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Proceedings of the FAO Global Conference on Sustainable Plant Production

2–4 November 2022

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FOREWORD

The international community adopted the Sustainable Development Goals (SDGs) back in 2015 and pledged to work together to end hunger, malnutrition and poverty by 2030. However, current trends are telling us that the world is off track – with over 828 million people affected by hunger in 2021 and over 2 billion people lacking regular access to safe, nutritious and sufficient food. The ripple effects of the climate crisis, including extreme weather events, the COVID-19 pandemic, ongoing conflicts and the war in Ukraine have exacerbated food insecurity, thereby jeopardizing the achievement of the United Nations 2030 Agenda for Sustainable Development.

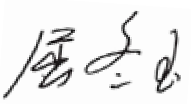
This calls for urgent action, for a transformation of global agrifood systems to become more efficient, more inclusive, more resilient and more sustainable. The FAO Strategic Framework 2022–2031 aims to support this needed transformation for better production, better nutrition, a better environment and a better life for all. One of the key attributes of these transformed agrifood systems should be that they enhance productivity and significantly increase yields, but with less external inputs and diminished environmental footprints. Tomorrow's agriculture will need to produce more food with fewer inputs and contribute to strong local and diversified agrifood systems that are more resilient to shocks and disruptions.

Sustainable plant production is at the heart of agrifood systems transformation. Plant production systems will need to meet increasing global demands, since plants make up 80 percent of the food we eat and contribute in multiple ways to economies and livelihoods. Sustainable plant production systems rely on integrated approaches that promote biodiversity and sustainable use of natural resources and are farmer-centric – placing farmer needs, knowledge and constraints at the core of solutions. They are not "one-size fits all" solutions but ones that acknowledge the need to adapt to local conditions and have the capacity to respond to climate change and its impacts.

In light of this, FAO organized its first ever Global Conference on Sustainable Plant Production (GPC) (Rome, 2 to 4 November 2022), with a focus on *Innovation, Efficiency and Resilience*. Its main objective was to provide a neutral forum for FAO Members, farmers, scientists, development agencies, policy makers, extensionists, civil society, opinion leaders and the private sector to engage in dialogues around sustainable plant production. Discussions encompassed aspects required to make these systems sustainable and on the use of innovation to ensure they are resilient to biotic and abiotic stresses. The conference, which gathered over 4 500 participants – in-person and participating virtually – was timely, informative and inclusive.

To achieve impact towards implementing the 2030 Agenda, the GPC developed 20 actionable recommendations. The recommendations encompass all the thematic areas highlighted in the GPC, with a focus on adaptation to local contexts, needs of small-scale farmers, and include cross-cutting issues to guide active innovation for global sustainable plant production systems. The recommendations clearly establish (i) priorities for targeted mobilization and pooling of scientific, technical and financial resources; (ii) evidence and knowledge sharing through the creation and management of functional technical networks; and (iii) testing and scaling evidence-based sustainable plant production practices, partnerships and policies.

I encourage all stakeholders, especially governments, researchers, extension agents and all development practitioners engaged in transforming agrifood systems to build on the momentum of this conference and to use this important publication to continue discussions around the importance of sustainable plant production.



QU Dongyu
FAO Director-General

PREFACE

FAO organized the first ever Global Conference on Sustainable Plant Production (GPC) from 2 to 4 November 2022, with the theme of *Innovation, Efficiency and Resilience*. The hybrid event, held in person and virtually, allowed for a wide spectrum of GPC stakeholders to debate and consider innovations that confer efficiency and resilience to various components of sustainable plant production systems.

To plan and implement the GPC, three governance bodies were created. The Steering Committee (SC), chaired by FAO Deputy Director-General, Beth Bechdol, provided strategic advice on all aspects of the conference. The Technical Advisory Panel (TAP), chaired by CGIAR's Managing Director, Resilient Agri-Food Systems, Martin Kropff, assisted in the development of the technical programme, selecting pertinent themes and prominent speakers. The Secretariat, led by Jingyuan Xia, Director of the FAO Plant Production and Protection Division (NSP), provided support to the organization of all core activities of the event. In addition, 111 key players worldwide have directly contributed to the success of the GPC, including moderators of plenary sessions, chairs and co-chairs of parallel sessions, keynote presenters, and thematic speakers as acknowledged individually in these proceedings.

The two-and-a-half-day hybrid event at FAO headquarters in Rome consisted of an opening and keynote address plenary sessions, a high-level ministerial segment and a closing plenary session. There were 12 parallel sessions, which consisted of two sessions for each of the six conference themes: seed systems, field cropping systems, protected cropping systems, natural resource management, integrated pest management, and mechanization and digitalization. In addition, there was a single session on the theme of farmers and enabling environment. Dialogue was fostered throughout the GPC by alternating presentations and open discussions.

The conference convened over 200 participants in person and engaged about 4 500 participants virtually. Of these participants, it is estimated that 42 percent were female, 36 percent were from research or academic institutions, 13 percent were from the private sector, 14 percent were from civil-society organizations, farmers' organizations and cooperatives, 17 percent were from governments or governmental organizations, and 8 percent were from international non-governmental organizations and other United Nations agencies.

These proceedings, which are an important legacy for the conference, are composed of ten sections:

- Chapter 1 begins with the opening remarks of FAO Director-General, QU Dongyu, testimony to the organization's high-level commitment to the event, and follows with the keynote addresses of eight high-level speakers.
- Chapters 2 to 8 include abstracts of the presentations given by global experts and representatives of stakeholders in the thematic sessions.
- Chapter 9 contains the statements delivered in the high-level ministerial segment by the representatives of six countries, followed by concluding remarks by FAO Deputy Director-General Beth Bechdol.
- Chapter 10 contains the 20 recommendations and calls to action, forged by members of the SC and TAP, and enriched by contributions of Members and a diversity of stakeholders.

The two parallel sessions on the theme "Seed systems" were titled "Adapted varieties" and "Quality seeds". The two parallel sessions on the theme "Field cropping systems" were titled "Efficient cropping systems" and "Resilient cropping systems". The two parallel sessions on the theme "Protected cropping systems" were titled "Optimizing production efficiencies" and "Transforming urban horticulture". The two parallel sessions on the theme "Natural resource management" were titled "Maximizing resource-use efficiency" and "Ecosystem approaches to resilience". The two parallel sessions on the theme of "Integrated pest management" were titled "Challenges in plant pests and diseases" and "Solutions for plant pest and disease management". The two parallel sessions on the theme "Mechanization and digitalization" were titled "Smart mechanization" and "Digital agriculture". In each parallel session, ten speakers were invited to make presentation.

In the session on the theme of "Farmers and enabling environment", case studies were presented on accelerating digital innovation and making big data work for smallholders, governance and integrated landscape management, promoting access and adoption of sustainable inputs and technologies, overcoming extension gaps – increasing access to extension and advisory services, and confronting risk and incentivizing positive stewardship in production.

All parallel sessions and the single session on farmers and enabling environment contained a moderated discussion during which the presenters responded to participant questions. These proceedings reflect the richness of the GPC in focusing attention on actions to achieve sustainable plant production systems as a key driver to transform agrifood systems.

To streamline the follow-up to the event, 20 strategic actions were developed as conference recommendations that were proposed and agreed upon. These could serve as guidelines for promoting sustainable plant production to 2030 and beyond.

I hope you enjoy reading these proceedings.

Jingyuan Xia
FAO NSP Director

ACKNOWLEDGEMENTS

The organization and implementation of the Global Conference on Sustainable Plant Production (GPC) was possible due to the invaluable support and commitment of many people. Particular thanks are owed to contributions from members of the three GPC governance bodies: the Steering Committee, the Technical Advisory Panel and the Secretariat (listed in Annexes I and II).

The Steering Committee provided strategic advice on all aspects of the conference, and was skilfully chaired by FAO Deputy Director-General, Beth Bechdol, co-chaired by Martin Kropff, Managing Director, Resilient Agri-Food Systems, CGIAR, and vice-chaired by Alzbeta Klein, Josse de Baerdemaeker, Michael Keller, Sunday Ekesi, Xiangzhao Gao, Marcela Quintero and Ana María Loboguerrero Rodríguez.

The Technical Advisory Panel (TAP), expertly deployed their significant expertise and technical networks to develop the programme for the conference, guided by chair Martin Kropff and co-chair Ismahane Elouafi, FAO Chief Scientist, with active support from Niels Louwaars, Jon Hellin, Yüksel Tüzel, Graciela Metternicht, Robert Bertram, Geoffrey Mrema and Channing Arndt as vice-chairs. Deserving of special commendation are the members of the Panel's working groups who developed the draft programme for two parallel sessions dedicated to each of the seven conference themes, namely seed systems (Emmanuel Okogbenin and Tammi Jonas); field cropping systems (Juliana Jaramillo and Bernard Vanlauwe); protected cropping systems (Weijie Jiang and Pietro Tonini); natural resource management (Shamie Zingore and Felix Reinders); integrated pest management (Roma Gwynn and Ibrahim Al-Jboory); mechanization and digitalization (Saidi Mkomwa and Salah Sukkarieh); and farmers and enabling environment (Rasheed Sulaiman Vadakkel and Elizabeth Nsimadala). The TAP was deftly supported by FAO thematic session focal points, namely Fenton Beed, Maged Elkahky, Buyung Hadi, Karim Houmy, Wilson Hugo, Josef Kienzle, Ivan Landers, Joseph Mpagalile, Anne Sophie Poisot, Emma Siliprandi and Makiko Taguchi.

The FAO Plant Production and Protection Division, led by the Director, Jingyuan Xia, served as the GPC Secretariat, and was responsible for the core technical and organizational activities for the event. In particular, the contributions of Nadine Aschauer, Fenton Beed, Shangchuan Jiang, Haekoo Kim, Mirko Montuori and Bruno Telemans, who oversaw the day-to-day running of the Secretariat, were invaluable. The Secretariat was also responsible for the publication of the conference proceedings.

Additionally, sincere recognition is owed to the 111 experts who served as chairs, panellists, presenters, moderators and rapporteurs of the different thematic subsessions, who ensured a wide diversity of global technical views and opinions on sustainable plant production.

COVID-19 pandemic restrictions meant that the GPC was organized as a hybrid event. This was a significant undertaking that demonstrated the resilience of FAO's information technology infrastructure and the expertise of those who supported the secretariat. Also, the sterling resourcefulness, patience and flexibility of FAO's audio-visual, communications and multilingual interpretation teams were instrumental in creating the conducive atmosphere in which the conference was held. The work of all these behind-the-scenes professionals is gratefully acknowledged.

ABBREVIATIONS AND ACRONYMS

AIMforClimate	Agriculture Innovation Mission for Climate
ALN	Adaptive learning networks
AMSEC	Agricultural mechanization services
APPSA	Agricultural Productivity Programme for Southern Africa
AR4D	Agricultural research for development
AUC	African Union Commission
AVRDC	World Vegetable Center
AWD	Alternate wetting and drying
BD-GNSS	Beidou Global Navigation Satellite System
CABInternational	Centre for Agriculture and Bioscience International
CATIE	*Centro Agronómico Tropical de Investigación y Enseñanza*
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CCARDESA	Centre for Coordination of Agricultural Research and Development for Southern Africa
CEA	Controlled-environment agriculture
CEB	United Nations System Chief Executives Board for Coordination
CFS	Committee on World Food Security
CGIAR	A global partnership that unites 15 international organizations engaged in research about food security (formerly the Consultative Group for International Agricultural Research).
CIAT	International Centre for Tropical Agriculture
COVID-19	Coronavirus disease 2019
CNHRRDC	China National Hybrid Rice Research and Development Centre
CNRS	*Centre national de la recherche scientifique*
CNY	Chinese Yuan
COP27	Twenty-seventh session of the Conference of the Parties of the United Nations Framework Convention on Climate Change
COE	Centres of Excellence
CSA	Centre for Sustainable Agriculture
DSS	Decision support system
EAFF	Eastern Africa Farmers’ Federation
EAS	Extension and Advisory Services
FAMEWS	Fall Armyworm Monitoring and Early Warning System
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer field school
FIA	Farmer Interface Application
FIFF	Food Import Financing Facility
FPO	Farmer producer organization
F-SAMA	Framework for Sustainable Agricultural Mechanization for Africa
GHU	Germplasm Health Unit
GPC	Global Conference on Sustainable Plant Production

GSI	Global Seed Initiative
HM	Holistic Management
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFA	International Fertilizer Association
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
IMF	International Monetary Fund
INIFAP	*Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias*
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated pest management
IPPC	International Plant Protection Convention
ISFM	Integrated soil fertility management
ISH	International Seed Health Initiative
ISPM	International Standards for Phytosanitary Measure
ISSM	Integrated soil–crop system management
ISTA	International Seed Testing Association
LMIC	Lower middle-income country
MaDiPHS	Malawi Digital Plant Health Service
NAMA	Nationally appropriate mitigation actions
NATESC	National Agro-Technical Extension and Service Center (China)
NERCITA	National Engineering Research Center for Information Technology in Agriculture (China)
NGO	Non-governmental organization
NIBIO	Norwegian Institute of Bioeconomy Research
NPAAC	National Center for International Collaboration Research on Precision Agricultural Aviation Pesticides Spraying Technology
NPPO	National plant protection organization
NSP	FAO Plant Production and Protection Division
OCOP	One Country One Priority Product
OECD	Organisation for Economic Co-operation and Development
PA	Protected agriculture
PAAT	Precision agricultural aviation technology
PFAL	Plant factories with artificial lighting
PGRFA	Plant genetic resources for food and agriculture
PxD	Precision development
QDS	Quality declared seed
R&D	Research and development
SADC	Southern African Development Community
SAT	Semi-arid tropics
SC	Steering Committee
SDG	Sustainable Development Goal
SDG 1	End poverty in all its forms everywhere

SDG 2	Create a world free of hunger
SDG 3	Ensure healthy lives and promote well-being for all at all ages
SDG 5	Achieve gender equality and empower all women and girls
SDG 6	Ensure access to water and sanitation for all
SDG 10	Reduce inequality within and among countries
SDG 12	Ensure sustainable consumption and production patterns
SDG 13	Take urgent action to combat climate change and its impacts
SDG 14	Conserve and sustainably use the oceans, seas and marine resources
SDG 15	Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss
SERT	Seed Emergency Response Toolkit
SET	Social–ecological–technological
SIDS	Small Island Developing States
SSA	Sub-Saharan Africa
STB	Science and technology backyards
STI	Science, technology and innovation
TAP	Technical Advisory Panel
TIGEM	Türkiye General Directorate of Agricultural Enterprises
TT	Technological transition
UA	Urban agriculture
UAV	Unmanned aerial vehicle
UH	Urban horticulture
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States dollar
USDA	United States Department of Agriculture
WHOFCTC	WHO Framework Convention on Tobacco Control
WHO	World Health Organization
WTO	World Trade Organization
WUE	Water-use efficiency

Chemical formula and units of measurement

CO2	carbon dioxide
Ha	hectare
T	tonne

Participants at the Opening Plenary Session. From left to right, Jingyuan Xia, Beth Bechdol, Qu Dongyu, Martin Kropff and Fenton Beed.
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Chapter 1. Opening and keynote address plenary session

1.1 Opening remarks

QU Dongyu
FAO Director-General

Excellences, Ladies and Gentlemen,

Thank you to all globally for joining us at this conference, which is the first ever of this kind.

