where a major driving force in convincing farmers to convert to crop rotation systems. The trial has also built capacity in terms of postgraduate students, a comprehensive Conservation Agriculture (CA) research programme was initiated over other regions and this has lead to climate change resilience in production systems over the province.

The Conservation Agriculture (CA) research programme is seen as one of the game changing initiatives of the Western Cape Department of Agriculture. It has shown how starting out with a long-term multidisciplinary crop rotation research project in 1996, has led to the development of a small grain industry norm and practice, resulting in farmers being competitive, resource smart and climate smart.

***Keywords**: grain, systems, adaptation, sustainability, resilience*

Co-design and test of biodiversity-based pesticide-free Conservation Agriculture in the long-term CA-SYS platform in France

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The French National Institute for Agricultural Research (INRA) has established an ambitious experimental infrastructure (the CA-SYS platform) in autumn 2018 after 5 years of co-design with farmers, crop advisors and researchers. CA-SYS covers an area of 125ha divided into 42 fields. The originality of CA-SYS is that it is explicitly conceived for the design and evaluation of biodiversity-based and pesticide-free agroecological systems across agriculturally realistic scales. An agroecological system will comprise a matrix of fields of one (or a few) cropping systems over a number of years interacting with adjacent semi-natural habitats (hedges, grass margin strips, flower strips). This spatio-temporal arrangement of fields and semi-natural habitats is considered as a coherent strategy, implemented to meet specific goals. CA-SYS has ambitious objectives, including a high multi-performance of systems (profitability and productivity identical to neighbouring farmers over a 10 year-horizon, low environmental impacts, etc.), by maximising the use of biological processes (biological control of pests, improving nitrogen cycling, etc.) and reducing the use of inputs (nitrogen, water, pesticides). Among the four pesticide-free cropping systems tested, CA-SYS tests 2 cropping systems implementing conservation tillage and agriculture principles: a permanent no-till cover crop-based system (SD1) and a rotation no-till system (SD2). They are both 6-year crop rotation including 7 cash crops (buckwheat is cropped as secondary crop in between winter barley and winter wheat). Soil remains covered as much as possible through a high temporal and spatial diversity of cropped-plants. Oilseed rape is cropped with spring fababean and Berseem clover as companion crops. Fallow periods in between winter wheat/soyabean is covered by two successive cover crops (i.e. summer and automn sown). Cereals are intercropped with legumes (wheat/fababean, spring barley/spring pea) to enhance crop complementarity. A mix of 4 cultivars are sown for oilseed rape and winter wheat to manage pests.

Keywords: *cropping system design, multicriteria assessment, crop diversification, Conservation Agriculture, conservation tillage*

The influence of Conservation Agriculture on topsoil stratification in the Western Cape of South Africa

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Over the last years Western Cape grain farmers have adopted one or more principles of Conservation Agriculture (CA) namely: minimal mechanical soil disturbance, permanent soil cover with crop residue and/or cover crop and crop rotation. This change from conventional winter wheat production to CA-principle has led to changes in topsoil nutrient distribution.

Stratification refers to the accumulation of soil nutrients in certain areas more than in others. Stratification may influence availability of nutrients in various soil depths of the root zone, especially during prolonged dry spells in the growing season. This study determines if stratification has occurred after a 12 year period under CA on an existing project at Tygerhoek Research Farm (34˚29'32" S, 19˚54'30").

Four tillage treatments, namely: (1)zero-till(ZT) – soil left undisturbed (weeds controlled with only herbicide) and planted with a star-wheel planter, (2)no-till (NT) – soil left undisturbed until planting and then planted with a tined planter, (3)minimum till (MT)– soil scarified March/April to depth of ± 100-150 mm in late March/early April and then planted with a no-till planter, and (4)conventional tillage (CT)– soil scarified late March/early April to a depth of ± 100 - 150 mm, then disked to a depth of ± 200 mm before planting with a no-till planter, was studied in combination with four crop rotations, namely: monoculture wheat, wheat/medics/wheat/medics, medics/wheat/medics/wheat and lupine/wheat/canola/wheat.

The soils are all shallow and have a high stone content (soil forms Entisols and Alfisols). Soil samples were collected using a 40 mm diameter steel tube in 0-5, 5-10, 10-15, 15-20 and 20-30 cm depth increments. Ten subsamples per plot were bulked to give a composite sample. The soil was dried, passed through a 2 mm sieve and analysed chemically.

Crop rotation had no significant effect on nutrient stratification; however the degree of soil disturbance had an effect. The pH in the 0-5 cm soil layer of ZT and NT were significantly ($P<0.05$) higher than the other depths (pH (KCl) 6.15 and 6.21 respectively). CT was more evenly distributed. P decreased with depth for all the tillage treatments. The P content in the 0-5 cm depth was the highest in ZT and NT and the lowest in MT and CT. Potassium followed the same trend as P. Carbon stratification was clearly visible in the 0-5 cm layer under ZT with significantly higher ($P<0.05$) C content compared to the 5-15 cm layer.

We need to understand the unique conditions in CA that influence nutrient behaviour. Changes in soil pH are important for determining P and micronutrient availability, root growth and microbial activity. Producers should consider taking soil sample under conservation tillage at depth increments for a better understanding of the nutrient status, to optimize fertilizer and lime recommendations. The traditional 0-30 cm soil sampling procedure may not detect the deficiencies at lower depths.

Keywords: *stratification, Conservation Agriculture, soil depth*

Adaptations of the LIFE+ Climagri Project GIS. Platform for its application to olive groves

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LIFE Climagri project (LIFE13 ENV/ES/000541) proposed a set of Best Management Practices (BMPs) for the improvement of the environmental conditions of farms in the Mediterranean area. These BMPs include the three principles of Conservation Agriculture as well as other practices related to the optimization in the use of inputs, to the use of advanced technology or to the promotion of biodiversity.

For the monitoring of the aforementioned BMPs a series of indicators (25) were proposed. Since the calculation of the indicators is linked to a particular plot, the project uses a GIS platform in order to georeference the info provided and obtained. Calculations are based on info made available by the user, who must provide all data related to the crop management and inputs used (fertilizers, plant protection products, water, etc.), as well as reply to a questionnaire on which both technical and personal perception questions are asked. Additionally, although not necessary for the calculation of the indicators, the platform allows to conduct a self-evaluation of the level of fulfilment of the recommended BMPs.

Taking into account all the info provided, the output provided by the GIS-Platform is a report on which the values for the indicators are shown and, in case the self-evaluation questionnaire has been filled in, a series of recommendations about the BMPs on which emphasis should be placed upon in order to improve the sustainability of the plot.

As the project was focussed in annual irrigated crops, some of the indicators are not suitable to be calculated in olive orchards. Nevertheless, olive is one of the main crops in the Mediterranean area, particularly in the Andalusian region, where, according to data provided by the Spanish Statistics National Institute (2016), more than one third of the agricultural area is dedicated to this crop.

The importance of olive groves in the region makes it very much worthwhile to adapt the platform so that indicators can be calculated and recommendations can be provided for this crop. To this end, it is necessary to allow a selection between "Annual crop" and "Perennial crop" before starting to include the farms information which feed the system. This means that the platform should be duplicated and, for the case of the "Perennial crop" the algorithms for the calculation of some indicators, as well as some of the questions included in the questionnaire and in the self-evaluation should be re-formulated. This paper, details the adaptations which would make it possible to use the platform for olive groves.