Where does food and agriculture start?

It starts with seeds. That is why last year we held the Global Conference on Green Development of Seed Industries.

After seeds, comes better production.

The FAO Strategic Framework 2022–2031 sets out the four betters, but the first one is better production.

I am so delighted to welcome you all to the first ever FAO Global Conference on Sustainable Plant Production!

This conference is the result of the joint efforts and collaboration among many organizations, institutions and individuals, under the guidance of the FAO Strategic Framework 2022–2031.

The theme of resilience, efficiency and sustainability is key, it provides the right design and defines our discussions.

Today we meet at an opportune time, when the world urgently needs to make the shift towards more efficient, more inclusive, more resilient and more sustainable agrifood systems.

We cannot only talk about a better environment and a better life, we also need to talk about better production and better nutrition – it is the starting point.

The COVID-19 pandemic, the climate crisis, protracted conflicts, compounded by the war in Ukraine, have pushed the world closer to the brink of a global food crisis.

I have just participated in the United Nations System Chief Executives Board (CEB) for Coordination, and we had a discussion with all the United Nations Principals regarding food security.

Food security should cover food availability first - availability is production.

And then accessibility - the supply chain.

Thereafter, affordability - the purchasing power.

That is why I am so happy with the strong political support from the UN Secretary-General and other key members of the CEB, such as the IMF which recently endorsed the Food Import Financing Facility (FIFF), called the Food Shock Window.

There are about 62 vulnerable countries that have no way to import food – this amounts to 1.79 billion people who face the problem of food affordability.

For this reason, the Secretary-General has expressed his appreciation for FAO's professional role of raising these issues and bringing them to the foreground.

We are at risk of facing a food accessibility and affordability crisis now, and a food availability crisis in the coming months if we do not handle the situation properly, and with international solidarity, especially with regard to fertilizers, seeds, fuels, and other agricultural inputs for farmers.

However, we also cannot have availability without sustainable production – this is the key goal of this conference on Sustainable Plant Production.

Dear Colleagues,

The number of hungry people around the world is rising; we have reached the alarming figure of 828 million people facing hunger.

And a third of the world's population – 2.3 billion people – do not have access to adequate food.

This is why I said even in the most developed countries have about 5 to 8 percent of the population face day-to-day food affordability problems.

These are the three dimensions: availability, accessibility and affordability. Different countries have different combinations.

Some countries have all three, and most developed countries only have one. But food affordability is a problem even in these countries.

We are not on track to achieve the 2030 Agenda and the Sustainable Development Goals (SDGs).

The distance to reach many of the SDG 2 targets to achieve Zero Hunger – as well as SDG 1 No Poverty, and SDG 10 Reduced Inequalities – is growing wider each year. And we only have seven planting seasons left until 2030.

Based on estimates, poor populations will be back to 2015 levels when we reach 2030 – that is a dire reality. We have to double and even triple our efforts if we want to change these numbers.

We must speed up action, be more innovative, more efficient, more effective and more coherent.

The tools are in the toolbox! But we need to also have efficiency, effectiveness and coherence to work better together.

The global demand for food, feed, fuel and fibre is increasing – the 4 Fs – which are all part of the FAO mandate for food and agriculture.

Agriculture is not only crops, it includes fisheries, animal husbandry, forestry and biodiversity, among others.

It is estimated that the world will need 50 percent more food by 2050 to feed an increasing global population, by changing and improving diets.

Because more and more people live in cities, and more and more middle-income people are moving to cities, their diet and consumption patterns are changing.

This is creating a lot of challenges, as well as a lot of opportunities for us. Current agricultural practices are unsustainable, and investment is urgently needed. This is what I always tell politicians: you need to invest in agriculture.

The statistics on the percentage of investment in agriculture per country speak for themselves, with Europe having the lowest percentage – only 16 percent. This is why I particularly tell politicians in Europe: you need more investment in agriculture, research, infrastructure, and in rural areas.

Even in Europe, there is great pressure on the environment and on our finite natural resources, including biodiversity, land and water.

The use of fertilizers and pesticides has increased unevenly – both overuse and underuse coexist on this planet.

The key is not merely to reduce, but to improve the efficiency of all the agriculture inputs, especially pesticides, insecticides and chemical fertilizers.

You know the marginal utility curve economists tell us about: with any kind of investment and input – for example chemicals, fertilizers – you have to increase it to a certain level and then you will reduce the marginal utility. That is the basic law of economic investment.

The message is clear: do not go from one extreme to another; zero from one or one from zero.

Dear Colleagues,

The threats from plant pests and diseases are increasing, and are compounded by the effects of the climate crisis, which has created big fluctuations, with extreme cases globally.

Land conversion from natural ecosystems to agriculture is contributing extensively to deforestation, biodiversity loss and greenhouse gas emissions.

We cannot continue "business as usual" – we need to get on a technology-driven sustainable track. That is the only solution.

Tomorrow's agriculture will need to produce more food with a lower environmental footprint – this means producing more with less.

We also need to produce more food, more diverse food, higher quality food and different kinds of food.

That is why I encourage my colleagues to not only talk about biodiversity, but also food diversity – and then we can have a conversation about germplasm, not only virtually, but *in situ*.

Science-based sustainable plant production can enable this, because it has the potential to build greater resilience and efficiency to address these challenges, and to protect and sustainably manage biodiversity and natural resources through integrated approaches, endorsed by scientific evidence.

We cannot talk about agriculture without talking about farmers. Farmers must be part of the solution and action.

Farmers in general are private holders, both big and small. They are part of the private sector. Their needs, knowledge and constraints must be at the core.

To address these global challenges we need to:

- **First:** implement solutions that are accessible and can be locally adapted;
- **Second:** establish strong local and diversified agrifood systems that are more resilient to shocks and disruptions by biotic, and abiotic stress;
- **Third:** harness the potential of agricultural innovation to create efficient plant production systems;
- **Fourth:** we need to be inclusive, taking into consideration the needs of all, including the most vulnerable groups, rural women, youth and Indigenous Peoples; and

- **Fifth:** we have to keep international trade open and functional.

We need a global picture and that is the beauty of agrifood systems: we can have complementary roles – your sustainability depends on our sustainability. Your sustainable production solved the problem I could not solve sustainably.

For example, if we faced water scarcity, would you still develop water-intensive crops? Is that sustainable? No. You can develop water-saving high-value cash crops to trade with staple foods that can be produced in an ideal, favourable environment such as soybeans, wheat, rice or corn.

This first ever Global Conference on Sustainable Plant Production will focus on these critical aspects of sustainable plant production systems.

Farmers will be central to the discussions, and farmers' perspectives will be the thread that links each of the sessions, to ensure their full participation in shaping an enabling environment for sustainable plant production.

FAO is a technical organization established under Article 57 of the United Nations Charter as a specialized agency within the United Nations family – that is the legal origin of FAO.

To generate knowledge and provide a neutral and professional platform for science- and evidence-based information sharing.

This is one of the four key roles, and mandate, of FAO set out in its Basic Texts and Constitution.

Through this first ever FAO Global Conference on Sustainable Plant Production, we are convening a wide range of relevant shareholders to raise awareness of the importance and contribution of sustainable plant production to achieve the SDGs, and to share information, practices and policies on strategies, investment, research and development (R&D) and capacity building.

We have identified four expected outcomes from this conference, on which you will debate:

- **First:** establish priorities for targeted mobilization and pooling of scientific, technical and financial resources.
- **Second:** create and manage technical networks to share knowledge and evidence.
- **Third:** produce a global knowledge product – an evidence-based guide to promote sustainable plant production.
- And **Fourth:** propose a set of recommendations to guide active innovation for sustainable plant production worldwide, in support of the 2030 Agenda.

FAO is committed to leveraging the momentum generated by this conference to transform evidence into action on the ground,

Together with our other flagship initiatives such as Hand-in-Hand, One Country One Priority Product (OCOP) and 1000 Digital Villages.

For the transformation of our agrifood systems to be more efficient, more inclusive, more resilient and more sustainable,

For better production, better nutrition, a better environment and a better life for all, leaving no one behind.

I wish you a fruitful conference.

I thank you.

Keynote addresses

1.2 Sustainable plant production is at the heart of agrifood systems transformation for resilience

Martin Kropff
Managing Director, Resilient Agri-food Systems, CGIAR

In the next 50 years, we must produce as much food as has been consumed in all human history, but with fewer resources (Harridge, 2009). More than 800 million people worldwide are hungry, mainly in South Asia and sub-Saharan Africa, while 2 billion more people will be there by 2050 and climate change reduces staple crop yields in the same regions. This is what I called a "perfect storm" several years ago in my presentations. Besides that, 3 billion people suffer from malnutrition (United Nations, 2022). Agrifood systems are further threatened by COVID-19 and the war in Ukraine.

Worldwide average yields for many staple crops has steadily increased in recent decades, triggered by genetic and agronomic improvements and better policies, although there is still much more to accomplish. CGIAR, together with partners in the Global South, has played a key role in this success with its innovations and impacts, especially in lower middle-income countries (LMICs). To meet future food demand, annual yield gains must sharply increase. Yet climate change, water, nutrient and energy scarcity, coupled with transboundary diseases and pests, have significant negative effects on crop yields, thus threatening the food and nutritional security of millions of people in the Global South.

To meet these challenges, agrifood systems must transform to be resilient and harness affordable, sufficient and healthy diets within the limits of resources available on the planet.

Sustainable plant production requires a science-based, integrated approach focused on enhancing livelihoods, food security and diversification for farmers – many of them women – through **(1) improved seed development and delivery**, **(2) crop management and agronomy**, and **(3) enabling policies**. In the presentation, examples of science-based innovations in these areas were presented based on experiences in the network of CGIAR and partners in the Global South.

(1) Genetic innovations and improved seed delivery

We need to accelerate breeding and delivery of climate-resilient seed varieties with higher grain yield, tolerance to abiotic stresses such as drought or heat, and resistance to biotic stresses such as disease and insect pests, improved nutrient content via biofortification, and enhanced nitrogen-use efficiency. CGIAR has provided national agricultural research systems and (mainly small) seed companies with improved germplasm in an array of crops, achieving impact at scale (e.g. in maize, Krishna *et al.*, 2023). For example, the drought-tolerant maize varieties developed by CIMMYT-CGIAR are now grown on nearly 5 million hectares in eastern and southern Africa (Chivasa *et al.*, 2022). Approximately 50 percent of improved maize varieties in sub-Saharan Africa (SSA) are CGIAR-related. The aggregate benefit of new CGIAR-related maize varieties was estimated to be USD 0.8–1.3 billion annually across 18 countries in SSA, with a benefit–cost ratio of 22:1 to investment in CGIAR's global maize research (Krishna *et al.*, 2023).

In many staples such as potato, climate-resilient varieties can now be developed in four years, instead of 14 years, and there are examples of drought-tolerant varieties as well. In rice, submergence-tolerant varieties have been developed for flood-prone areas in Asia. Many examples can be given on host-plant-resistant varieties of the CGIAR-mandated crops, such as resistance to blast and rust in wheat, maize varieties with resistance to fall armyworm and maize lethal necrosis, etc. These are important for preventing serious yield losses through integrated pest and disease management strategies. Future threats to yields from climate change will require solutions based on both agronomy/agroecology and plant breeding.

(2) Crop management and agronomy

The challenge for the immediate future is producing more food, but in a sustainable manner, within the planetary boundaries. Sub-Saharan Africa can increase production from one to three tonnes per hectare (t/ha) by ensuring better access to improved seeds and fertilizers. In some countries, such as Ethiopia, this has happened already. Increases from three to five t/ha will require interventions across agricultural value chains, including production, processing and markets. Ten t/ha is agronomically possible (of course depending on crop and environment) but may require new technologies beyond short-term interventions. Monitoring nitrogen balance on agricultural land is key: food grown with nitrogen fertilizers feeds almost half the Earth's population, but benefits are not equally distributed. In sub-Saharan Africa, 239 million people go hungry each year as crops fail, soil is stripped of nutrients and fertilizers are not available or accessible for small-scale farmers. Elsewhere, fertilizer overuse pollutes waterways and releases greenhouse gasses. CGIAR's Excellence in Agronomy Initiative is working with farming communities to improve fertilizer-use efficiency and to valorise alternative sources of nutrients. As part of the CGIAR, the International Food Policy Research Institute's fertilizer dashboard tracks availability, affordability and trade restrictions. The agricultural sector needs solutions to absorb fertilizer prices and supply shocks, while increasing fertilizer use in Africa and raising organic matter. This will require (1) deploying tools and analytics to deliver locally relevant fertilizer recommendations at scale, following the "4R" principles (right type, right amount, right time and right place), (2) disseminating integrated soil fertility management (ISFM) options at larger scale, (3) working with CGIAR's Nature Positive Initiative to identify locally available sources of organic inputs, and (4) repurposing fertilizer subsidies, which drive 50 percent of global fertilizer demand.

Strategic crop management buffers crops against multiple stresses. Small-scale farmers need machines to improve production and site-specific agronomic advisory services and digitalization. More than 40 years of tropical agronomy R&D can be drawn on to maximize input-use efficiency, incorporating good fertilizer application practices using improved/adapted varieties, combining fertilizer with organic or other complementary inputs, applying good agronomic practices, and addressing localized constraints.

(3) Enabling policies

Pathways for rethinking the global food system are: (1) to invest in agrifood R&D for innovation, "more with less", and global systems approaches; (2) to transform small-scale agriculture and empower women in agriculture; (3) to fix the fundamentals, including markets, infrastructure and trade; (4) to strengthen partnerships for co-innovation, especially with new players, and (5) to design effective and implement enabling policies for scaling innovations.

Transformation is needed to develop resilient, diversified agrifood systems that support rural livelihoods, healthy and affordable diets, and environmental protection, through coordinated implementation by partners and the integrated deployment of existing and emerging knowledge and technologies.

To overcome global challenges, we need science and science-based innovations that need to be "taken to the farmer", as coined by Norman Borlaug, considered by many to be the father of the Green Revolution. We need region-specific agrifood system solutions, policy and governance support, and a new consensus. Through the new CGIAR research strategy and portfolio of initiatives, we have launched regional integrated initiatives in six regions in the Global South with our partners. We need to work together to achieve **genetic**, **agronomic** and **governance** gains in an integrated way. To achieve this, we need the different science communities and international organizations like CGIAR, FAO, IFAD, WFP, development banks, NGOs and the private sector to work together with national governments and organizations in the Global South.