The continuous monitoring of the BMPs carried out to the farms included in the Climagri project through the calculation of the indicators in the GIS platform contributed to an average increase of the implementation of the BMPs of 30%. Based on this experience, similar results are expected to be achieved in the olive groves of the Mediterranean area thanks to the improvement of this very useful tool.

Keywords: *Georeference, Best Management Practices, Indicators, Monitoring*

Estimation of Conservation Agriculture through SWOT Matrix: the new alluvial reality of West Bengal, India

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With the diversity of climate and topography, agricultural practices also keep evolving over space and time. These changes are often influenced by the social norms and culture, as well as environmental and ecological conditions of the area. West Bengal, having six agro-climatic zones, needs to undergo comprehensive adaptation and mitigation strategies at grassroot level of agriculture in response to the sharp variations as bestowed by different zones. In such diverse condition, introducing a new technology requires a lot of ground truth verification to identify its strength, weakness, opportunities and threats (SWOT) interactively operating within a system dynamics. One of the most popular approach for this ground work is conducting a SWOT exercise of the introductory site. The entire response profile has been built up by organizing Focus Group Discussions (FGDs). Seven FGD groups were formed in seven villages under the alluvial zone of West Bengal, with ten farmers in each group to extract their perceptual responses and got prioritized by them. Most of the respondents have been conspicuous by a non-cognitive adoption behavior which offers a splendid opportunity for CA in this zone. The SWOT matrix was developed using these responses. This paper elaborates the findings of SWOT matrix to develop appropriate extension strategies for successful implementation of conservation agricultural practices in the region. The paper examines the strengths, weaknesses, opportunities and threats of ongoing agricultural practices in the micro situation reality of alluvial region of West Bengal. It can go persuasive in socializing Conservation Agriculture (CA) as a response that can transform the weaknesses into strength, and also minimizes the ingress of the threats, based on a critical analysis of its three main principles- minimum soil disturbance, permanent soil cover and diversification of plant species. The outcome reveals that external input intensive agriculture has made soil resources nutrient deficient and fatigued as one of the major weaknesses. Depleting water table associated with arsenic contamination, decline in soil organic carbon status and sharp decline of livestock counts are the serious threats to agriculture in the alluvial region. Conservation Agriculture, by its principles, adds to soil organic carbon pool through crop residue retention and follows integrated nutrient management approach, thus addresses both weakness and minimizes threat in the region. The SWOT exercises done through participatory processes has offered huge operative and methodological innovation for successful execution of CA practices and its subsequent socialization.

Keywords: *Conservation Agriculture, focus group discussion, ground truth verification, strength, weakness*

Remote sensing of winter wheat growth under conventional and no-tillage cultivation

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A pilot field was established in order to compare winter wheat performance under the following treatments: 1) Conventional cultivation (CO) including ploughing, seedbed preparation and sowing at a normal date, 2) No-tillage, (NT2) with direct drilling at the same date as 1, 3) No-tillage (NT1) with direct drilling three weeks earlier. The opportunity of early sowing is an important asset for no-tillage and the purpose of the present study was to showcase this benefit.

During the growing period, time-series of two vegetation indices (VIs), the Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI) were calculated from Sentinel-2 images. At the same time, Leaf area Index (LAI) was measured seasonally at certain points. The final yield was recorded with a combine harvester provided with a yield monitor.

The two VIs revealed different growth patterns for the three treatments. Until the end of February, the late sown CO and NT2 followed a similar, delayed pattern with low NDVI and EVI. The similar pattern evince that the absence of soil tillage doesn't actually affect the initial growth of the crop. On the other hand, the opportunity for earlier sowing with direct drilling on NT1 proved to be rather advantageous for seedling early emergence and performance. Indeed, the earlier crop emergence led to higher values of the two VIs until the beginning of March. These higher VIs were associated with a higher LAI as depicted from the corresponding regression analysis (R^2=0.88 and R^2=0.67 for NDVI and EVI respectively).

After March however, NT1 showed a delay and CO outperformed both NT1 and NT2. The weather data revealed a shortcoming of rainfall from 5/2 to 10/3 coincided with the critical stage of stem elongation on NT1.Therefore, growth was suppressed. Contrariwise, the two later sown methods (NT2 and CO) pulled through this adverse period because the plants were still at the less sensitive, tillering stage.

The superiority of CO lasted until the beginning of grain filling, at the end of April. After that period, it was the turn of NT2 to excel. The VIs showed that the crop remained green while the plants on the other two treatments were maturing. The yield data reveal that this was a decisive period. It is the stage where assimilates from photosynthesis are translocated from the leaves and the stem to the grain. And apparently, it was favored by no-tillage. Compared with CO, grain yield on NT2 was 1.7 times higher (1.91t/ha and 3.23t/ha respectively). The NT1 also outweighed CO with a mean yield of 2.63t/ha, which though was lower from NT2.
Remote sensing proved a valuable tool both for phenological monitoring between treatments, but also for determining critical stress periods during growth. Such data in conjunction with weather information are particularly essential and could be used in decision making systems under the framework of precision agriculture, to enhance yield quantity and quality when sustainable systems are adopted and the ordinary cultivation practices have to be adapted accordingly (i.e., earlier sowing, modification of irrigation and/or nitrogen application).

Keywords: *no-tillage; remote sensing;NDVI; winter wheat*

The adoption of automatic navigation technology for row-followed no-till seeding in China

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Automatic navigation technology (ANT), a promising technique for promoting smart agriculture because of its high precision and efficiency, was applied at no-till seeder in China to avoid the standing stubble and root system of the crop in the underground during row-followed no-till seeding. Relevant studies have revealed that ANT was effective in escalating quality and efficiency of row-followed no-till seeding, especially for wheat no-till seeding in North China Plain where annual maize-wheat rotation.

According to the principle of navigation, there were mainly three automatic navigation technologies applied at row-followed no-till seeding: touch type ANT, machine vision type ANT and Global Navigation Satellite System (GNSS) type ANT. For touch type ANT, a detection device designed according to crop cultivation characteristics is the key component of the system. The detection device mounted on the front of the tractor can generate a path signal while row-followed no-till seeding. Then, the control center processes and decides the steering command, and controls the actuator to avoid the stubble. The maximum error of touch type ANT was less than 6 cm when the tractor forward speed was no more than 1m/s. However, the touch type ANT could not be extended because the error path signal will be generated when there’s inconsistent plant spacing or plant absence. For machine vision type ANT, the stubble row images can be collected by the industrial camera during row-followed no-till seeding. After that, the relative spatial information between the stubble row and the no-till seeder can be calculated through image processing algorithms. Afterwards, the control center activates the actuator to avoid the stubble. The seeder forward speed was not more than 1.2m/s to avoid the standing stubble and root system of maize. Nevertheless, robust and effective algorithms for stubble row recognition need to be explored due to the little color difference between stubble row, residues in rows and naked land surface. In recent years, GNSS type ANT was proposed to apply at row-followed no-till seeding because of its high precision. Unlike Touch type ANT and machine vision type, ANT of GNSS type captures absolute location information of stubble. Therefore, the electronic map of the stubble spatial location information needs to be obtained in advance. According to the electronic map of the stubble spatial location information and GNSS, the control center can guide the actuator to avoid the stubble. However, the electronic map of the stubble spatial location information is difficult to obtain because GNSS ANT is not fully applied at agricultural production in China.

In short, ANT can be employed to improve the level of automation, informatization and smart in row-followed no-till seeding, hence achieving variable operations, ultimately leveraging quality and efficiency of Conservation Agriculture (CA) operation.

Keywords: *no-till, automatic navigation, technology, stubble, row-followed, China*

Smallholder agroecology training – the low-hanging fruit of Conservation Agriculture

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The world's lowest hanging fruit for a global shift to Conservation Agriculture is in the opportunity for smallholder farmers to adopt regenerative agroecology practices. Our global food system is responsible for about half of greenhouse gas emissions but small farms in economically disadvantaged countries also hold the greatest promise to stop global warming.

A shift to regenerative agroecology could be the cornerstone for stabilizing the climate and feeding the world. The '4 per 1000' (4p1000) initiative [Soussana et al. 2019] launched by France during the UNFCCC COP21 in 2015 aims at capturing CO2 from the atmosphere through changes to agricultural and forestry practices at a rate that would increase the carbon content of soils by 0.4% per year [Rumpel et al. 2018]. If global soil carbon content increases at this rate in the top 30–40 cm, the annual increase in atmospheric CO2 would be stopped [Dignac et al. 2017].
At the same time, it will increase soil fertility, improve public health, secure food sovereignty, reduce global strife, and protect water sources.

Seventy percent of the world's food is produced by 500 million smallholder farmers [HLPE 2013] who are ready to embrace agroecology as the most beneficial form of Conservation Agriculture. Those who get adequate technical assistance demonstrate how it improves biodiversity, water resources, climate stability, diet, health and income for the long-term.

An agroecology extension program such as the one operated by Sustainable harvest International would cost $250 billion per year for four years before farmers would become self-sufficient. This is a fraction of the $600 billion provide in agricultural subsidies ever year [Mamun et al 2019] And, this shift in funding will get us more and better food, as well as our best chance at regenerating a healthy planet. Tragically, half of the world's hungriest people are themselves smallholder farmers, who only need access to a farmer-centric, multi-year training program to grow plenty of good food for themselves and others with techniques that improve the health of the planet too. For most of these smallholders, the shift to regenerative agroecology comes with little to lose and much gain.

Keywords: *smallholders, extension, training, regenerative, agroecology*

Application of soil suppression technique in no-tillage sowing in China

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No-tillage sowing is a conservation tillage technique which can effectively save production cost and increase harvest benefit, its soil covering and suppression are of great significance in no-tillage sowing. The application of mulching and suppression techniques in the tillage process directly affects the germination and growth of seeds.In the seeding operation, the seeds are first opened into the ditch through the seed guide pipe, then the seeds are covered under the action of the soil covering device, and then the soil is compacted by the suppression wheel to maintain a certain soil compactness. The Turns the soil process had a certain effect on the sowing depth and distribution uniformity of seeds falling into the seed ditch, while suppression affected the emergence of seeds by controlling the soil compactness. In addition, in terms of the current soil covering technology, the common passive recovery of Turns the soil has a certain degree of uneven return soil. In terms of suppression technology, there is a lack of active suppression according to the real-time operation requirements combining soil moisture and agronomic requirements. In the future research direction, based on electronic control technology and hydraulic transmission technology is the main research direction to solve the above mentioned soil covering and suppression initiative.

Keywords: *No-till sowing, Turns the soil*

The development and extension of subsoiling technology in China

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Subsoiling is a typical mechanized tillage method used in conservation fields in China. Due to long-term conventional tillage, soil bulk density and hardness are increased while soil porosity is decreased, which is unfavorable to crop growth. Current studies in China show that subsoiling can break the compacted soil hardpans, increase aeration and permeability of the soil, and improve physical and chemical properties of the soil. Because of these obtained effects, this technology makes the root elongation into deeper soil, benefits to the absorption and utilization of water and nutrients by crop roots, and then increases the crop yields.

The subsoiling technology started to be studied in 1960s in China. In recent years, more and more attention has been paying to the research and development of subsoiling shanks and subsoiling machines. According to the specific soil condition and farming system in different regions of China, several subsoiling technology and supporting machines have been developed, such as interval subsoiling, omni-directional subsoiling, layered subsoiling and vibrating subsoiling. Since the State Council decided to subsidize the subsoiling in 2009, this technology has been rapidly adopted in suitable provinces in China. Within four years after the implementation of subsoiling subsidy, the national subsoiling area increased significantly. In 2012, the national subsoiling area was 10.5 M ha, which was 1.83 M ha more than that in 2008. In 2016, the Ministry of Agriculture and Rural Affairs issued the *National agricultural machinery subsoiling and land preparation operation implementation plan(2016-2020)*, which points out that during the 13th five-year plan period, the nationwide annual operation area of subsoiling and land preparation via agricultural machinery exceeds 10 M ha. And in 2020, the national suitable cultivated land will be able to be subsoiled once, and then enter the positive cycle of suitable periodic subsoiling. According to *The maximum subsidy amount of national general agricultural machinery central financial funds (2018-2020)* formed by the Ministry of Agriculture and Rural Affairs, the maximum subsidy for purchasing subsoiler was 4900 RMB. In 2018, the national subsoiling area was 10.6 M ha, which was 1.93 M ha more than that in 2008. The national policy and financial support, locally applicable scientific research, better extension and training for farmers, and international cooperation and communication will further accelerate the extension and adopation of subsoiling technology in China.

Keywords: *subsoiling; technology; machine; development; extension; experiences; measures*

TOPPS PROJECT: A successful way to promote soil and water quality improvement through Conservation Agriculture

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TOPPS project (Train Operators to Promote best Practices and Sustainability) is an European stewardship project in partnership from Universities and Research Centers and the European Crop Protection Association (ECPA). The aim of TOPPS project was to develop dissemination activities to promote Best Management Practices (BMP´s), focussing on Conservation Agriculture and multifunctional field margins establishment, to prevent soil, water and landscape degradation by runoff and erosion.

Several factors influence the risk of pollutants transference to water by runoff and erosion. Some of these factors can be controlled by farmers, mainly related to soil management. To increase soil knowledge among stakeholders (farmers, policy makers, students and civil society), and how Conservation Agriculture can improve soil and water quality, more than 50 training courses has been carried out in Spain since 2012, where around 4000 people attended. The aim of these training days was to raise awareness about soil and water conservation, showing them the importance of knowing some soil characteristics and implementing Conservation Agriculture principles in farms to greatly increase soil health and water quality. To reach this objective, training courses were carried out focussing on the following aspects:

- Comparing soil characteristics (Texture, structure and Soil Organic Carbon content) between Conservation Agriculture and conventional one through a visual soil assessment.
- Showing water and soil relationship and how soil management influence soil water holding capacity and water movement through agricultural soil.
- Demonstrating through a rain simulator how Conservation Agriculture reduces runoff and erosion, and how to avoid the movement of pollutants to surface water.

A survey distributed after each training shows that 65% of the attendees consider that runoff and erosion is the main agricultural problem in their region, and 81% of them think that is caused because the coverage of soil is not enough.