References

CGIAR. *2023*. CGIAR. Montpellier, France. Cited 14 Mar 2023. www.cgiar.org

Chivasa, W., Worku, M., Teklewold, A., Setimela, P., Gethi, J., Magorokosho, C., Davis, N. & Prasanna, B.M. 2022. Maize varietal replacement in eastern and southern Africa: Bottlenecks, drivers, and strategies for improvement. *Global Food Security,* 32: 100589.

Harridge, M. 2009. VCE International Studies: 'An Apocalyptic Warning' - the Malthusian Politics of the Global Food Crisis. *Ethos,* 17(4): 26-29.

FAO, IFAD, UNICEF, WFP & WHO. 2022. *The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable.* Rome, FAO. https://doi.org/10.4060/cc0639en

Krishna, V.V., Lantican M.A., Prasanna, B.M., Pixley, K., Abdoulaye, T., Menkir, A., Bänziger, M. & Erenstein, O. 2023. Impact of CGIAR maize germplasm improvement in sub-Saharan Africa. *Field Crops Research,* 290: 108756.

1.3 Transforming food, land and water systems under climate change

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Climate change is affecting planetary systems at a higher and faster rate than previously estimated (IPPC, 2021; von Braun *et al.*, 2021) with the 1.5° C global warming level now expected to be reached by the early 2030s (UNFCCC, 2021), a trajectory United Nations Secretary-General Antonio Guterres has called "catastrophic". If the United Nations Framework Convention on Climate Change (UNFCCC) and Paris Agreement targets (temperature increases held to 1.5° C by 2030, carbon neutrality by 2055) are to be met, urgent – and early – action on the twin goals of **climate mitigation** (reducing emissions, creating carbon sinks) and **climate adaptation** (boosting countries' resilience to climate change) is required.

One of the principal challenges to be addressed is the poor climate adaptation preparedness of the food and agricultural systems in low- and middle-income countries (LMICs). The adverse impacts of climate variability and extremes in the Global South are well documented (Ortiz-Bobea *et al.*, 2021) The loss of productive assets and human capital, coupled with the effect of uncertainty on agricultural investments, stymie small-scale farmers' efforts to improve livelihoods, exacerbating poverty and social tensions. There is urgency to transform the climate-adaptation capacity of food, land and water systems in LMICs, ultimately increasing the resilience of small-scale production systems to withstand severe climate change effects like drought, flooding and high temperatures.

Demand has shifted from understanding climate change impacts to designing innovations and directing financial flows to achieve ambitious climate and food systems targets (Loboguerrero, Campbell and Millan, 2021) Isolated interventions to increase crop yields or strengthen markets no longer suffice; it is critical to transform systems to simultaneously enhance resilience, productivity and equity. It is imperative to design and scale social–ecological–technological bundles (Hellin, Fisher and Loboguerrero, 2021) that empower people in the Global South to build climate resilience to a tipping point capable of triggering system-wide transformation.

Transforming food, land and water systems under climate change

At the same time, our current food systems are at increasing risk of failing to produce the quantities of food needed to feed a growing world population that satisfies nutritional needs, benefits everyone equally and equitably, and minimizes the negative impacts of food systems on the environment and the natural resource base. To address the challenges, numerous goals and targets have been proposed and many initiatives established. Unfortunately, we can take almost any one of these goals and show that we are not on track to achieve them.

Multiple reports have been developed to support the idea of transforming food systems. Most of them argue that since current trajectories are not going to be enough to meet the Sustainable Development Goals (SDGs) and the Paris Agreement, a change in food systems is necessary.

Over the past years, the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) worked with many partners to consider how to achieve this rapid, deep-seated change in food systems. Background papers on strategic areas to foster these reconfigurations were developed and presented at international events accompanied by deep discussions on the key set of actions needed. This work has culminated in the report of Steiner and colleagues (2020) which discusses a set of actions for transformation that is intended to raise ambition for adapting our food systems to climate change and reducing their emissions, while not losing sight of the many other functions of, and challenges to, our food systems. The actions involve:

1. **Rerouting** farming and rural livelihoods to new trajectories, to reduce inequality, address gender and social inclusion, and incentivize climate-resilient practices that meet dietary needs.
2. **De-risking** livelihoods, farms and value chains, reducing the impact of variable weather and extreme events through attention to inclusive early warning systems, adaptive safety nets and climate-informed advisories and other services.
3. **Reducing** emissions through diets and in value chains, involving significant dietary shifts and massive reductions in food loss and waste.
4. **Realigning** policies and trade, bringing in billions of dollars in public and private investment, providing support to social movements, and innovation systems to build more resilient and sustainable food systems.

The report also outlines 11 specific and concrete actions within these four areas. Taken together, these can help shift our food systems towards more sustainable, inclusive, healthy and climate-resilient futures.

From gender gaps to social equity-transformative climate actions in agriculture

There is extensive literature related to women's vulnerability and closing the gender gap through climate action in agriculture. Much of what is known to support this effort needs to be applied. The challenge lies in integrating the interconnected and divergent approaches to effectively transform food systems. Research should therefore aim to gain a deeper understanding of the effects of global social and environmental changes on food systems transformation, including the gendered impacts of climate change, also of men and young people, their experience of and responses to climate change, and their resource needs. Future work should therefore combine gender equality, social and youth-inclusion mechanisms, and intersectionality if we are to develop truly transformative, inclusive and sustainable food systems.

Transformative adaptation – actions needed to address root causes rather than symptoms of vulnerability (Few *et al.*, 2017) – is a powerful strategy that has emerged to build resilience in agricultural systems. However, a focus on social equity has not been a key component of the design of climate-adaptation strategies (Fisher *et al.*, 2019). This is a critical issue because addressing climate risk through adaptation can reinforce inequities, creating winners and losers. These inequities and related social inequalities, including those connected to the uneven distribution of climate risk, shape resilience building. To systematically address these issues, a social equity framework to guide climate change research is proposed (Hellin *et al.*, 2022). The framework encompasses: (1) recognitional equity (how acknowledgement and respect are given to identity, values, social norms and rights); (2) procedural equity (how decisions are made, and the degree to which different groups of people can influence these decisions); (3) distributional equity (how costs and benefits, and resources are distributed between people and groups); and (4) intergenerational equity (how justice and injustice are perpetuated or changed through generations). By addressing "equity of what" and "equity between whom" the framework includes gender but treats it as part of a broader contextual framing that recognizes differential exposure to vulnerability and to how people's lived experience reflects multiple identities (Leach *et al.*, 2018).

We need to transform the way we do research

While innovative technological interventions are critical, technology alone won't solve our problem. We need enabling social, institutional and governance factors that are the actual drivers of the transformative process. Not only will we need to harness all available tools, but everyone also has a role to play. To bring these pieces together and ignite true transformation, we need to work across sectors and disciplines to build inter- and transdisciplinary approaches.

Yet in doing so, care must be taken to avoid maladaptation and inadvertently reinforcing or increasing exposure and risk for some of the most vulnerable groups. Treating farmers, for example, as a homogenous category, instead of a group of unique individuals with different circumstances and power imbalances, will result in blanket actions that fail to meet the needs of many. Tackling the root causes of vulnerability and enabling truly transformative adaptation will require a social equity lens.

The CGIAR, through one of its Initiatives (ClimBeR), proposes one identified adaptation pathway for achieving this transformative adaptation, foregrounding social equity and including reducing risk in food systems; mitigating conflict; informing policy through participatory scenarios; enabling multi-scale governance; and attracting much-needed climate finance (Hellin *et al.*, 2022).

References

Few, R., Morchain, D., Spear, D., Mensah, A. & Bendapudi, R. 2017. Transformation, adaptation and development: relating concepts to practice. Palgrave Communication, 3.

Fisher, E., Hellin, J., Greatrex, H. & Jensen, N. 2019. Index insurance and climate risk management: Addressing social equity. *Development Policy Review,* 37(5): 581–602.

Hellin, J., Fisher, E. & Loboguerrero A.M. 2021. Reflections on Enhancing the Impact of Climate Risk Management Through Transformative Adaptation. *Frontiers in Climate,* 3:751691. http://doi:10.3389/fclim.2021.751691

Hellin, J., Amarnath, G., Challinor, A., Fisher, E., Girvetz, E., Guo, Z., Hodur, J., Loboguerrero, A.M., Pacillo, G., Rose, S., Schutz, T., Valencia, L., & You, L. 2022. Transformative Adaptation and Implications for Transdisciplinary Climate Change Research. *Environmental Research: Climate,* 1: 023001.

IPCC. 2021. Climate Change 2021: The Physical Science Basis. In: Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu B. Zhou, eds. *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK, Cambridge University Press.

Leach, M., Reyers, B., Bai, X., Brondizio, E.S., Cook, C., Díaz, S., Espindola, G., Scobie, M., Stafford-Smith, M. & Subramanian S. M. 2018. Equity and sustainability in the Anthropocene: a social–ecological systems perspective on their intertwined futures. *Global Sustainability,* 1: e13. www.cambridge.org/core/product/identifier/S2059479818000121/type/journal_article

Loboguerrero, A.M., Campbell, B. & Millan, A. 2021. More, but not of the same – new funding for a new type of AR4D needed. *Rural 21 – The International Journal for Rural Development,* 1/2021, Volume 55.

Ortiz-Bobea, A., Ault, T.R., Carrillo, C.M., Chambers, R.G. & Lobell, D.B. 2021. Anthropogenic climate change has slowed global agricultural productivity growth. *Nature Climate Change,* 11: 306–312. https://doi.org/10.1038/s41558-021-01000-1

Steiner, A., Aguilar, G., Bomba, K., Bonilla, J.P., Campbell, A., Echeverria, R., Gandhi, R. *et al.* 2020. *Actions to Transform Food Systems under Climate Change.* Wageningen, Kingdom of the Netherlands, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

UNFCCC. 2021. Nationally determined contributions under the Paris Agreement: Synthesis Report by the Secretariat. *Conference of the Parties serving as the meeting of the Parties to the Paris Agreement. Third session.* Glasgow, 31 October to 12 November 2021.

von Braun, J., Afsana, K., Fresco, L.O. & Hassan, M. 2021. Science and Innovation for Food Systems Transformation and Summit Actions, *Papers by the Scientific Group and its partners in support of the UN Food Systems Summit.* ScGroup of the UNFSS (2021). https://scfss2021.org

1.4 Collaborating towards achieving progress on SDG 1, SDG 2 and SDG 12

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We are all aware that the present-day challenges to achieve the SDGs are numerous. On top of this, the global population will continue to suffer the consequences of climate change and conflict – to name just two factors – leading to poverty, hunger and stunted social development. What we need today is to bridge, in an inclusive way, the collaborative efforts of each actor to progress on the SDGs.

No one actor or sector can address these challenges alone. The complementarities of research and the public and private sectors need to be strengthened more than ever. The time for action is now!

In the seed sector, opportunities have never been greater to develop synergies and take advantage of the diversity and complementarity of roles in the agricultural supply chain to achieve sustainable food production that adapts and adjusts to a changing world.

Farmers need access to more productive varieties developed by the private sector that are based on joint activities with research programmes.

It is about our joint capacity to provide seed choice for farmers to address needs at a local level and meet consumer demands; not imposing on the farmer what the market has developed, but allowing the farmer to decide based on their needs.

Only then can genetic gains, developed by science-based institutes, be brought within reach of farmers.

Interaction between public and private sectors, science and breeding companies, and farmers are indeed increasing, as also reflected during the Global Conference on Sustainable Plant Production.

Eight thousand seed companies, large, medium and small, associated with the International Seed Federation (ISF) – many of whom have their own private breeding programmes – engaged on a journey to sustainability and resilience, based on efficiency and innovation.

It is important to bear in mind that, for seed as well, we cannot consider one-size-fits-all solutions. FAO recognizes this and is aware that there will be no solution without science or innovation. The public sector, farmers and Indigenous Peoples also know this, and need to work together to develop seed that is locally adapted and based on needs expressed by the farmers, not imposed on them.

The private sector is actively involved in contributing to the achievement of the SDGs. It is in the interest of all to have the best-quality seed accessible to all, with the objective of achieving a world where sustainable plant production can be achieved, thereby supporting the SDGs.

A common and fundamental goal for the public and private sectors, civil society, Indigenous Peoples and farmers – in being efficient in the development of varieties and production of seed – is the *conservation of genetic resources*, since guaranteeing *access* to and *sustainable use* of genetic resources is essential.

Through the sustainable use of plant genetic resources, we create better varieties and diversity in fields. Access to a diverse pool of genetic resources in gene banks is needed, which can be facilitated through the conservation and use of plant genetic resources for food and agriculture (PGRFA). The private sector sees the need for the PGRFA treaty as well as the need to share benefits generated by using genetic resources. The private seed sector is working globally on over 80 crops, engaging thousands of researchers in several hundreds of breeding programmes.

Breeding has indeed always been at the core of the private seed sector, developing varieties that respond to farmers' and consumers' expectations (regarding crop yields, taste, nutritional quality, drought tolerance, disease resistances, etc.). This was true in the past and may now become even more pertinent with the effects of climate change and the incidence of pests and diseases, making the need for new adapted varieties more urgent.

While we may face increasing challenges, breeding tools like genome editing contribute to more efficiency and less time in developing crops with improved performance. Public and private breeding programmes are using genome editing for over 40 crops in more than 30 countries. But it must be said that plant breeders need predictable, consistent and science-based rules for the use of genome editing tools to successfully drive research programmes on pests and diseases, drought resistance, better yields and nutritional value. Other innovations like digitalization, bioinformatics and access to big data are extremely important tools for both public and private research.

The private sector is conscious of the fact that it needs to bring healthy seeds onto the market, in a context where there is interdependency of seed supply and access to genetic plant resources. Plant health starts with seed health, from prebreeding to commercialization. Consistent science-based trade rules to move healthy seed to different countries can support this endeavour.

The endeavour is also one of the reasons why the private seed sector created the International Seed Health and Regulated Pest List Initiatives to allow the movement of healthy seed. The collaboration with the IPPC, the WTO and national plant protection offices is crucial.

Plant breeding is costly and requires investment that can be significant but can lead to economically sustainable win–win situations between public and private sectors and farmers. Achievements are impressive, with approximately USD 10 billion per year invested in over 80 crops in the Northern and Southern Hemispheres. Every year, over 20 000 new varieties are added to the already 200 000 varieties that are accessible worldwide.

This has a positive impact on farmers, who can produce better yields and better quality products, and achieve more resilient farming and better livelihoods.

The public and private sectors need to mutually recognize their complementarity, and continuously build bridges to make progress on achieving the objectives of the SDGs by defining common goals, while adopting diverse approaches to achieve continued innovations and access to high-quality seed for all farmers.

1.5 Plant nutrition – key connector between food and energy

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Over the past year, the world started to understand the close interconnections between food, energy and plant-nutrient markets. Energy – natural gas and other fossil fuels – are used as both a feedstock and energy source in the production of ammonia, a base material for nitrogen fertilizers. **The world realized in 2022 how closely food and energy are related, and how plant nutrients are the transmission mechanism of this connectedness**.

In 2022, the world also realized how geographically uneven the production of plant nutrients is. The Russian Federation and Belarus are major suppliers of fertilizers. In 2021, the Russian Federation accounted for 16 percent of major fertilizer exports globally – including about 13 percent of urea, the most commonly used nitrogen fertilizer, 13 percent of ammoniated phosphates, and 19 percent of potash. The Russian Federation was also the largest global exporter of ammonia, which is the intermediate source of urea and nitrate fertilizers, and a key raw material for ammoniated phosphates production. Belarus provided 21 percent of global supplies of potash in 2021, according to IFASTAT. And these sources of plant nutrients are not available in their full capacity in global markets.

The world also realized in 2022 what it takes to feed the world sustainably. Sustainability cannot take a back seat to current issues of affordability and availability; the three must go hand in hand. Much more needs to be done on the proper use of plant nutrients, especially now when these nutrients are hard to come by, particularly in emerging markets.

How do we ensure proper prioritization to target mobilization and pooling of scientific, technical and financial resources to achieve global sustainable plant production systems?

First and most importantly, **we need to bring the private sector to the forefront of discussions**. As we are seeing with the current delivery of plant nutrients to Africa, it is the private sector that makes the difference. The private sector brings mobilization, and it brings agility that few others can. There are many examples of how this has been done over the past few weeks, for example in Ghana and Uganda, and more to come in southern Africa.

Second, **we need to work with governments, in both developing and developed markets, on prioritizing policies that bring availability and affordability of plant nutrients**, without unnecessarily disrupting the markets or sound principles of plant nutrition. We need to be led by scientists and data to ensure plant-nutrient applications are done in a sustainable manner.

Third, **this is not the time to be lax on sustainability issues**. We need to ensure that the nitrogen value chain is decarbonized to the degree possible and allowed by science, without harming farmers' access to nutrients. We want to avoid knee-jerk reactions that harm farmers and impede food security.

Fourth, **the new paradigm of plant nutrition brings about new investment opportunities**. The private sector needs to be properly incentivized to bring these opportunities to the fore.

And, last but not least, we need to work on a **well-designed, well-flowing global trading system**. It was international trade that allowed for the flow of plant nutrients, and ultimately a revolution in economic development that lifted many people out of poverty. It is that same system, adjusted for the current environment, that will ensure sound nutrition for the global population, today and tomorrow.

References

IFA (International Fertilizer Association). 2022. *Public Summary: IFA Medium-Term Fertilizer Outlook 2022–2026*. Paris, IFA Marketing Intelligence Service. 12 pp. https://api.ifastat.org/reports/download/13707

IFA (International Fertilizer Association). 2022. *Public Summary: IFA Short-Term Fertilizer Outlook 2022–2023*. Paris, IFA Marketing Intelligence Service. 14 pp. https://api.ifastat.org/reports/download/13806

1.6 Agroecology: more than practices. A holistic approach to make a sustainable transition to sustainable food systems

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Currently, agroecology is best understood through a set of principles that are meant to guide changes in agriculture and food systems. If applied properly, these principles can lead to systems that are environmentally sound, socially inclusive and resilient to climate change and other external shocks. These principles include aspects related to the foundation of healthy agroecosystems (including soils, animals and plants), biodiversity conservation, diversification of production and food systems, circularity, and social inclusion, among others. The incorporation of these principles in the context of systems transformation is ultimately meant to change the way food is produced and how it reaches consumers. This process of incorporating agroecological principles into food systems entails working at different scales, making changes that avoid environmental deterioration at the agroecosystem level and favouring circularity. It also involves making systems more resilient to shocks, changing the way farmers connect to markets and consumers, and how they influence policy processes. Furthermore, ensuring better conditions for farmers about their relationship with other food-system elements, involves considering aspects related to fairness, inclusion and participation. In other words, approaching agroecology beyond the agroecosystem level acknowledges that sustainable farming practices alone are not sufficient for the transformation of food systems.

Despite the increasing relevance of agroecology as a systemic approach to food-system transformation, it is still commonly understood solely as a set of sustainable farming practices. Examples of agroecological practices include reduced tillage, cover crops, agroforestry, integrated pest management and the use of biofertilizers. Scientific evidence on the performance of these practices is increasing but still highly focused on the field-level impact of agroecology, e.g. on crop yields and environmental indicators, and less so on socioeconomic factors.

Notwithstanding the importance of agroecological practices as contributors to sustainability of food production, there is still a need to embrace a systems approach to agroecology that could lead to increasing efforts towards understanding the extent to which, among others, farmer preferences, value chains, markets, extension services and policies contribute to a favourable environment for the application of agroecological principles at the food-system level.

In this regard, the technological transitions (TT) framework proposed by Geels (2005) could be adapted to agroecology, as it acknowledges that various innovations and changes must coevolve at different levels for transformational changes to occur in a system. This framework is compatible with Gliessman's (2016) five levels of agroecological transformation, which start with changes at the field level but are complemented by changes at the agroecosystem level and the global food system level. The TT framework can complement Gliessman's agroecology transformation framework by acknowledging that, beyond technological innovations at farm level, different social, political and institutional changes need to coevolve for those practices to be scaled, ultimately contributing to improving current systems. Furthermore, the TT framework recognizes that agroecological transformations do not follow a sequential process in which innovations (i.e. agroecological practices) are first created, and consequently assimilated by markets and users, but that they rather consist of a process where multiple changes (in markets, institutions, policies, regulation, etc.) coevolve, at different scales and points in time, until food systems reconfigure to sustainably adopt new practices and institutions, and other food system innovations. The TT framework also helps to understand that, if innovation processes in agriculture are not supported by a deep understanding of the required adjustments in the social, economic and political environment, farm-level technological innovations will not reach the levels of acceptance, applicability and access that transcend to the desired improvement of systems. In other words, innovation in agriculture requires the involvement of food-system actors beyond the farm (e.g. policymakers, scientists, financial capital providers and input suppliers) that support farmers in transforming food systems through innovation processes.

To date, agroecological research has focused on technical aspects rather than the sociopolitical dimensions beyond the farm level that are necessary to transform whole food systems. In response to this situation, CGIAR has joined forces with a variety of partners to establish a new Research for Innovation Program in Agroecology that aims to inform and facilitate agroecological transitions through the generation of scientific evidence and adaptive scaling strategies, by establishing landscape-level living labs in diverse contexts in seven countries. In this process, the Agroecological Initiative of CGIAR and its partners aims at understanding which technological innovations in agroecology work, for whom and for which purpose. This inquiry is also concerned with changes in markets, sociopolitical contexts and the overall enabling environment that are needed to advance the implementation of agroecological practices, and to mainstream agroecological principles in the wider food system. This initiative also responds to the increasing demand for scientific assessments that incorporate a holistic approach to analyse the effects of agroecological practices, as compared to conventional ones, i.e. on multiple dimensions (such as nutrition, the environment, social capital, etc.), which will further allow an understanding of trade-offs in diverse impact components.

References

Geels, F. 2005. *Technological Transitions and System Innovations. A Co-evolutionary and Socio-technical Analysis*. Cheltenham, UK, Edward Elgar Publishing. https://doi.org/10.4337/9781845424596

Gliessman, S. 2016. Transforming food systems with agroecology. Agroecology and Sustainable Food Systems, 40(3): 187–189. https://doi.org/10.1080/21683565.2015.1130765

1.7 Crop yield increase and green agricultural development in China

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In recent years, China has made great achievements in green agricultural development and sustainable plant production, producing 24 percent of the world's grains, 57 percent of its vegetables and 32 percent of its fruit, with only 9 percent of the world's arable land and 6 percent of its freshwater resources, feeding 18 percent of the world's population, accompanied by a reduction of fertilizer use by 14 percent and pesticide use by 18 percent (National Bureau of Statistics of China). These achievements in green agricultural development and sustainable plant production can be attributed to the following:

(1) The development of improved varieties and seed systems increases productivity. China has further developed improved varieties and seed systems, with high independent selection and breeding capacity. China's improved variety rate has reached 96 percent. The supply of 70 percent of crop seeds (including rice, wheat, soybean and others) can be guaranteed, and accounts for 95 percent of the national seed market.

(2) The construction of well-facilitated farmland and science-based water management has solidified the foundation of increasing yield. China has been developing the construction of well-facilitated farmland, with fertile soils and strong disaster resistance that is compatible with modern agricultural production methods. Well-facilitated farmland has proven to give high and stable yields, reduce soil erosion, improve farmland ecology and save costs. Additionally, China is developing water-saving and rain-fed agriculture to suit local conditions.

(3) Reducing pollution sources in agricultural production to support eco-friendly agriculture. China attaches importance to eco-friendly agricultural development, and has made great efforts in reducing the use of agrochemicals (e.g. fertilizers and pesticides), recycling agricultural plastics, biodegradable plastic replacement and conservation agriculture.

(4) Science-based fertilization improves resource-use efficiency. In recent years, China promoted science-based fertilization techniques such as soil testing and formulated precision fertilization. This significantly reduced the use of chemical fertilizers and improved the fertilizer utilization rate without compromising crop yield. Meanwhile, the composition of fertilizer products has been improved, and a variety of new and efficient fertilizers have been developed to support sustainable plant production.

(5) Precision monitoring services reduce effect of pests and disasters, to increase resilience and prevent crop loss. China has arranged multiple precision monitoring sites in major agricultural counties to accurately monitor changes in agricultural environments and maintain the stability of the agricultural market. Monitoring systems record crop growth and soil moisture, forecast pests and on-farm weather, and follow seed-market, fertilizer-market and pesticide-market trends. Nowadays, professional plant protection service organizations have contributed to over 41 percent of pest prevention and control efforts in 2020, preventing 17.5 million tonnes of crop yield losses.

(6) Agricultural mechanization and digitalization can reduce labour-intensiveness while enhancing efficiency for large-scale agriculture. The development of agricultural machinery equipment is thriving as Chinese farmers migrate to urban areas. High-tech innovative agricultural machinery products with the integration of mechanization and digitalization are emerging, such as unmanned agricultural seeders based on the Beidou navigation system and unmanned aerial vehicles for precision spraying and fertilization.

(7) Extension services and support mechanisms for farmers and an enabling environment. More than 10,000 advanced and applicable agricultural technologies have been promoted in China annually; CNY 2.3 billion has been invested in capacity development for farmers, with 717 000 farmers participating. Supporting policies and subsidies for application of advanced sustainable technologies significantly contributed to sustainable agriculture development in China, e.g. reporting an annual investment of CNY 2.5 billion for green circular agriculture, CNY 1.5 billion for soil testing, formulated fertilization and chemical fertilizer reduction, and CNY 500 million for plastic-film recycling.

China attaches great importance to innovation, efficiency and resilience in sustainable plant production. In the future, the relevant advanced technologies and enablers will be further promoted.

1.8 Confronting the global burden of pests and pathogens in a changing climate: challenges and opportunities

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To meet the growing demand for food, global agricultural production must increase by 70 percent by 2050. Yet, a myriad of crop pests and pathogens present a threat to achieving food and nutrition security in various parts of the world. Yearly, it is estimated that 40 percent of food crops are lost due to plant pests and pathogens, causing an annual agricultural trade loss of over USD 220 billion (IPPC Secretariat, 2021; Savary *et al.*, 2009). Globalization in travel and trade facilitates the spread and invasion of pests and pathogens. Climate change and variability is driving pest and pathogen distribution, spread and host-range shift. This is further compounded by the COVID-19 pandemic that has disrupted supply chains and availability of crop-protection inputs, contributing to severe impacts of pests and pathogens on crops. For example, it is estimated that the global invasion of fall armyworm could put the food and nutrition security of 600 million vulnerable people at risk, especially in some of the poorest parts of the world. Recent outbreaks of locust ruined the livelihoods of millions of small-scale farmers in eastern Africa and the Horn of Africa.

Although management of pests and pathogens has relied heavily on the use of synthetic pesticides, the concept of integrated pest management (IPM) is the globally accepted principle that has been incorporated in several public policies and regulations. According to FAO, "integrated pest management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM promotes the growth of a healthy crop with the least possible disruption to agroecosystems and encourages natural pest control mechanisms".

A very important component of IPM is surveillance and monitoring. Indeed, global coordination of pest and pathogen diagnoses and surveillance systems is crucial to minimize the frequency of pest and pathogen invasions and outbreaks, stabilize effective management practices and enhance global food production (Carvajal-Yepes *et al.*, 2019). Surveillance systems should be backed by modelling, risk assessment, forecasting and preparedness for proactive management and containment of invasive pests and pathogens.

Decision support systems (DSS) that complement existing extension advisory systems including short message service system (SMS), interactive voice response advisory, and smartphone applications supporting large scale implementation of IPM. The Fall Armyworm Monitoring and Early Warning System (FAMEWS) app developed by FAO and its partners is a pragmatic response to DSS, and helps farmers and field scouts collect data from pheromone traps to inform management decisions. With the app in place and the availability of effective management tools and technologies (e.g. traps, semi-chemicals, tolerant and resistant varieties, biopesticides, parasitoids, push–pull technology), systems integration of the various management components is required within the framework of IPM. It is encouraging to note that this is being pursued through the FAO Global Action for Fall Armyworm Control.

When effectively used, IPM reduces excessive use of pesticides that are harmful to humans, biodiversity and the environment, and greatly increases farmer income. Another solid example of IPM application in horticultural crops is the availability of a robust IPM package for the management of fruit flies that attack tree crops such as mango, avocado and citrus. Adoption of two or three components of the fruit fly IPM (based on bait sprays, biopesticides, field sanitations, male annihilation techniques and use of parasitoids) reduces fruit fly infestation of mango by >80 percent; providing yield gains of 27 percent and 95 percent, corresponding to income increases of 33 percent and 137 percent, respectively. This has benefitted over 100 million people in Africa (Niassy *et al.*, 2022).

Nevertheless, for all the various success stories attributed to IPM implementation, IPM remains a knowledge-intensive technology and concerted efforts are still required to address barriers to its adoption (Deguine *et al.*, 2021). Ecological functioning of the ecosystems is gaining attraction about how agroecology and ecosystem service providers, including pollination, can be optimally used for the benefit of crop protection. The innate immune system or plants, providing them protection against biotic constraints, should be exploited to mitigate the impact of pests and pathogens.

In addition to diverse immunological strategies, involving physical and epigenetic modification at the cellular level, crop plants employ external strategies that rely on recruitment of natural enemies to attack pests and pathogens, which should be considered within a holistic agroecological crop protection strategy. Sustainable management of pests and pathogens must embrace a culture of systems thinking because the health of plants, required to sufficiently produce food to meet growing demand, is intrinsically connected to the health of humans, animals and the environment. It is recommended that nature-based plant protection practices, to tackle pests and pathogens for sustainable plant production, are conducted in a holistic manner within the context of "One Health" for the benefit of humans, animals, plants and the environment.