As a conclusion, after TOPPs training courses attendees consider that direct sowing (Conservation Agriculture), use of cover crops, crop rotation and multifunctional margins, are the most effective agricultural practices to prevent runoff and erosion. In consequence, the most successful way to improve soil health and reduce water contamination.

Keywords: *Runoff, Erosion, Best Management Practices, soil conservation, trainings*

Experiences of novel methods in evaluation of no-till quality and agronomic efficacy

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The so-called Smart Agriculture and several environmental aspects are raising many agronomic and environmental issues into spearhead. We have a great task and difficulty to provide actual information to support the modern decision-making process in field husbandry.

A team Juha and Jussi Knaapi have started a novel advising work via Finnish "Neuvo 2020"-program, (in English "Advising-2020").

We have set up a Veris MSP3 soil scanner and included a Wintex 3000 soil sampler on the same tractor unit and equipped with a modern RTK-accuracy autosteer and coordinate system.

The idea is to combine both scanning and reference sampling in a manner that makes it possible to provide reliable data of parcels carbon status (0-90 cm) on top of modern agronomic data collection. By RTK-accuracy it is possible to recollect specific data after several years. This is aiming at precise carbon content measurement and finally carbon credit trade.

During the first year of action, our team has collected unique information of over 100 parcels from northern to southern Finland. Not only carbon content but also soil quality and other parameters. The result shows that there is more carbon in soil profiles that previously anticipated. We have also demonstrated the great diversity that hides inside individual fields. This should be recognized not only in day to day agronomy but also in research and field trials.

To make proceedings even more useful the team has implemented novel add-ons to basic field scanning. There is a software platform to combine meteorological, spectral, biological and physical information gathering into a basic farm management system, FMIS.

By utilizing all these field measurements into a bigger datahub, we have a possibility to raise farming toward the very next level – resilient, sustainable and profitable.

Keywords: *Soil scanning, reference sampling, FMIS, datahub*

Investigating farmers' habits and opinions to design an appropriable sustainability diagnosis for Walloon field crop practices

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In Belgium, different alternative models of agriculture are developing: Conservation Agriculture or organic agriculture constitute good examples of that. However, each movement is creating its own definition and assessment system for sustainability, which makes communication between farmers and objective comparison of these new farming systems difficult.

In this context, we have decided to develop a sustainability diagnosis that can serve as a tool for common dialogue between the cultural systems of the Province Walloon Brabant. This diagnosis is focused on the crop field scale. It will include a component about the economic margin of the cultural system and the farmer well-being, for which data will be collected during interviews. It will also include an ecological dimension, for which data will be collected via measurements in the fields of participating farmers. The ecological dimension will be studied through the concept of ecological modernisation (Duru *et al*., 2014), observing both input and output material flows and the provision of ecosystem services in the crop fields. This approach was chosen for the ecological dimension of the study on the one hand because it is a way of representing the agro-ecosystem that was presumed very tangible for farmers, and on the other hand because it echoes the transition towards an ecologically intensive agriculture promoted by the Walloon region. In order to make the tool appropriate and usable by as many farmers as possible, the first step in its development was to assess the value farmers place on the different indicators that could be included in the diagnosis. To this end, we conducted a survey of twenty farmers from Walloon Brabant. The diversity of cropping practices represented by this sample was checked in regard to the organic certification, the presence of livestock on the farm, and the degree of application of the three pillars of Conservation Agriculture - minimum tillage, soil cover, and rotation diversification. For the ecological part of the diagnosis, we provided them with a list of indicators of ecosystem services conventionally used by scientists. We collected data on their opinions about these indicators - are they understandable, interpretable, interesting and modifiable via your practices? - and on the empirical methods they already use in everyday life to assess the provision of ecosystem services in their fields.

Farmers' opinions on the indicators were quite similar, regardless of their cropping system. All interviewees felt that their farming practices could influence the provision of different ecosystem services. Most of the indicators used by scientists were understandable to farmers. The indicators they feel able to interpret on their own are those they already use regularly: soil nutrient and carbon content, presence of pests and diseases, crop yield, etc. Many empirical evaluation methods used by farmers were identified. We will use them to develop simple but rigorous measurement methods for the selected indicators.

Keywords: *ecosystem services, indicators, farmers' measurement method, sustainability diagnosis, cropping system*

Facts and figures on 16 years of a comparative study of conventional and conservation tillage in Hungary

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Intensive tillage can lead to severe soil erosion and biodiversity losses. Conservation Tillage (CT) is a sustainable agricultural system. Its main advantages are the protection against erosion and deflation, the improvement of soil and soil fauna, the protection of surface waters and the preservation of biodiversity. In 2003, an experimental area was set up in Western Hungary for the comparison of the Conventional- (ploughing, inversion tillage; PT) and CT (non-inversion, minimum tillage, with 30% residue cover and combined machines) on hummocky Luvisol (10% slope steepness). 12 pairs of plots (4–5 ha/plot) were created in an area of 107 ha (Dióskál) and 2×2 uniquely designed erosion plots of 24×50 m size were configured (Szentgyörgyvár). During the last 16 years, agroecological and economical experiments took place at Dióskál, while continuous soil and erosion monitoring were carried out at Szentgyörgyvár. The effect of CT on erosion was favourable compared to PT. The soil loss on CT could be kept one order magnitude lower than the tolerable amount. The runoff was reduced by 60–70%, which increased crop safety in dry periods and decreased pesticide and nutrient loss. As a result retaining soil moisture, soil earthworms activity increased (3 times more and 2 times larger earthworms). Until now, applying CT resulted in a 5% reduction of costs and 5–10 % increase of yields on PT basis. CT had a positive effect on the small songbird population as well because they found better feeding and habitat during the critical winter period. Our long-term experiment suggests that CT allows soil conservation and biodiversity preservation even under productive agriculture.

The project was supported by EU LIFE-Syngenta (LIFE03ENV/UK/000617), Syngenta Hungary Ltd.; Bolyai Research Scholarship of the MTA (B.M); ÚNKP-19-4 New National Excellence Program of the Ministry of Human Capacities.

Keywords: *soil loss, runoff, yield, total organic carbon, soil aggregates*

Effect of cover crops on modern agricultural production of cherry trees in Chile

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The use of plant covers has a positive impact on soil management, since they allow to increase the content of organic matter and nutrients, product of the degradation of above-ground and underground biomass. Vegetable covers can also improve the porosity and structure of the soil, because some of the species used, can provide a deep decompression of the soil (Chen and Well, 2010). They also increase moisture retention and biological activity, as well as reduce water runoff and prevent erosion (Frye and Blevins, 1989). In recent years, other benefits associated with plant covers have also been discovered, such as weed control, due to the competitive effect of plant cover on weeds, which it exerts through shading and competition for water and nutrients (Ovalle et al., 2007) Another important effect of the use of plant covers is on pest control, since its implementation favors the development and action of natural enemies, which increases their abundance and effectiveness in reducing pests (Ripa and Larral, 2008).