References

Carvajal-Yepes, M., Cardwell, K., Nelson, A., Garrett, K.A., Saunders, D.G.O., Kamoun, S., Legg, J.P. *et al.* 2019. A global surveillance system for crop diseases – Global preparedness minimizes the risk to food supplies. *Science*, 364(6447): 1237–1239. https://doi.org/10.1126/science.aaw1572

Deguine, J-P., Aubertot, J-N., Flor, R.J., Lescourret, F., Wyckhuys, K.A.G. & Ratnadass, A. 2021. Integrated pest management: good intentions, hard realities. A review. *Agronomy for Sustainable Development*, 41: 38. https://doi.org/10.1007/s13593-021-00689-w

IPPC Secretariat. 2021. *Scientific review of the impact of climate change on plant pests – A global challenge to prevent and mitigate plant pest risks in agriculture, forestry and ecosystems*. Rome. FAO on behalf of the IPPC Secretariat. https://doi.org/10.4060/cb4769en

Niassy, S., Murithii, B., Omuse, E.R., Kimathi, E., Tonnang, H., Ndlela, S., Mohamed, S. & Ekesi, S. 2022. Insight on fruit fly IPM technology uptake and barriers to scaling in Africa. *Sustainability*, 14: 2954. https://doi.org/10.3390/su14052954

Savary, S., Willocquet, L., Pethybridge, S.J., Esker, P., McRoberts, N. & Nelson, A. 2019. The global burden of pathogens and pests on major food crops. *Nature Ecology & Evolution*, 3: 430–439. https://doi.org/10.1038/s41559-018-0793-y

1.9 Digital opportunities and appropriate agricultural mechanization

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Agricultural mechanization in Africa and Asia has received a lot of attention over the past decade as an essential agricultural input that can considerably contribute to sustainable regional or national development and to transforming and enhancing the lives and well-being of millions of rural families. The African Union Commission (AUC) has posited that agricultural mechanization needs to be developed along the value chain, and should be private-sector driven, environmentally compatible and climate-smart, affordable, friendly to small-scale farmers, and inclusive of the interests of women and young people (FAO and AUC, 2018). In this presentation, we started from a typical production cycle for crops where we looked at the operations that involve agricultural equipment and the level of power requirements.

Power requirements in crop production

If we look at power requirements in a crop-production cycle, then operations such as land preparation, transport, milling, grinding and threshing are power-intensive where 2- or 4-wheel tractors are used and replace animal traction. Fertilizer distribution, weeding and winnowing have a lower power need but are control-intensive to do the job correctly. The length of the land-preparation period is an important determinant of the capacity utilization of animal-drawn and tractor-drawn ploughs (Pingali, Bigot and Binswanger, 1987).

The period when mechanical tillage equipment can be used in the arid and semi-arid tropics is extremely short, since timeliness of ploughing is crucial to have adequate time for a crop to emerge before soil-moisture stress becomes a problem. Hence, equipment costs cannot be spread over a large area. Ploughing periods are longer in the subhumid and humid tropics, in areas where the rainfall regime is bimodal, and in high altitudes. Rental markets, collective ownership or service delivery enterprises are easier to establish and develop in these areas. Utilization of tractor capacity can be increased by providing contract-hire operations that span several rainfall zones, or by using these operations for transport.

Mechanized technologies, like tractors for ploughing, have given men the opportunity to increase the land area under cultivation, often with negative consequences for women. Increased land area also has resulted in an increase in weeding and harvesting operations, control-intensive jobs often performed by women. Moreover, weeding with short-handled hoes is most laborious and time-consuming (Ekeleme *et al.*, 2016). These control-intensive operations mostly do not need heavy equipment or large power sources. The operations can use new low-cost designs of sprayers for hand-held microdosing or battery-assisted mechanical weeding. This can lead to the establishment of new service centres of solar-powered charging stations for batteries. The technologies also have the potential to be developed as a service (by men and women) using batteries charged by solar energy, and can greatly reduce drudgery for woman who are the main workforce for these activities.

Precision agriculture as a management concept

The concept of precision agriculture is unjustly associated or linked with high-end technology that most small-scale farmers would likely view as alien (Mupambwa *et al.*, 2022). Precision agriculture seeks to promote site-specific recommendations, like variety selection and seeding density, and this can be applied to small fields. This also applies to fertilizer recommendations, where blanket fertilizer applications at the time of planting are still being used to date. Timely staggered fertilizer application in combination with weather expectations can greatly improve fertilizer efficiency if applied when it can best be utilized by the crop. Other timely operations like weed control, disease control, or irrigation and harvesting are activities within the precision agriculture concept. Observations and interpretations about the soil and the crop can be made by the farmer, an operator or an advisor, and followed up by action of the farmer.

Equipment for precision agriculture

Putting precision crop production management into practice can be very simple through manual actions. However, as stated earlier, the data about different soil crop characteristics should best be registered so that more complete information of a crop's needs is available for decision-making for a next treatment. This may mean that a farmer (man or woman) must walk the field several times during a growing season and note, on paper or smartphone, crop, soil or weed features at different locations in the field. Larger farms or a cooperation of smallholders can perhaps have simple, but more advanced tools or sensors installed in a backpack or on a low-power machine to electronically register these features. It is believed that more insight can come from the variation of the crop condition within a field as well as the changes over time.

All these data form the information base that together with expert knowledge leads to decisions towards treatments to be carried out. These treatments can be done manually or make use of relatively simple tools. Over time, these tools can evolve into more advanced or sophisticated equipment, but the cost-effectiveness must be considered. For example, a battery-operated self-propelled low-cost carriage is a basic transportation tool. It carries an amount of fertilizer to be manually applied at the specific locations indicated by signposts or by a map on a smartphone with GPS capabilities. More tools or features can be added. Crop production activities are then site-specific within the context of precision agriculture. Other external information sources can be coupled, such as weather forecast, and prices of fertilizer, grain or produce. In any case, this management concept aims at more efficiency in crop production by applying the treatment doses in a manner that the utilization rate is optimum, leading to more crop yield per gram of input. Farmers have also invested in precision irrigation methods such as drip and pivot systems to efficiently deliver water to crops, increasing yield and consequently improving food security. There are examples of successful precision agriculture applications in both the commercial and small-scale farming sector in Africa. While for commercial farmers, adoption of precision agriculture has been largely quick and welcome, there may be some challenges for small-scale farmers such as the limited local availability of components (Ncube, Mupangwa and French, 2018).

Workforce for digitalization of agriculture and mechanization

The transformation towards precision agriculture requires the development of equipment to be appropriate for implementing such concepts. The question arises how this can be achieved without the import of advanced machinery that is not suitable to operate in a predominantly small-scale farming context. Agricultural research and innovation centres should stimulate and support entrepreneurs for adaptation or retrofitting of existing equipment by installing digital tools for sensing and control, such that site-specific crop treatments can be easily carried out. We are confident that these entrepreneurs will have the creativity for novel designs of mechatronic agricultural tools adapted to local farms. For some (especially young people), it may be more challenging and rewarding to develop the information and communication technology or the mechatronic tools rather than being a small-scale farmer. The digitalization of agriculture practices in Africa is emerging from introducing new materials requiring specific skills to embark on everyday farming activities, where it is being reinvented by the linking of the three elements: digital tools and solutions, digital skills to access and utilize emerging technologies, and shifting meaning of farming in the digital age (Mohammed and Abdulai, 2022). At the same time, the digitalization of food production is a phenomenon along the entire commodity chain, and it seems to facilitate the stronger participation of tech companies in the agrifood system in general. Agrifood companies have started to extract value from the data they collect and to use digital technologies to lock in farmers into their own product ecosystems (e.g. through farm inputs or machinery), without facing effective government regulation regarding the protection of farmer data (Prause, Hackfort and Lindgren, 2021).

References

Ekeleme, F., Hauser, S., Atser, G., Dixon, A., Weller, S., Olorunmaiye, P., Usman, H., Olojede, A. & Chikoye, D. 2016. Weed management in cassava in Africa: Challenges and opportunities. *Outlooks on Pest Management*, 27(5): 208–212. https://doi.org/10.1564/V27_OCT_04

FAO & AUC. 2018. *Sustainable Agricultural Mechanization: A Framework for Africa*. Addis Ababa. www.fao.org/documents/card/en/c/CA1136EN

Mohammed, K. & Abdulai, A.-R. 2022. Toward digitalization futures in small-scale farming systems in Sub-Sahara Africa: A social practice proposal. *Frontiers in Sustainable Food Systems*, 6: 866331. https://doi.org/10.3389/fsufs.2022.866331

Mupambwa, H.A., Nciizah, A.D., Dube, E. & Fanadzo, M. 2022. Precision Agriculture Under Arid Environments: Prospects for African Smallholder Farmers. *Food Security for African Smallholder Farmers*, 113–127. https://doi.org/10.1007/978-981-16-6771-8_7

Ncube, B., Mupangwa, W. & French, A. 2018. Precision agriculture and food security in Africa. In: P. Mensah, D. Katerere, S. Hachigonta, A. Roodt, eds. *Systems Analysis Approach for Complex Global Challenges*, 159–178. Springer International Publishing. https://doi.org/10.1007/978-3-319-71486-8_9

Pingali, P., Bigot, Y. & Binswanger, H.P. 1987. Agricultural Mechanization and the Evolution of Farming Systems in Sub-Saharan Africa. *Economic Geography*, 64(4): 391–393. https://doi.org/10.2307/144242

Prause, L., Hackfort, S. & Lindgren, M. 2021. Digitalization and the third food regime. *Agriculture and Human Values*, 38(3): 641–655. https://doi.org/10.1007/s10460-020-10161-2

Chapter 2. Seed systems

Parallel session: Adapted varieties

2.1 Needs of Indigenous farmers in a changing world

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For peasants and Indigenous Peoples communities around the world, seed represent life. They are living organisms that deserve respect, love and care. They are at the basis of the food that feeds their own communities but also people in other communities. They embody a close connection to their natural environment, and they are fundamental to build the social fabric and sustain cultural expressions of their communities. Agricultural biodiversity – that is, the diversity of all living things above and below the ground and in the waters that are part of the productive ecosystem, and by extension the biodiversity of the ecosystems at large – is the result of the interaction of cultural and biological diversity, in all ecosystems and over thousands of years.

Peasant and Indigenous Peoples' seed systems, as well as their agricultural and agroecological management practices, are fundamental components of local food systems, which feed more than 70 percent of the world's population and contribute to improving human health and well-being while respecting and maintaining the natural environment. They are therefore a fundamental pillar of peoples' food sovereignty and the autonomy of peasants and Indigenous Peoples, as they ensure resilience in the face of climate change, conflicts and different types of shocks and crises.

No peasants' or Indigenous Peoples' seed exists without a community that preserves it, uses it, nurtures it and continues to develop it within its production system and culture and the ecosystem in which it lives. For this reason, seed has been recognized as a human right of peasants and Indigenous Peoples, which is intrinsically collective and holistic and closely related to other human rights, such as the right to food and nutrition, the right to health, the right to work and the right to culture and self-determination.

Despite their importance for food and nutrition security, the realization of human rights and the conservation of biodiversity and ecosystems, peasant and Indigenous Peoples' seed systems are increasingly marginalized and threatened. In the last century, industrial agriculture and the promotion through public policies of industrial and hybrid seeds of a limited number of high-yielding homogenous and uniform crops and varieties have led to the loss of about 75 percent of agricultural biodiversity. It is feared by the author that new technologies, such as gene editing and digital sequencing of genetic information, further increase corporations' monopolistic power over seeds and biodiversity, and can lead to extracting wealth from rural populations.

2.2 Breeding with farmers

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It is now widely accepted that farmers should not only be the central focus, but also be actively involved in plant breeding. The advantages of involving farmers are diverse: their perspectives are rooted in specific and different conditions and are potentially effective inputs to define breeding objectives; and as end users, farmers are the final proof of successfully bred varieties.

However, farmers should not be considered as mere end users of varieties developed in breeding programmes. Even when successful varieties are being developed, this approach would not be sustainable as it weakens or neglects the role of the farmer as an important partner in agricultural research. Therefore, a new paradigm of plant breeding *with* farmers, not only *for* farmers is needed.

Breeding with farmers is not limited to only genetics and technology aspects. Possible bottlenecks in the use of diversity and of superior varieties (for specific agroecological and socioeconomic conditions) can also be of socioeconomic and political nature. Participatory action research, incorporating sociological aspects must be utilized to consider the fact that focus is on farmers too, and not only on seed.

Active involvement of farmers in research has been pioneered by FAO with the farmer field school (FFS) approach, through which science in entomology and agronomy was not acquired by farmers in a top-down approach but discovered by farmers through their own research, increasing their capacity to observe and interpret phenomena in their fields. Farmers learned, typically in groups of 25, by acquiring experience and building confidence, and their schools transmuted into farmer study groups to sustain their learning and findings.

Similar progress has been achieved with plant breeding farmer field schools in Guatemala, Lao People's Democratic Republic, Nepal, Peru, Philippines, Viet Nam, Zambia, Zimbabwe and many more. In FFS, farmers' perspectives inform the breeding objectives, and varieties are developed or evaluated under different conditions by farmers themselves. Experiences so far show that FFS in plant breeding succeeds when plant breeding institutions provide support.

Partnerships between researchers and farmers are crucial to be able to face the difficult and complex challenges of agriculture today and in the future. The role of researchers to develop varieties is extremely important, but institutional plant breeding needs to give a more important role to farmers, recognizing them as co-creators of knowledge when codeveloping new varieties.

2.3 Responding to diversity of farmers' needs

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Inadequate seed supply and delivery systems, sometimes misaligned with user and market demand, often lead small-scale farmers to recycle seed or use seed from older varieties that are more vulnerable to pests and diseases. Small-scale farmers, especially women and other disadvantaged groups, are particularly vulnerable to climate-related challenges, such as more frequent and severe droughts and erratic rainfall. Additionally, farmers may not be well informed about varietal options available to them or may be reluctant to experiment with new varieties. These challenges threaten agricultural production and can compromise small-scale farmers' ability to meet their own food, nutrition and income needs.

Improved varieties, innovations and approaches developed and promoted by One CGIAR and its partners could transform agrifood systems and reduce yield gaps, "hunger months" and other disparities. However, limited access to and use of affordable, quality seed of well-adapted varieties with desired traits means bottlenecks remain.

Understanding why varieties are adopted (or not) by farmers ensures that breeding programmes can meet the needs of end users. To do this, One CGIAR is incorporating the Seed Equal initiative, which includes forward-looking analyses of market opportunities and the feasibility of producing and scaling crop varieties in given contexts, as well as understanding what influences farmer adoption.

The data produced aim to shorten adoption lag times and increase adoption levels as new varieties are better suited to satisfy specific market segments. This leads to more complete and more accelerated varietal turnover. This work requires the insights and expertise of people from a wide range of disciplines and backgrounds who are willing to cross the boundaries of their expertise, including gender, marketing, economics, geospatial science, nutrition and food technology, and requires the presence of representatives from national breeding programmes. This transdisciplinary perspective helps ensure that innovations are equitable and impactful, and meet the needs and priorities of disadvantaged groups.