A research project is being developed in Chile jointly by Syngenta and Pontificia Universidad Católica de Chile. It aims to determine protocols for addressing the challenge of making modern agricultural production more sustainable by finding means to improve the condition of biodiversity in agro-environments. This project has been entitled LivinGro™, which aims to create scientific data from field trials that demonstrate that the use of products, together with ecological compensatory measures can sustainably improve biodiversity and soil health in agricultural landscapes. Specifically, this study monitors the effects of the use of plant covers on soil parameters (physical, nutritional), soil microbiota, diseases, insects (beneficial and pests) and the possible impact on the quality and quantity of fruit produced.

Keywords: *Sustainable cherries, biodiversity, sustainability, regenerative agriculture, soil health*

Monitoring, tracking and estimation of Conservation Agriculture and ecological resilience: a participatory approach followed in operating agro-ecosystem of new alluvial zone in Eastern India

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New alluvial zone of eastern India is characterized by high-intensity agriculture which in turn is both coercive and depletive by nature. Almost 120 blocks in West Bengal are under the clutch of arsenic contamination which is enjoying a pervasive passage through the food chains to kill both humans and livestock. High intensity mechanization, as it is becoming exponentially popular due to lack of agricultural labourers associated with unaffordable wage, is ushering soil erosions and declining organic carbon level. The sharp decline of the livestock population can be correlated with the lowering of organic carbon status. The social ecology of this zone is predominantly represented by farmers who are mostly owner of small, marginal and fragmented holdings. This has further made the tiny holdings energy prodigal and economically non-manageable. The present study was conducted on 100 farmers, small and marginal farmers in 5 selected FGD (focussed group discussion) locales. A structured schedule has been administered to generate responses against a shade of queries. Ecological resilience has been estimated by using a set of dummy variables by calculating the slope and pattern of changes of crop residue admixture, yield topography, livestock count, rainwater harvesting, application of mulching and change in cropping intensity over a time period of last 30 years in 3 decadal cohorts. The study further elicits that the variables like cropping intensity, water productivity, soil conservation extent, biodiversity indexing, frequency of visit to crop field, performance and product monitoring have contributed substantially to the regime and level of ecological resilience as have characterized the dynamics of agriculture. MCDA (multi criteria decision analysis), ANN (Artificial neural network) and Logistic Regression analyses have been applied to estimate the role, function and contribution of respective variables to the criterion character i.e., ecological resilience in Conservation Agriculture. The study offers huge micro sociological policy in dealing with diverse issues of Conservation Agriculture towards attaining sustainability and productivity through socializing Conservation Agriculture across the small and marginal land holders in India.

Keywords: *Artificial neural network, Conservation Agriculture, ecological resilience, monitoring and tracking, multi criteria decision analysis*

Exploring approaches to strategic and effective communication for profitable and sustainable farming with Conservation Agriculture

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Conservation Agriculture (CA) provides many answers to the world's food production and environment issues. While its uptake in the Americas and Australia has been remarkable, in Africa, Asia and Europe uptake needs to be accelerated through greater policy and institutional support. The question is how? CA stresses the importance of system thinking but why should this philosophy stop at the farm gate? The paper's authors are communications experts working in the international and rural development sectors and they suggest that a systems approach must be central to communication about CA. They argue that a simultaneous, three-layered approach focusing on the farmer and aimed at the grassroots, at the institutional level and also at the level of policy and governance can cut through at all levels, to reveal how CA represents a food system to which all global stakeholders can subscribe for a sustainable future.

Both policymakers at the top and farmers at the bottom of the decision-making hierarchy depend upon institutions for knowledge, advice and support. Knowledge needs to flow both ways and institutions are at the intersection of that information traffic. But how is that information conveyed and manufactured? Farmers are willing to risk change when they can analyse and assess what is involved. But who do they believe most when it comes to their livelihoods? Policy makers have the power to effect change and provide a safety net for managing the bottom-of-the-pyramid risk-taking, but how do they make informed decisions if they can't hear the very practitioners for and about whom they are making crucial decisions? And how can they become convinced that CA represents a means of addressing the broader, pressing issues which they and society must face.

Institutions, where improved systems are theorised and farmer experiences categorised, have a crucial role to play in convincing the grassroots *and* policymakers that CA works in everyone's best interests. Peer-to-peer messaging tools overcome a credibility barrier when it comes to communicating with farmers. That evidence of impact is also key to underpinning institutional and governmental decision-making.

A systems-based communication strategy requires innovative communication approaches and, crucially, durational commitment and vision: what needs to be conveyed, how will it be conveyed, to whom and to what end? As any Theory of Change chart will demonstrate, impact takes time. Documenting to demonstrate that impact also takes time. As much as any field development project needs to be planned, any communications project also needs to be planned. The authors advocate an integrated, long-duration and evidence-based approach to documentation.
There is a wealth of supporting empirical evidence that such approaches work. Examples drawn from the authors' own experience with other innovatory agricultural systems is called upon to show through a poster illustration that 'stories from the field' do provide talking points at conferences, they have an impact in the media and crucially also have the ability to influence policy advisers and change makers.

Keywords: *Conservation Agriculture, Development, Communication, ComDev*

Effect of Conservation Agriculture and precision water management on wheat productivity and irrigation water use under rice-wheat cropping systems in the Indo- Gangetic Plains of India

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In the present scenario the biggest challenge is to produce more food for the continually increasing world population with in the limited land and water resources. Serious water deficits, diminishing profitability and deteriorating natural resources are some of the major threats to the agricultural sustainability in many regions of South Asia. Food security and water sustainability may be achieved by bringing improvement in the crop water productivity and the amount produced per unit of water consumed. The increase in the crop water productivity may be achieved by pursuing alternative agronomics approaches, which are more friendly and efficient in utilizing natural resources. Therefore, a research trial on Conservation Agriculture (CA) and precision water management (PWM) was conducted in 2018-19 at Karnal, India to evaluate the effect on crop productivity and irrigation in rice-wheat (RW) systems of Indo-Gangetic Plains (IGP). Eight scenarios were compared varied in the tillage, crop establishment, residue and irrigation management *i.e.,* {First four scenarios irrigated with flood irrigation method;Sc1-Conventional tillage (CT) without residue, Sc2-CT with residue, Sc3- Zero tillage (ZT) without residue, Sc4-ZT with residue}, and {last four scenarios irrigated with sub-surface drip irrigation method; Sc5-ZT without residue, Sc6- ZT with residue, Sc7-ZT inclusion legume without residue and Sc8- ZT inclusion legume with residue}. Results revealed that CA-flood irrigation (S3, Sc4) and CA-PWM system (Sc5, Sc6, Sc7 and Sc8) recorded about 3-5% and 12-15% higher wheat yield, respectively compared to Sc1. Similar, CA-PWM saved 30-40% irrigation water compared to Sc1. Rice yield was not different under different scenarios in the first year (kharif 2019) but almost half irrigation water saved under CA-PWM system. Therefore, results of our study on best agronomic practices including CA and precision water management (subsurface drip irrigation) systems for RW rotation would be of huge interest to farmers, for addressing the existing and future challenges in the RW system.