In parallel and informed by market intelligence, the Seed Equal initiative aims to support, through partnerships, the delivery of seed of improved, climate-resilient, market-preferred and nutritious varieties of priority crops. The development of inclusive seed systems will include increased on-farm testing and promotion of candidate varieties with farmers to identify those varieties that truly match the product profile and hence farmers' needs.

Research for development by the One CGIAR Action Area on Genetic Innovation, in collaboration with its many partners and the One CGIAR Market Intelligence and Seed Equal Initiatives, will purposefully ensure that the benefits of plant breeding are shared equitably among small-scale farmers and respond to their current and future needs.

2.4 Research progress on super-hybrid rice in China

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Hybrid rice originated in Hunan Province, China, where the first three-line hybrid rice was successfully used in 1973. The promotion of hybrid rice is one of the most effective ways to increase rice grain yield per unit area and to contribute significantly to food security. By 2021, the annual planting area of hybrid rice in China had exceeded 13.33 million hectares and accounted for about 57 percent of the total rice production yield.

More than 60 countries and regions in the world have planted or carried out research on hybrid rice. Annually, more than 8 million hectares are planted with hybrid rice outside of China, and the area continues to increase rapidly. FAO expects hybrid rice to play a major role in contributing to sustainable food security in low- and middle-income countries.

In 1996, China launched a super-rice research programme. The China National Hybrid Rice Research and Development Center (CNHRRDC) is committed to tapping into the high-yield potential of hybrid rice and super-hybrid rice, which achieved yield returns of 10.5 t/ha to 15 t/ha. In 2018 and 2022, super-hybrid rice achieved the highest recorded returns of 17.3 t/ha and 18.17 t/ha respectively in small-scale trials.

Looking to the future, the CNHRRDC will continue to breed high-yield, high-quality hybrid rice and develop highly efficient cultivation technologies to promote the sustainable development of hybrid rice.

References

FAO. 2014. *A regional strategy for sustainable hybrid rice development in Asia*. FAO, Bangkok.

Wu, J., Deng, Q.Y., Yuan, D.Y. & Qi, S.W. 2016. Progress of super hybrid rice research in China. *Chinese Science Bulletin*, 61: 3787–3796 (in Chinese). https://doi.org/10.1360/N972016-01013

Xie, F.M. & Peng, S.B. 2016. History and prospects of hybrid rice development outside of China. *Chinese Science Bulletin*, 61: 3858–3868 (in Chinese). https://doi.org/10.1360/N972016-01018

Yang, Y. & Hu, J. 2018. *International practices on development and extension of hybrid rice*. Beijing, China Agriculture Press (in Chinese).

Yuan, L.P. & Cheng, H.X. 2020. *Super hybrid rice: breeding and cultivation*. Changsha, China, Hunan Science & Technology Press (in Chinese).

2.5 Gene bank contributions to seed systems

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Plant genetic resources are the building blocks of agriculture, as researchers and farmers develop plant varieties that are more nutritious and better adapted to the abiotic and biotic stresses of specific environmental conditions.

Sustainable Development Goal 2 (SDG 2), Target 2.5, explicitly calls for the maintenance of the genetic diversity of seeds, cultivated plants and related wild relatives, and the management of gene banks at national, regional and international levels.

Gene banks across the world conserve an estimated 7 million samples of plant genetic resources in the form of seed, trees, tubers, *in vitro* explants and cryopreserved tissue. The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) has set the terms to conserve and sustainably use plant genetic resources for food and agriculture, and to share the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security.

In 2021, despite the limitations imposed by the ongoing COVID-19 pandemic, international gene banks distributed 96 590 samples of plant genetic resources to 91 countries. Of the requesters, 51 percent were universities or research institutes, followed by national agriculture research systems (34 percent). Lower-middle income countries were the largest recipients of the shipments (72 percent), with India, Morocco and Viet Nam being the three top recipients of germplasm. Of the materials distributed, 65 percent were landraces. The main destination of the material requested was reportedly for research (50 percent), direct use (15 percent), evaluation (14 percent) and plant improvement (12 percent) (Global Crop Diversity Trust, 2021).

In 2020, scientists found that rice samples from the International Rice Gene bank (Los Baños, Philippines) contributed to 45 percent of the genetic composition of an improved rice variety developed to raise productivity on farms in eastern India (Villanueva *et al.*, 2020).

In the early 2000s, scientists screened the international plant collections of cassava, beans, maize, sweet potato, wheat and rice on key micronutrient content such as vitamin A, iron and zinc (Gregorio, 2002). Promising samples were used in conventional plant improvement programmes to develop nutrient-enriched varieties for communities with diets with poor essential micronutrient content. Today, more than 400 nutrient-enriched varieties of 11 biofortified crops have been released for consumption in 30 countries (Harvest Plus, 2022).

In the early 2000s, farmers and scientists in Burkina Faso partnered to search for new varietal options of sorghum adapted to the changing environmental conditions of their locality. The four cultivars most often selected by farmers corresponded to landraces that originated from gene banks. Farmer selection criteria comprised adaptation to agroclimatic conditions and specific grain qualities for processing and consumption (vom Brocke *et al.*, 2013).

In 1995, after the Rwandan Civil War, 165 bean landraces from Rwanda, conserved in gene banks, were reintroduced as part of the efforts to support agricultural production in the country and prevent genetic erosion (Scowcroft, 1996).

These are only a handful of examples of the contribution of gene banks to seed systems and the development of new and better varieties. Gene banks provide a unique service to agriculture. Supporting them ensures the availability of plant genetic diversity for current challenges and future generations.

References

Global Crop Diversity Trust. 2021. *2021 Annual report: CGIAR Genebank Platform*. 22 pp. www.genebanks.org/wp-content/uploads/2022/06/2021-Genebank-Platform-Annual-Report_21June2022.pdf

Gregorio, G.B. 2002. Progress in breeding for trace minerals in staple crops. *The Journal of Nutrition*, 132(3): 500S–502S. https://doi.org/10.1093/jn/132.3.500S

Harvest Plus. 2022. Biofortified crops. In: *HarvestPlus*. Washington DC. Cited 14 March 2023. https://bcr.harvestplus.org/about/howToDevelop

Scowcroft, W.R. 1996. Seeds of hope: An emergency program to assist restoration of crop production and rehabilitation of food security in Rwanda after the civil war. *CIAT reports*. Cali, Colombia, CIAT. https://hdl.handle.net/10568/71655

Villanueva, D., Smale, M., Jamora, N., Capilit, G.L. & Hamilton, R.S. 2020. The contribution of the International Rice Genebank to varietal improvement and crop productivity in Eastern India. *Food Security*, 12(5): 929–943. https://doi.org/10.1007/s12571-020-01036-9

vom Brocke, K., Trouche, G., Weltzien, E., Kondombo-Barro, C.P., Sidibé, A., Zougmoré, R., & Gozé, E. 2013. Helping farmers adapt to climate and cropping system change through increased access to sorghum genetic resources adapted to prevalent sorghum cropping systems in Burkina Faso. *Experimental Agriculture*, 50(2): 284–305. https://doi.org/10.1017/s0014479713000616

Parallel session: Quality seeds

2.6 Community knowledge and technological innovations

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Community knowledge evolved through a complex farming system approach as it manifested into Indigenous knowledge systems to improve farm productivity and agricultural research. Indigenous knowledge is not documented formally but preserved through secrets or public domain – no literature is produced or shared.

The role of traditional knowledge and ecosystems has tended to be under-represented in adaptation responses and economic evaluation of adaptation (World Bank, 2010). In addition, the linkages between traditional knowledge and genetic resources or ecosystems are not always adequately recognized, e.g. there has been limited attention to traditional knowledge in some work related to ecosystem-based adaptation (Campbell *et al.*, 2009).

In this regard, farmers domesticated, improved and conserved thousands of crop species and varieties, using their traditional knowledge. The diversity of traditional varieties sustained by farmers around the world is increasingly valuable for adaptation as climate changes, particularly as modern agriculture relies on a very limited number of crops and varieties (Mutta *et al.*, 2011).

The success of community knowledge and innovations therefore depends on information transfer channels, farmer-to-farmer extension and informal networks. This leads to community-led processes of research, agriculture development and natural resource management. Research and development are driven and comanaged by communities. Public and private sector research institutions need to partner with communities to tap into Indigenous knowledge and conduct on-farm trials where communities set the research agenda.

Community knowledge and innovations thrive on:

- inclusiveness and participatory consultative processes;
- support of farmer experimentation and capacity building;
- promotion of participatory technology and innovation development;
- interconnectedness;
- building healthfulness of community;
- prioritizing diversity of ideas/practices, values agricultural, ecological and cultural heritage;
- enhancing social justice and equity; and
- building resilience.

Community knowledge and innovations opportunities are:

- adopting crops/technologies appropriate to their needs, ecology and holistic understanding of communities;
- translating issues, problems, policies and research findings to the farm level;
- achieving greater food and nutrition security through higher and more sustainable yields, crop diversification and food preservation;
- accessing more agrobiodiversity that contributes to greater resilience to environmental risks, pest and disease management;

- adapting various types of locally appropriate innovations at community level and scaling up; and
- facilitating sharing of data and learning experiences as opposed to competition, which tends to generate a culture of knowledge-hoarding and competition.

Breeding and selection of sorghum and millet varieties based on bird-damage-resistant traits

Some farmer-managed varieties are very stable, distinct and uniform, and could be registered as pure distinct varieties. These materials have survived seasonal gene interactions naturally and rarely outcross. These varieties have sociocultural relevance to society and hence they continue to be cultivated in small portions for their conservation. Environmental adaptations to resist predation by birds include goose necking, spikes/awns, complete glume cover, hissing panicles, high levels of tannins and compact heads.

Performance of farmer varieties during on-farm trials

Most sorghum and millet varieties outperformed improved varieties in terms of yield and organoleptic preferences. Yields were higher especially in drought years, as well as rainy years. No major diseases were observed during on-farm trials and excellent bird-resistance was displayed, making the varieties ideal for production by elderly households, as the need for bird scaring was limited.

References

Campbell, A., Kapos, V., Scharlemann, J.P.W., Bubb, P., Chenery, A., Coad, L., Dickson, B., Doswald, N., Khan, M.S.I., Kershaw, F. & Rashid, M. 2009. Review of the literature on the links between biodiversity and climate change: Impacts, adaptation and mitigation. *CBD Technical Series No. 42*. Montreal, Canada, Secretariat of the Convention on Biological Diversity (CBD). www.cbd.int/doc/publications/cbd-ts-42-en.pdf

Huq, N., Renaud, F. & Sebesvari, Z. 2013. Ecosystem based adaptation (EbA) to climate change – integrating actions to sustainable adaptation. Impacts World 2013 Conference Proceedings. Potsdam, Germany.

Mutta, D., Paul Ongugo, P., Swiderska, K., Reid, H., Song, Y., Li, J., Pakia, M., Oros, R. & Barriga, S. 2011. The role of traditional knowledge and crop varieties in adaptation to climate change and food security in SW China, Bolivian Andes and coastal Kenya. UNU-IAS workshop on Indigenous Peoples, Marginalised Populations and Climate Change: Vulnerability, Adaptation and Traditional Knowledge, July 2011. Mexico City.

Mofokeng, M.A. & Shargie, N.G. 2016. Bird damage and control strategies in grain sorghum production. *International Journal of Agricultural and Environmental Research*, 2: 320–325.

World Bank/International Bank for Reconstruction and Development. 2010. *Economics of Adaptation to Climate Change: Synthesis Report*. Washington DC, World Bank. 101 pp. http://hdl.handle.net/10986/12750

2.7 Emergency seed assistance: updates on what to do and what not to do

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Emergency seed assistance aims to give farmers in distress the means to produce their own crops for food or sale. In theory, it is a sustainable form of emergency aid (needed only one-off), should limit food aid and is cost-effective (e.g. 1 kg of sorghum seed can yield 100 kg of food). In practice, the use of emergency seed aid has escalated over decades. For instance, FAO supported 186 emergency seed aid projects in 2020 alone, and the United States Agency for International Development (USAID) humanitarian assistance financed 121 seed-aid projects totalling USD 234.7 million in 2021. Current levels are not only high, but seed aid has also become repetitive. As examples, Burundi has implemented seed aid for over 35 seasons since 1995, and Ethiopia for over 40 years since 1974. Practices need to be improved.

The types of seed-aid assistance have been expanding from the dominant direct seed distribution responses to market-based approaches supporting demand (stressed farmers) or supply (formal or informal markets). Technical aid guidance has also sharpened, particularly over the past two years. A Seed Emergency Response Toolkit (SERT) (Sperling *et al.*, 2022) synthesizes decades of lessons learned and complements guidance from, for example, FAO (2010).

The ***Ten guiding principles of good seed aid practice*** form the core of SERT. They cover assessment, response type, goal of intervention, context, timeliness, market-based assistance, crop and variety choice, seed quality, farmer choice, and feedback – with gender issues embedded in all. The guidance is built around themes of "what to do" and "what not to do".

In terms of positive practice, several principles focus on crop, variety and seed-quality issues. Crops and varieties should be tailored according to the specific goal: food security, nutrition, resilience or income-generation. Crops and varieties should also be linked to context and direct user needs (accounting for preferences and realistic management conditions). Seed-quality standards should be shaped by communities as well as humanitarian practitioners and donors. Also, describing the processes for selecting and maintaining quality are as important as a label itself. Ultimately, farmers should always be given the choice to strategize and shape assistance to meet immediate household needs as well as to support an overall cropping strategy.

In terms of halting negative practice, special warnings and advice are given around introducing modern varieties in periods of crisis. Risky introductions can make stressed farmers even more vulnerable. Also, ***stop-action checks*** are recommended at concrete intervals, such as if no assessment is provided, if seed will arrive too late in the planting season, and if seed aid is repeated for three seasons in a row in the same area.

To further improve the quality of emergency seed assistance, immediate policy actions are required from humanitarian governance bodies (within the United Nations and the wider global donor community). As a start, the ***Ten guiding principles of good seed aid practice*** should be officially endorsed – to give a leap towards better implementation. Also, ***stop-action checks*** should become a norm guiding seed aid implementation. Stop bad practice before it does harm.

Finally, looking to critical gaps, a ***Conference on Emergency Agricultural Aid in Conflict Areas*** is proposed.