Keywords: *Sub-surface drip, crop residue, crop yield and zero tillage*

Strategic tillage in Conservation Agriculture: consequences on weed communities and winter wheat productivity

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In Europe, Conservation Agriculture is currently challenged by higher weed pressure, potential glyphosate ban and reduced crop yield. The introduction of strategic tillage could be a viable option to diversify selection pressures on weeds and increase crop yield. Three types of fallow management (ploughing (CT), reduced tillage (RT), no-till with glyphosate (NT)) were compared on four fields after 17 years of no-plough, which ended with 7 years of NT. Weed density, weed composition, crop productivity and yield components were assessed in the following winter wheat. The reintegration of tillage after 17 years of Conservation Agriculture proved to be a major driver of weed communities before weeding (density, richness and composition). Weed density and species richness before weeding was greatest in RT, intermediate in CT and lowest in NT. Density of Alopecurus myosuroides, the most problematic weed of the experiment was higher in RT than in CT or NT. Differences in weed community composition were discussed in terms of weed seed longevity and weed seed movements associated to RT and CT. The number of grains per ear and crop yield increased with tillage intensity (+11% for RT, +31% for CT). Specific weight and protein content were not affected by tillage treatments. Differences in winter wheat productivity were possibly related to enhanced soil structure and increased mineralization of soil organic matter. Strategic ploughing could be a viable solution to manage herbicide-resistant weeds in no-till cropping systems. Potential benefits will depend on the density and composition of the newly upwelled weed seedbank.

Keywords: *weed diversity, weed composition, glyphosate, yield components, strategic tillage*

Conservation Agriculture (CA) in Malawi: Integrated assessment of soil health outcomes

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Climate change challenges across sub-Saharan Africa (SSA) require more resilient food production systems. To improve agricultural resilience, the FAO proposed the Climate Smart Agriculture (CSA) framework including Conservation Agriculture (CA). Despite positive results on soil parameters such as soil water retention, yield and heat stress resilience, CA uptake across southern Africa has remained low. The variety in agro-ecological and socio-economic conditions requires more local empirical data to examine CA's soil health benefits and farmer decision-making. Previous studies on soil health have mainly focused on 'scientific' measurements, thereby not including local knowledge to understand farm system experience of soil health improvement. This study aims to 1) develop a stepwise framework to combine local knowledge and conventional soil science to develop a contextualised understanding of the impact of CA on soil health on farm trials in two Malawian communities; and 2) evaluate the advantages and limitations of such integrated approach to assessment of soil health outcomes. Soil measurements and farmer observations from study sites in both southern and central Malawi show that CA leads to soil structural change, with significant improvement in infiltration, and soil structure indicators of soil health. However, the recorded higher ammonia, nitrate/nitrite values in conventional practice (likely to result from structural improvement and higher vertical water flow in CA systems) show that scientific assessments alone can be difficult to interpret. The integration of local and scientific knowledge highlights discrepancies, such as the outcomes of ridge-making. Farmers perceive ridges as positive due to aeration, and nutrient release, fitting with the recorded higher ammonia, nitrate/nitrite values in conventional practice but not supported by the higher total N and yield in CA. Learning across knowledges for soil health can build a wider evidence base for CA's performance on farm and improve understanding of farmer decision-making.

Keywords: *Farming systems, Climate-smart agriculture, Southern Africa, No-tillage , Local knowledge*

Modeling and verification of corn straw based on no-tillage cutting process in Conservation Agriculture

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Corn straw as an important agricultural resource plays an important role in Conservation Agriculture. However, the existing corn straw model cannot reflect the stress and strain of each part of the straw corn during the shearing process and cannot be used for the numerical simulations and structure optimization of no-tillage stubble cutting device.

A Discrete Element Model of corn straw was established by Hertz-Mindlin with Bonding model in discrete element software EDEM. The normal stiffness per unit area, shear stiffness coefficient per unit area, critical normal stress, critical shear stress and bonded disk radius were demarcated by the mechanical test of straw rind and inner pith. The straw rind model was transversal isotropic and formed by two kinds of 264 longitudinal fibres bonded along elliptical coordinates, each fibre was bonded by 222 particles with a radius of 0.225 mm along a straight line. The calibrated longitudinal bonding parameters between the rind particles were 2.86×10^{10} N/m^3, 1.11×10^{10} N/m^3, 1.42×10^8 N/m^2, 1.2×10^7 N/m^2 and 0.6 mm; The calibrated transverse bonding parameters were 8.84×10^9 N/m^3, 1.23×10^9 N/m^3, 2.00×10^6 N/m^2, 1.54×10^6 N/m^2 and 0.6 mm. The inner pith model was isotropic and made up of 1090 particles of the same type at equal intervals, and the radius of particle was 1.05mm. The calibrated bonding parameters between the inner pith particles were 4.15×10^8 N/m^3, 5.00×10^6 N/m^3, 1.32×10^6 N/m^2, 4.42×10^6N/m^2 and 1.2 mm. The verifying tests revealed that the shear force trend of the straw model in the simulation test was consistent with that in the physical test, and the maximum shear force deviation remains within 10%, the deformation and damage of the straw mechanical model in the shearing process were identical. The results demonstrated that the discrete element model can be used to simulate compared of shearing force and shearing process of the stubble cutting device, which was of great significance to the study of the interaction mechanism of the stubble cutting device with straw and the structure optimization of the stubble cutting device.

Keywords: *corn straw; straw shear; transversal isotropy; discrete element method; model*

Multi-mixes cover crop species effects on soil attributes and soybean grain yield in the Southwestern of Paraná – Brazil

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The winter cover crops use is an important practice to promote better management and conservation of soil and water in southern Brazil. Different cropping systems where nutrients are removed by crop harvest and not replaced by mineral weathering or organic and inorganic inputs are unsustainable. Historically, crop residues have played an important role as mulch for soil and water conservation and as an input for maintaining soil organic matter and returning nutrients to soil (G. Basch et al., 2012). Studies carried out in southern Paraná State, South Brazil on clay soils, showed that conservation farming systems, like no-till, including winter cover crops species it was efficient to control the soil degradation process, enhancing soil attributes (chemical, physical and biological) contributed to increase soybean grain yield (Calegari et al, 2008; Tessaro et al., 2019). The objective of this work was to evaluate the biomass (green and dry mass) in the aerial part of winter cover crops (cc) in monocropping and mix species in southwestern Paraná, in the years 2016 and 2017. Randomized blocks/Plots were used as experimental design with a subdivided plot scheme of 50 m² with five replications. The cover crops used in monocropping were black oat and wheat, while for the mix; black oat + radish + rye + white lupin, black oat + radish and black oat + radish + rye + vetch + white lupin + buckwheat. The data were subjected to analysis of variance and the means were compared by the Tukey test at 5% probability. The intercrop composed of black oat + radish + rye + vetch+ white lupin + buckwheat had a higher green mass production, with an average value of 50.880 kg ha^{-1}. For the dry mass, the monocrop of black oat had higher mass with an average value of 5.168 kg ha^{-1}. The highest soybean grain yield after cover crops was obtained in the area with mix of: black oat + radish + rye + vetch + white lupin + buckwheat, achieving soybean grain yield in 2017 of 4.487 kg ha^{-1}. The purpose of this study was to demonstrate that growing winter species rotated with summer crops can promote soil conservation, increase nutrients recycling capacity, increasing biodiversity during the fallow/winter and may increase the summer crop yield. The adoption of conservation farm system may be a rational way to reduce the soil degradation, recover soil fertility, decrease production costs and improve crop yield. In our Brazilian conditions it is estimated that more than 32 million hectares under no-tillage systems contributed to improved farmers livelihood (small, medium and large scale), and also when normally properly fit cover crop species, locally and regionally adapted, better environmentally conditions are achieved towards sustainability.

Keywords: *Conservation Agriculture, tropical agriculture, cover crop mixes, no-tillage, rotation*

Effects of Soil bioactivation and fertilizer on common bean grain yield in Brazil

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The technology use of soil and plant bioactivation has been proposed for increasing soil microbiota, promote better nutrient equilibrium and enhance general soil attributes (biological, physical and chemical), as well achieving higher crop yield due to further optimization in the use of soil nutrients, especially phosphorus. The objective of the study was to determine the common bean performance, grain yield and yield components of common bean as affected by bioactivation and different dosis of inorganic phosphorus. The experiments were conducted in field conditions irrigated in two growing seasons. The experimental design was a randomized block design in a factorial 4 x 2. The treatments consisted of four levels of phosphorus in the soil (0, 40, 80 and 120 kg ha^{-1} of P_2O_5) in the presence and absence of bioactivation (penergetic) applying. Phosphorus applying allowed significant increases in grain yield and yield components of common bean in the two growing season. The bioactivator applying independent of the phosphorus use attained higher bean grain yield than the treatments without applying in the two growing season. In 2013, the bioactivator applying allowed the highest grain yield (5,313 t ha^{-1}) at a lower phosphorus than in the absence of the bioactivator (3903 kg ha^{-1}) at the highest dose of P (120 kg P_2O_5 ha^{-1}). The results showed that cultivate in a good P status in the soil, with an adequate soil management including the bioactivation it´s possible to enhance soil attributes, optimize the use of phosphorus, increasing bean grain yield, decreasing production costs and enhance the net income in a sustainable way towards sustainability.

Keywords: *nutrient uptake efficiency, better soil attributes by soil and plant bioactivation, phosphorus use efficiency, Phaseolus vulgaris reduction production costs*

Challenges and Opportunities for Adopting Conservation Agriculture Practices in Grain-Legume Rotation Systems on Smallholder Farms of Rwanda

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A farmer cooperative led pivot irrigation project was recently implemented in Rwanda to tackle recurring drought stress on farm productivity in the Kirehe region. This irrigation project covers nearly 2,300 ha of farmland owned by about 1,800 cooperating farmers in the Nasho valley. Cooperative mandated a monotypic cropping pattern of grain (corn)-legume (faba bean or soyabean) rotation and follow similar management guidelines, (fertilizer rates and seeds), irrigation scheme, and has set consistent yield goals. However, soil types, inherent soil health and productivity are highly variable between the farms and may require tailored approach to address major soil fertility gaps. Moreover, continued decline of soil health attributes under current intensive production practices is a major barrier to sustainably take advantage of the irrigation incentive on crop yields and thus must be improved significantly by implementing effective Conservation Agriculture practices (CAPs). This study was conducted to identify feasible and effective CAPs to address major soil fertility gaps and sustain productivity. Representative farms under variable soil types (productivity levels) were implemented one or combination of CAPs. Three practices compared in this study were minimum tillage, compost application and residue retention, to their respective control farms. Farms were sampled and monitored for four cropping seasons between 2018-2020. Results indicated a soil organic carbon (SOC) range of 5-19 g/kg, plant available-N at critical growth stage was 6- 23 mg/kg and P at 8-46 mg/kg. Inadequate availability of soil N and P to maize, and P and micronutrients to bean crops were the major yield limiting factors. Corn yield range was at 3.2 - 8.8 t/ha, confirming high variability of farm productivity. Yields were generally higher in farms implementing any or all of CAPs. However, compost application was more effective in increasing both corn and bean yields. It was also noted that compost application was readily accepted by farmers compared to minimum-till and residue retention, which was in high demand for animal feeding. Apart from additional nutrient benefits of compost, pH buffering potential after lime application was increased and nodulation numbers were also higher in legumes of these farms. Lower soil organic carbon stocks correlated with lower yields. Changes in SOC stocks between CA and control farms were not yet noticeable within the two-year period of this study, but trends suggested SOC gains in CA farms which implemented compost application. Lime application was more effective in resolving major soil fertility bottlenecks in compost applied farms. Thus, it was concluded that combination of liming with compost application demonstrated potential to significantly increase the corn-legume yields at moderate fertilizer rates. Among CAPs evaluated in this study, compost application was more feasible and was most promising for increasing soil health and crop yields sustainably. Thus, integration of livestock to enhance residue recycling and composting will be an impactful CAP for this region.

Keywords: *soil variability, fertility constraint, compost, beneficial microbes*

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ANNEXES

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The future of farming

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Declaration & Action Plan

DECLARATION

The 8th World Congress on Conservation Agriculture (8WCCA) was held virtually on 21-23 June 2021 in Bern, Switzerland and attended by 783 participants from farmer associations, international organisations, scientific institutions, private sector, non-governmental and civil society organizations, from more than 108 countries, from the developed and developing world. The main objective of the 8WCCA was to celebrate the Conservation Agriculture Community's success as the driver of the biggest farming revolution to have occurred in our lifetimes, and to build on this and boost the quality and speed of this transformation globally towards sustainable agriculture in support of the Sustainable Development and the international climate goals.

Naturally grown soil is a limited, scarce, nonrenewable resource. It is the base for the production of healthy food and native wood, a buffer element for the global hydrological cycle, filter substrate for clean drinking water, global carbon store, habitat of a huge biodiversity and element of attractive landscapes. At the interface of atmosphere, hydrosphere and lithosphere, the soil fulfills indispensable ecological, economic and social functions. The future of the world's food security requires soils which are unpolluted, of stable structure and productive, in short – a sustainable soil use.

Conservation Agriculture (CA) and its many locally adapted variants offer the best means of using soils for productive farming while enhancing their ability to fulfil their vital societal and planetary functions.

Accumulated positive experiences and scientific knowledge about Conservation Agriculture (CA) are leading to its rapid adoption world-wide. Farmers now apply CA on over 200 million hectares (15% of the word's annual cropland area) in over 100 countries across a diverse range of agro-ecological zones and farm sizes, in all continents but particularly in Africa, Asia and Europe. It has enhanced farm production and reduced costs while conserving and enhancing the natural resources of land, water, biodiversity and climate.

In contrast, conventional tillage practices are not ecologically sustainable since they degrade land by destroying soil structure and biodiversity, reduce soil organic matter content, cause soil compaction, increase run-off and erosion and contaminate water bodies with pollutants and sediments, threatening land productivity, environment and human health. In addition, they produce unacceptable levels of greenhouse gas emissions, speeding up climate change. World-wide, they have accelerated degradation of many natural ecosystems, decreased biodiversity and increased risks of desertification.

CA avoids many of the negative consequences of conventional tillage agriculture by replicating natural processes through the continuous avoidance of soil tillage, permanent maintenance of a soil mulch cover through which diverse crops are directly seeded or planted and rainfall can enter the soil and be retained, cutting erosion. CA enhances the crop root environment (soil structure, carbon, nutrients and moisture) and cuts the build-up of pests and diseases.

In these ways, CA results in a productive agriculture for food security and improved rural livelihoods, especially women's welfare since they provide a high proportion of agricultural labour. Its many economic, social and environmental benefits justify a fundamental re-appraisal of common farming methods.