References

FAO. 2010. Seeds in Emergencies: a technical handbook. *FAO plant production and protection paper* 202. Rome. www.fao.org/3/i1816e/i1816e00.pdf

Mcguire, S. & Sperling, L. 2016. Seed systems smallholder farmers use. *Food Security*, 8: 179–195. https://doi.org/10.1007/s12571-015-0528-8

Sperling, L. 2020. Seed security response during COVID-19: building on evidence and orienting to the future (L. Sperling). *Food Security*, 12: 885–889. https://doi.org/10.1007/s12571-020-01068-1

Sperling, L., Cooper, H.D. & Remington, T. 2008. Moving toward more effective seed aid. *Journal of Development Studies*, 44(4): 586–612. https://doi.org/10.1080/00220380801980954

Sperling, L., Holmquist, C.T., Ouko, W., Mottram, A. & Love, A. 2022. *Seed systems in conflict-affected areas: Context Analysis Tool. Version 1.* Produced by Mercy Corps and SeedSystem as part of the ISSD Africa activity. https://issdafrica.org/wp-content/uploads/2022/07/CAT_Final_English.pdf

Sperling, L., Mottram, A., Ouko, W. & Love, A. 2022. *Seed Emergency Response Tool: Guidance for Practitioners*. Produced by Mercy Corps and SeedSystem as a part of the ISSD Africa activity. https://reliefweb.int/report/world/seed-emergency-response-tool-guidance-practitioners-june-2022

2.8 Perspectives on the sustainability of seed business and African small-scale seed supply

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Well-functioning seed systems have the potential to deliver multiple benefits to small-scale African farmers: enhanced food security and income, better nutrition, and resilience to climate stress (Sperling *et al.*, 2020). This necessitates seed systems to offer access to a wide range of farmer-preferred and locally adapted crops and varieties, with seed of acceptable quality. In sub-Saharan Africa, quality and improved seed is generally supplied by public and private seed enterprises, concentrating on a few cereal crops, particularly hybrid maize. Yet, the market share for improved maize remains about 10 percent. For all other crops, including some that are a priority for food security and nutrition such as grain legumes, vegetables, millets, cassava and sweet potatoes, the market share is considerably lower. This leaves farmers with no option but to resort to informal sources. Seed business models that operate on the basis of highly integrated and inclusive partnerships with key value chain actors are argued to address this gap (Louwaars and de Boef, 2012).

This presentation provides perspectives on the sustainability of seed business models, drawing closer attention to small-scale seed businesses and their ability to deliver benefits to seed producers and the wider community. It uses evidence from action research conducted by the CABI-led Good Seed Initiative (GSI) in Uganda and the United Republic of Tanzania (2013–2016) and an impact assessment in 2019 (Kansiime *et al.*, 2021). The GSI aimed to enhance access to quality seed of African indigenous vegetables using two models: contract farming and quality declared seed (QDS).

Results showed that both models are viable for enhancing access to quality seed and creating avenues for income diversification and contributing over 50 percent to small-scale farmers' household incomes. Contract farming created consistent and lucrative market opportunities for farmers to boost incomes and enable subsequent investments in productivity-enhancing inputs and resilience-building assets. The long-term nature of the partnership encourages the seed company to invest in providing access to early-generation seed and ongoing extension support to farmer seed producers. QDS, on the other hand, proved a viable strategy for providing quality seed to farmers, especially in areas that do not have a strong formal seed sector (e.g. central United Republic of Tanzania). However, the sustainability of seed businesses employing the QDS model is doubtful due to lack of effective linkages to technical services, e.g. breeders, extension, inspections and seed testing, which are key for quality seed production. Also, working capital financing for seed business activities was a pressing bottleneck for QDS growers, unlike contract farmers who accessed financing from contracting seed companies.

Results reveal unequivocally that farmer seed production offers a potentially sustainable solution to the problem of seed supply while providing income benefits for seed producers. Farmer seed systems were particularly important in conserving and multiplying seed of landraces and neglected varieties. The market-based approach of the farmer seed businesses and partnerships with the formal sector are strong contributory factors to the survival of farmer seed production. QDS is particularly useful in delivering quality seed in areas less served by the formal sector, and deserves support from government-mandated agencies to develop a tailored and appropriate seed system that meets the ever-evolving needs of small-scale farmers.

References

Kansiime, M.K., Bundi, M., Nicodemus, J., Ochieng, J., Marandu, D., Njau, S.S., Kessy, R.F., Williams, F., Karanja, D., Tambo, J.A. & Romney, D. 2021. Assessing sustainability factors of farmer seed production: A case of the Good Seed Initiative project in Tanzania. *Agriculture & Food Security*, 10(1): 15. https://doi.org/10.1186/s40066-021-00289-7

Louwaars, N.P. & de Boef, W.S. 2012. Integrated Seed Sector Development in Africa: A Conceptual Framework for Creating Coherence Between Practices, Programs, and Policies. *Journal of Crop Improvement*, 26(1): 39–59. https://doi.org/10.1080/15427528.2011.611277

Sperling, L., Gallagher, P., McGuire, S., March, J. & Templer, N. 2020. Informal Seed Traders: The Backbone of Seed Business and African Smallholder Seed Supply. *Sustainability*, 12(17). https://doi.org/10.3390/su12177074

2.9 Seed technology to upgrade crop sustainably

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Starting a crop season with healthy and protected seed is starting right. Genetics is one of the most defining factors influencing the quality of seed, but there are other seed-applied technologies that complement and help get the most out of seed (Incotec, 2022).

Seed priming, for example, can be a technology that triggers the physiological processes in seed that lead to germination, by imbibing the seed to a certain level and drying it (Bruggink, 2022). The different priming techniques help to increase speed of emergence, improve uniformity and overcome seed dormancies, thereby optimizing crop production (Incotec, 2022).

Physical coatings added to seed as pellets and encrusting also play multiple roles to the benefit of seed, such as aiding the use of sowing machines and improving plantability, and allowing the smart application of actives and additives. The subsequent addition of powder and liquid components to seed offers additional opportunity for more complex seed treatment, allowing incorporation and protection of microbials, for instance. It also enables the use of high-volume slurries and can protect the seed against countereffects of chemicals since different materials can be applied in different layers (Karam *et al.*, 2007; Kunkur *et al.*, 2007; Avelar *et al.*, 2009; Avelar *et al.*, 2010).

Seed treatment with plant-protectant materials can present a more sustainable option for agriculture because pesticide use can be reduced by 95 percent. Sustainable pest control is important to reduce crop losses.

Applying antimicrobial, fungicidal and insecticidal compounds directly to seed reduces the amount of compounds needed to provide adequate protection. This means fewer potentially harmful materials are being introduced into the environment and exposed to workers. Seed coating also helps move towards more efficient farming practices that further contribute to sustainable plant production (Kunkur *et al.*, 2007; Avelar *et al.*, 2009; Avelar *et al.*, 2010; Croda International, 2022).

Adequate seed treatment should involve: (1) coloured seed to identify that seed have received a treatment – it is common that seed with good cosmetics are associated with high quality treatment; (2) seed containing the plant-protection products in the proper dosage/rate; (3) optimized sowing processes – the planting operation should provide the proper stand, uniformity and yield to avoid skips and doubles; (4) limited/no exposure of potentially harmful compounds to workers and the environment; (5) maintenance of seed physiological quality – the treatment should not negatively affect the germination (Incotec, 2022; Croda International, 2022)

Advances in research of seed-applied technologies provide options to go beyond merely protecting seed against pests with regular chemical pesticides. New solutions for incorporating microorganisms as biopesticides or biofertilizers, incorporating biostimulants and nutrients, and solutions to mitigate abiotic stress from drought, salinity, heat, cold, etc. are examples of more recent innovations to upgrade plant production sustainably (Croda International, 2022).

References

Avelar, S.A.G., Baudet, L. & Villela, F.A. 2009. The improvement of the seed treatment process. *Seed News*, 8(5): 8–11.

Avelar, S.A.G., Sousa, F.V., Fiss, G., Baudet, L. & Peske, S.T. 2012. The use of film coating on the performance of treated corn seed. *Revista Brasileira de Sementes*, 34(2): 186-192. http://doi.org/10.1590/S0101-31222012000200001

Bruggink, H. 2022. Advances in seed priming techniques. In: J. Buitink & O. Leprince, eds. *Advances in seed science and technology for more sustainable crop production*. Cambridge, UK, Burleigh Dodds Science Publishing Limited.

Croda International plc. 2022. Seed Treatment. In: *Croda Crop Care*. Cited 14 March 2023. https://www.crodacropcare.com/en-gb/market-areas/seed-treatment

Incotec. 2022. What is seed technology? In: *Incotec*. Enkhuizen, Kingdom of the Netherlands. Cited 14 March 2023. https://www.incotec.com/en-gb/seed-technologies

Karam, D., Magalhães, P.C. & Padilha, L. 2007. Efeito da adição de polímeros na viabilidade, no vigor e na longevidade de sementes de milho [Effect of addition of polymer on viability, vigour and longevity of maize seeds]. Sete Lagoas, Brazil, Embrapa Milho e Sorgo. 6 pp. https://ainfo.cnptia.embrapa.br/digital/bitstream/CNPMS/20486/1/Circ_94.pdf

Kunkur, V., Hunje, R., Patil, N.K.B. & Vyakarnhal, B.S. 2007. Effect of seed coating with polymer, fungicide and insecticide on seed quality in cotton during storage. *Karnataka Journal of Agricultural Sciences*, 20(1): 137-139. http://doi.org/10.23910/IJBSM/2017.8.2.1716a

2.10 International seed trade – an essential component of resilient seed systems

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Quality seed cannot be produced everywhere, nor can countries produce all the seed they need themselves. For instance, cabbage seed is produced in cooler areas, but the crop itself can also be grown in the tropics. Seed of forage crops is produced in Oregon, United States of America, and in Denmark, and transported to where it is in demand. The international movement of seed is a logical consequence of the adaptation of crops to specific agroecological environments.

Additionally, crop breeding cannot be done for all crops in all countries. To facilitate breeding, allowances for breeding materials to cross borders, and to move from research centres to national breeders and seed producers are required. International exchanges of seed make it possible to support farmers with a wider choice of crops, which is important to adapt to changing conditions (e.g. climate, demography). The international movement of seed also allows us to deal with local shortages, often by importing from neighbouring countries.

As movement of seed is often strictly regulated, specific measures need to be taken to lift constraints. Some measures seem obvious. One example is to avoid undue variety registration requirements, by taking over official variety descriptions from other countries and to avoid or minimize value for cultivation and use testing where it has limited value for farmers (e.g. for growing vegetables). Seed certification and seed testing requirements can be facilitated by regional and international cooperation to remove significant hurdles, for instance in certification procedures, including Seed Schemes established by the Organisation for Economic Co-operation and Development (OECD) and seed testing procedures from the International Seed Testing Association (ISTA) and the International Seed Health Initiative (ISHI).

Phytosanitary controls remain a requirement, and clear rules need to be adopted to avoid introduction of (new) pests and seed-transmitted diseases. Phytosanitary checks can, however, obstruct the movement of seed (both bulk and research samples), and can affect farmers and food security. Reducing the administrative burden regarding import permits, export bans or quotas on seed, and reducing administrative costs and complexities can empower farmers and small seed companies. Increasing confidence among parties regarding safe international action is necessary.

For instance, the International Union for the Protection of New Varieties of Plants (UPOV) provides and promotes an effective system of plant variety protection, with the aim of encouraging the development of new varieties of plants, for the benefit of society. The International Seed Federation (ISF) promotes joint trade rules and arbitration, amongst other activities. Regional and bilateral trade agreements can support many of the required measures, but their implementation needs to be effective and efficient, requiring personnel at border offices to know about specific aspects of seed import and export.

In conclusion, the international movement of seed provides choice for farmers, fills gaps where national capacities encounter limits (environmental or otherwise), provides resilience in seed supplies and, as such, promotes sustainable plant production.

Chapter 3. Field cropping systems

Parallel session: Efficient cropping systems

3.1 Transitioning to sustainable and resilient smallholder farming in sub-Saharan Africa – Taking farmer perspectives into account

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African agriculture is at the forefront of current sustainability challenges, as the human population is growing at alarming rates, poverty and food insecurity are rising, and small-scale farmers are particularly vulnerable to climate change. Yield increases of major crops have not kept pace with increasing demands, which have primarily been met through land expansion and imports. To avoid further surpassing of planetary boundaries, African agriculture needs to produce more with less so that land expansion is restricted, and further environmental damage and biodiversity loss can be avoided. To achieve this and to build resilience against shocks and disturbances, sustainable intensification is key, through enhancing land-, nutrient- and labour-use efficiency.

To reach cereal self-sufficiency on the current cropland area in Africa by 2050, yield gaps will have to be closed through a combination of strategies, including (1) the use of adapted, high-performing cultivars and high-quality seed, (2) integrated soil-fertility management with increased application of mineral fertilizers in combination with organic amendments, (3) integrated pest management, and (4) a range of good agronomic practices such as crop rotations and timely operations. Nutrient application rates will have to rise drastically from current low rates, and this needs to be combined with improvements in agronomic efficiency (ten Berge *et al.*, 2019). As such, this approach can help reduce environmental pressure in terms of cropland expansion and greenhouse gas emissions, compared to a scenario in which increased demands would be met from larger cultivated areas (van Loon *et al.*, 2019).

However, the transition to sustainably intensified cropping systems is challenged by a range of intertwined barriers and constraints, which are better understood by taking a farmer's perspective. First, at farm and household level, closing yield gaps does not lead to significant improvements in food self-sufficiency and income for the large majority of small-scale farmers, who depend on less than 1 ha to 2 ha of land. Second, due to unfavourable cost–price ratios of fertilizers and crop products (grains), fertilizer profitability is very low. A third problem is posed by the risks associated with farming, farmers' risk-aversion attitudes and the limited number of risk-coping mechanisms at their disposal (Huet *et al.*, 2020). Combined, these factors are important disincentives for small-scale farmers to invest in sustainable intensification practices.

Strategies to address these bottlenecks can be categorized according to whether they address the financial, human or land capital of farmers. With respect to financial capital, investments of small-scale farmers in inputs can be effectively supported through subsidies as shown in a study where input vouchers led to an immediate doubling of maize yields (Marinus *et al.*, 2021). Human capital can be built through engaging farmers in colearning activities, which are conducive for more complex changes in farming practices, such as cropping system diversification (Marinus *et al.*, 2021). Labour bottlenecks are typically important determinants of yield gaps and can be mitigated through mechanization solutions that improve labour productivity. Given the enormous constraints posed by land fragmentation, building land capital is crucial, but difficult as land expansion is not desired. Hence, besides intensification on current cropland, land reforms and the creation of off-farm employment opportunities are essential. Finally, as small-scale farming systems are heterogeneous, solutions for transitioning towards more efficient and sustainable cropping systems need to be tailored to the farm context and the farmer's aspirations and interests (Descheemaeker *et al.*, 2019). A powerful way to achieve this is based on farmer segmentation and relies on on-farm testing of options in iterative research cycles enabling the codesign of innovative systems.