This Congress has confirmed that CA is here to stay. It has shown that the CA Community is in very good health, full of energy and new ideas. It has confirmed the validity of the Community's way of operating, with farmers in the driving seat, innovating, sharing experiences, spreading the word and creating demands for supportive services from the public and private sectors. All of us who have participated feel proud of our Community's achievements and are determined to do everything within our power - and working with others who share our determination - to contribute to the emergence of a truly sustainable future of farming world-wide. We are confident that the millions of CA farmers whom we have sought to represent here will echo our commitment.

We call upon politicians, international institutions, environmentalists, farmers, private industry and society as a whole, to recognise that the conservation of natural resources is the co-responsibility, past, present and future, of all sectors of society in the proportion that they consume products resulting from the utilization of these resources, noting the increasing interest in plant-based diets to improve human and planetary health. Further, it calls on society, through these stakeholders, to conceive and enact appropriate long-term strategies and to support, further develop and embrace the concepts of CA as a fundamental element in achieving agricultural-related Sustainable Development Goals including those with a social and economic perspective, and those of ensuring the continuity of the land's ongoing capacities to yield food, other agricultural products, water and environmental services in perpetuity. It follows that the environmental services provided by farmers who nurture soil health should be recognised and recompensed by society.

ACTION PLAN

The Congress participants declare their commitment to engage the CA Community in achieving the following goal and to taking the actions needed for this.

GOAL

Given the urgent need to accelerate the global move to sustainable food systems, and in particular to respond to the global challenge to mitigate the advancing climate change, the Congress agreed that the CA Community should aim at bringing at least 50% of the global cropland area or 700 million hectares under good quality CA systems by 2050.

These holistic CA systems would involve CA farmers in engaging progressively in the full array of sustainable approaches to farming, adapted to their ecological and social conditions so as to maximise the sustainability benefits of growing crops without tillage.

PRACTICAL ACTIONS

To achieve the goal, a massive boost should be injected into the momentum of the CA Community's activities with a concentration on the following six themes:

1. Catalysing the formation of additional farmer-run CA groups in countries and regions in which they do not yet exist and enabling all groups to accelerate CA adoption and enhancement, maintaining high quality standards.
2. Greatly speeding up the invention and mainstreaming of a growing array of truly sustainable CA-based technologies, including through engaging with other movements committed to sustainable farming.
3. Embedding the CA Community in the main global efforts to shift to sustainable food management and governance systems and replicating the arrangements 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.

In order to facilitate the implementation of above thematic activities, the Congress endorses the need to: (a) operate the Global CA-CoP as an independent non-profit mechanism, with ongoing hosting support of ECAF and FAO, with an advisory panel, and authorised to set up task forces and working groups to help implement the priority practical actions; (b) strengthen the CA-CoP Moderator capacity within the CA Community; and (c) create a CA Hall-of-Fame in time for the 9th Congress. It would also oversee and support future processes for convening CA World Congresses. The Global CA-CoP would require a permanent IT systems development and operating capacity, with sound financial management, programme monitoring and reporting capacities.

The Congress participants feel confident that much of the extended moderation function can continue to be provided by CA Community participants who are willing to provide their time, knowledge, expertise and energy on a voluntary basis.
This Congress has reinforced our conviction that it is entirely possible to meet the global goal of making our food systems sustainable in every sense of the word and that our Community has a vital role to play in this transformation. Our own experience shows that farming can quickly respond to new challenges when farmers see that these are in their own interests.

Our aim is to engage our whole Community as quickly as possible in creating and spreading optimal and profitable low-input, high-output CA-based farming systems that are dependent on biological forms of crop protection and plant nutrition management with maximum energy efficiency and minimal use of externally sourced inputs. This approach shows our commitment to making all we do together in future still better than what we do now.

We pledge to work at all levels with all who share this vision of farming for the future, seeking their guidance and sharing what we learn with them. And we will also partner with those who champion complementary changes in downstream elements of the food chain to eliminate food waste and to bring to healthy nutrition to all people..

Healthy soils are the very heart of healthy lives and a healthy planet!

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List of Actions

The Congress suggested the following specific list of action areas:

1. Farmer associations and networks should be encouraged and reinforced at national and international levels, as the most effective bottom-up means of disseminating and developing CA.

2. Benefits of CA such as increased land productivity, diversification prospects, climate change adaptability and mitigation and increased profits for smallholders and larger-scale farmers should be drawn to the attention of national and international communities as well as global benefits on land resources, health and environment.

3. Given that major information, experience, capacities and tools concerning CA are available in South and North America and Australia, and are quickly developing in Africa, Asia and Europe, international organizations should encourage south-south and south-north co-operation for CA development programmes to make greater use of the available knowledge and expertise.

4. The private and the public sectors as well as NGOs and civil society should actively collaborate in the development with farmers, of the technologies needed to achieve CA such as adapted and accessible information, practices, tools, seeds and safe use of chemicals when needed. Of particular importance in this context are technologies for a CA oriented sustainable agricultural mechanization including related agri-hire services and businesses with the potential of new jobs and increasing attractiveness of farming with specific focus on smallholder farmers particularly in Africa, Asia and Latin America.

5. Greater attention should be given to transform paddy rice systems into CA systems as well as to integrating legumes and cover crops, trees and shrubs, and perennial systems such as orchards and plantations, into CA systems.

6. Promote the adoption of CA as the most suitable way to restore degraded land and to stop future land degradation. Special attention should be given to promote the adoption of CA in areas with high degradation risks.

7. Increased support needs to be provided to strengthen CA Centres of Excellence worldwide as well as to the use of communication and information technology and digital tools to maximize the generation, sharing and application of CA knowledge and expertise.

8. The role of the public sector should be to promote CA as an institutional policy framework, with inter-agency working agreements to provide appropriate support from public sources for the adoption of CA:

    - to recognise the public benefits of CA – including fight against climate change, the conservation of natural resources (water, soil, biodiversity), the protection of the environment, the reduction of flooding and damage to civil infrastructure among others – which result from the farmers' private initiatives,
    - to recompense farmers for these societal services and help them to face the costs necessary to make the transition to CA, especially the purchase of machinery and implements conducive to the adoption of CA which farmers may not be able to initially afford,
    - to fund appropriate key research and advisory service with the public and private sectors, to support access to appropriate knowledge through the development of training and capacity building sessions for farmers, advisors, institutions, etc.,
    - to implement information campaigns, policies and activities to encourage CA and appropriate private investment into this area as well as to discourage inappropriate practices,
    - to provide appropriate infrastructures to facilitate the transport, processing, distribution and if necessary, the exportation of the surplus production,
    - to support adoption and continuity of CA systems managed at local levels through legislation, incentives and investment support.

    These measures should be linked with existing legislation and other appropriate instruments such as the UNFCCC, UNCCD, UNCBD and their programmes.

9. Contributions should be made to the work of international conventions (UNFCCC, UNCCD, UNCBD). Also, a special synergy with the IPCC and carbon-related initiatives should be examined so that carbon sequestration via CA systems could become a substantial incentive to make it happen.

10. The representatives of the various stakeholders attending the Congress should develop partnership and make commitments to design, plan and implement actions as well as monitoring procedures, in order to be able to present them along with some results during the 9WCCA in 2024.

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