References

Descheemaeker, K., Ronner, E., Ollenburger, M., Franke, A.C., Klapwijk, C.J., Falconnier, G.N., Wichern, J. & Giller, K.E. 2019. Which options fit best? Operationalizing the socio-ecological niche concept. *Experimental Agriculture*, 55(S1): 169–190. http://doi.org/10.1017/S001447971600048X

Huet, E.K., Adam, M., Giller, K.E. & Descheemaeker, K. 2020. Diversity in perception and management of farming risks in southern Mali. *Agricultural Systems*, 184: 102905. https://doi.org/10.1016/j.agsy.2020.102905

Marinus, W., Descheemaeker, K., van de Ven, G.W.J., Waswa, W., Mukalama, J., Vanlauwe, B. & Giller, K.E. 2021. "That is my farm" – An integrated co-learning approach for whole-farm sustainable intensification in smallholder farming. *Agricultural Systems*, 188: 103041. https://doi.org/10.1016/j.agsy.2020.103041

ten Berge, H.F.M., Hijbeek, R., van Loon, M.P., Rurinda, J., Tesfaye, K., Zingore, S., Craufurd, P. *et al.* 2019. Maize crop nutrient input requirements for food security in sub-Saharan Africa. *Global Food Security*, 23: 9–21. https://doi.org/10.1016/j.gfs.2019.02.001

van Loon, M.P., Hijbeek, R., ten Berge, H.F.M., De Sy, V., ten Broeke, G.A., Dawit Solomon, D. & van Ittersum M., K. 2019 Impacts of intensifying or expanding cereal cropping in sub-Saharan Africa on greenhouse gas emissions and food security. *Global Change Biology*, 25: 3720–3730. https://doi.org/10.1111/gcb.14783

3.2 Research and development of mechanized rice ratooning technology in China

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Rice ratooning, a practice to harvest a second crop from the stubble of the main crop, is an ancient technology with limited adoption in the past due to low and unstable grain yields in the ratoon crop. Manual harvesting of the main crop also limited the dissemination of this technology due to labour needs.

Over the past ten years, Huazhong Agricultural University, in collaboration with researchers and extension workers in Hubei Province, developed mechanized rice ratooning techniques, which involve mechanical harvesting of the main crop. High grain yield could be achieved in the ratoon season without sacrificing grain yield of the main season if proper cultivars and management practices were used.

Key practices for achieving high grain yield in mechanized rice ratooning systems include (1) using rice cultivars with high ratooning ability such as hybrid rice, especially two-line hybrid rice, and with suitable growth duration (Chen *et al.*, 2018), (2) optimizing the planting date of the main crop by emphasizing early planting so that there is sufficient thermal energy for the ratoon crop (Wang, Y. *et al.*, 2020), (3) achieving proper soil moisture content at the harvest of the main crop by heavy soil drying at mid-tillering and two weeks after heading during the main season in order to minimize crushing damage on the stubble by the harvesting machine (Zheng *et al.*, 2022), (4) applying bud-promoting nitrogen fertilizer two weeks before the harvest of the main crop and tiller-promoting nitrogen fertilizer within three days after the harvest of the main crop (Wang, Y. *et al.*, 2019), and (5) adjusting straw-cutting height during the harvest of the main crop to avoid cold damage during the panicle development and flowering of the ratoon crop (i.e. high stubble height for the late harvest of the main crop) (Yu *et al.*, 2022). With these key practices, grain yield of ratoon rice has increased significantly, and farmers could produce as much as 9–10 t/ha in the main season and 5–6 t/ha in the ratoon season.

Consequently, the planting area of mechanized ratoon rice has expanded rapidly in China. For example, the area of mechanized ratoon rice has increased by about seven times from 2013 to 2020 in Hubei Province. Now, this technology has been extended to other provinces in central China such as Hunan, Jiangxi, Anhui and southern Henan. Rapid development of mechanized rice ratooning technology in China strongly suggests that this technology is one of the most effective approaches in increasing total rice production with reduced labour requirement and reduced agronomic inputs. There are still several challenges for further scaling up of this technology, such as poor milling and eating quality of the main crop, poor milling quality of the ratoon crop, and lack of resistance to diseases, insects and lodging in most cultivars currently used in ratoon rice production. Because almost all rice cultivars currently used for ratoon rice production were selected from existing cultivars, breeding that is targeted to a mechanized rice ratooning system offers opportunities for further improvement in both grain yield and quality. For the future, it is projected mechanized rice ratooning technology will be extended to landlocked Central Asian countries (via the Belt and Road Initiative).

References

Chen, Q., He, A., Wang, W., Peng, S., Huang, J., Cui, K. & Nie, L. 2018. Comparisons of regeneration rate and yields performance between inbred and hybrid rice cultivars in a direct seeding rice-ratoon rice system in central China. *Field Crops Research*, 223: 164–170. https://doi.org/10.1016/j.fcr.2018.04.010

Wang, W., He, A., Jiang, G., Sun, H., Jiang, M., Man, J., Ling, X., Cui, K., Huang, J., Peng, S. & Nie, L. 2020. Ratoon rice technology: A green and resource-efficient way for rice production. *Advances in Agronomy*, 159: 135–167. https://doi.org/10.1016/bs.agron.2019.07.006

Wang, Y., Zheng, C., Xiao, S., Sun, Y., Huang, J. & Peng, S. 2019. Agronomic responses of ratoon rice to nitrogen management in central China. *Field Crops Research*, 241: 107569. https://doi.org/10.1016/j.fcr.2019.107569

Yu, X., Guo, Y., Yang, G., Zhang, Z., Liang, Y., Zheng, C., Xu, L., Yuan, S., Wang, F., Huang, J. & Peng, S. 2022. Nitrogen response of regenerated tillers varied among node positions in ratoon rice. *Field Crops Research*, 289: 108717. https://doi.org/10.1016/j.fcr.2022.108717

Zheng, C., Wang, Y., Yuan, S., Xiao, S., Sun, Y., Huang, J. & Peng, S. 2022. Heavy soil drying during mid-to-late grain filling stage of the main crop to reduce yield loss of the ratoon crop in a mechanized rice ratooning system. *The Crop Journal*, 10: 280–285. https://doi.org/10.1016/j.cj.2021.06.003

3.3 Practical precision agronomy in perennial systems to reduce cash, carbon and biodiversity costs

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Tree crops like coffee, cocoa, cashew and palm are key sources of income for (small-scale) farmers and countries in the tropics. These commodities are ingredients for high-value products in developed consumer markets. In those markets, consumers are increasingly concerned with the health and planetary impact of their shopping basket. Consequently, topics like farmer income, carbon footprints and regenerative agriculture have come at the centre of marketing efforts. Business-to-consumer companies have made considerable sustainability commitments, which impact operations at the start of their supply chains.

In our presentation, we provided an overview of the challenges and opportunities for tropical tree-crop systems, using coffee as an example. Tree crops are perennial in nature, with tendency for overbearing. Drought events or disease outbreaks during the plantation lifetime increase in-field variability. The bulk of the production (>66 percent) commonly originates from a minority (<33 percent) of trees. Blanket fertilizer applications are inherently inefficient in such cases and drip systems and fertigation are not suitable as the single delivery mechanism. Perennial systems also harbour some persistent pests, leading to overuse of certain pesticides in some production areas.

Regenerative agriculture is proposed as a solution to lower pesticide use and reduce carbon footprints; however, the concept is still relatively poorly defined and there is a need to translate it to context-specific actions to provide meaningful support to farmers.

The presentation provided an overview of solutions and challenges related to the improvement of crop productivity, income and environmental footprints in diverse coffee systems. Precision agriculture is applicable for low- and high-tech farmers, and primarily requires careful observation. Digital tools can help, but they are not a prerequisite to make significant progress in agronomic efficiency. Environmentally degrading practices such as excessive use of chemical inputs can be found in small-scale farms and high-input plantations, and often originate from constraints in labour efficiency, knowledge access and risk appetite. Examples of opportunities to improve tree-crop systems through stepwise approaches will be provided across a range of production systems.

3.4 Improving dryland production

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Drylands cover about 41 percent of the Earth's land surface and are inhabited by more than 2 billion people who rank among the poorest of the poor globally and face widespread challenges including food insecurity, malnutrition, frequent drought and environmental degradation. About 60 percent of the total arable land in South Asia is classified as dryland, while the corresponding figure for sub-Saharan Africa is around 70 percent. The COVID-19 pandemic has magnified the challenges inherent in these regions and has disrupted global efforts to achieve the 2030 Agenda for Sustainable Development, which envisions, among others, addressing agriculture and food security, livelihoods and the management of natural resources. This situation calls for urgent and sustainable action to transform dryland agriculture and improve the livelihoods of millions through new frameworks of cooperation, partnerships and innovations. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) deploys science-based solutions and value chain and policy innovations to transform agrifood systems for enhanced profitability, nutrition and climate resilience in drylands.

To transform agrifood systems, the following actions require consideration and implementation:

- Consultation with stakeholders to establish product profiles and develop improved cultivars with market-preferred traits that fit into various cropping systems.
- Mining of genetic resources for traits of interest, deploying cutting edge tools and data-driven decisions from multi-environment testing in breeding for improved product development.
- Development of inclusive, innovative and sustainable seed systems to fit into various contexts, e.g. with "buy-back mode" supplying seed to farmers annually.
- Establishment of digital seed corridors for deploying traceability in planning, quality seed production and seed supply.
- Landscape-based approaches for water management involving earthen field bunding along with field-drainage structures, and construction and renovation of check dams, community ponds/farm ponds, deepening and widening of drainage networks.
- Deployment of water-budget-based cropping systems for better harnessing soil, water and nutrients for sustainable crop intensification and cropping-system diversification for maximizing productivity.
- Deployment of regenerative agriculture principles for the restoration of degraded lands, enhanced soil health, microbial diversity and organic carbon content. Develop infrastructure and institutions to enhance adaptive capacity and scale up climate-smart options.
- Establish farmer producer organizations (FPOs) and reinvigorate commodity value chains through collectivization, reducing input costs, increased production, decentralized procurement, community processing, value addition and marketing.
- Empower FPOs in efficient management, record keeping and market understanding to maximize the benefits.

The government of India, FAO and ICRISAT collaboratively launched the International Year of Millets 2023 to increase awareness of consumers, create strategic demand, increase millet production, apply low-cost processing methods and develop sustainable value chains in the Global South for increased profitability, nutrition and climate resilience. Millets are high in iron, zinc, calcium and fibre, and have a low glycaemic index. ICRISAT and partners reported benefits of millets in terms of reducing stunting, promoting growth and reducing the risk of type 2 diabetes, anaemia and high cholesterol. High emphasis was given to promoting millets in daily food by consumers.

3.5 Climate change and variability: farm-level vulnerability, coping and adaptation opportunities

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Small-scale farmers are faced with major hazards and stresses from climate change and weather variability. Understanding the variability in local weather patterns, farm household exposure or vulnerability, and the possibilities and barriers to adaptation is key to designing effective farm-level adaption (Jellason *et al.*, 2022). Common shocks and stresses from climate change and variability in local weather patterns include prolonged dry spells, extreme temperature/heat, storms, erratic precipitation, increased occurrence of floods and increased incidence of drought. Farmers face additional hazards in the form of declining soil health and poor or no access to markets.

Farmers' exposure to hazards manifests as reduced crop yields or total crop failure, reduced livestock and fisheries productivity or death, high cost of controlling pests and diseases affecting crops and livestock, low returns to investment and debt. Small-scale farmers in sub-Saharan Africa are increasingly exposed to the negative impacts of climate change and weather variability. The priority should, therefore, be to help them reduce their exposure and vulnerability to climate change risk and achieve adequate and sustainable livelihoods.

Farmers' adaptive capacity is influenced by ownership and access to resources (financial, technological and information). It is also influenced, among others, by their ability and social networks, and by infrastructure (Smit and Wandel, 2006). Studies (Daze, Ambrose and Ehrhart, 2009; Abdul-Razak and Kruse 2017; Jellason *et al.*, 2022) suggest that farmer adaptation may be achieved through public investment in: (1) creating farmers' awareness of changes in climatic conditions; (2) improving farmers' access to extension services to help raise awareness of changing climate and adaptation measures; (3) guaranteeing accuracy, relevance and accessibility of weather information to increase farmers' trust and use of the information; (4) affordable credit schemes to increase financial resources at the disposal of farmers, thus enabling them to change their management practices in response to changing climatic conditions; (5) improving market access – to better make use of all the available information on changing conditions both climatic and other socioeconomic factors; (6) new irrigation technologies and other important inputs needed to change their practices to suit the forecasted and prevailing climatic conditions; (7) securing land tenure to increase investment in adaptation, including long-term adaptation options such as use of soil- and water-conservation techniques; and (8) increasing availability of cheap technologies – electricity, tractors or animal power, since farmers with access to technology have more flexibility to vary their planting dates, switch to new crops, diversify their crop options and use more irrigation and water-conservation techniques, as well as diversifying into non-farming activities.

With such investments, farmers are likely to adopt new technologies and change management practices in response to changing climatic and other conditions such as markets. However, farmers' perception of climate risks and adaptive capacity, as well as their interaction with resources, technologies, institutions and information varies with age and gender. Adaptation strategies should therefore be designed according to these differences.

References

Abdul-Razak, M. & Kruse, S. 2017. The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. *Climate Risk Management*, 17: 104–122. https://doi.org/10.1016/j.crm.2017.06.001

Smit, B., & Wandel, J. 2006. Adaptation, adaptive capacity and vulnerability. *Global environmental change*, 16(3): 282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008

Daze, A., Ambrose, K. & Ehrhart, C. 2009. *Climate vulnerability and capacity analysis handbook*. The Hague, Kingdom of the Netherlands, Care International. 77 pp. https://careclimatechange.org/wp-content/uploads/2016/06/CARE-CVCA-Handbook-EN-v0.8-web.pdf

Jellason, N.P., Salite, D., Conway, J.S. & Ogbaga, C.C. 2022. A systematic review of smallholder farmers' climate change adaptation and enabling conditions for knowledge integration in Sub-Saharan African (SSA) drylands. *Environmental Development*, 43: 100733. https://doi.org/10.1016/j.envdev.2022.100733

Parallel session: Resilient cropping systems

3.6 Integrated transformations to deliver climate-smart agriculture

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In the past year, a series of reports have been published that highlight the critical challenges to the environmental and climate systems on which our plant production systems rely. The Intergovernmental Panel on Climate Change (IPCC) detailed the existing and future trends in precipitation and temperature, and derivatives such as soil moisture and evapotranspiration. The changes are complex and variable, wherefore ensuring building climate resilience is critical in future plant production systems. Similarly, the FAO publication, *State of Land and Water Resources (SOLAW)*, highlighted the systems' breaking point following the impact of current agricultural practices.

If future plant production is to be sustainable, there is need to design practices that consider systems in their whole, recognizing that transformations are across the water, food, energy and environment nexus. In the presentation, a water lens is taken, as 76 percent of global croplands face green-water insecurity for at least one month a year. Three potential development pathways for sub-Saharan Africa are defined, that highlight solutions:

- **expansion** in irrigation, as 95 percent of the water is not utilized;
- **optimization** in irrigated agriculture; and
- **management** of soil moisture/soil health in rain-fed agriculture.

An example is given from Zambia, where a start-up offering financial services through digital technology, an agricultural-technology and data-service platform and a solar-energy pump provider have come together to equip thousands of small-scale farmers to cope with the impacts of climate change, which threatens to reduce water availability in Zambia by as much as 13 percent by 2050 and shrink GDP by 4 percent.

With climate change bringing increased precipitation and temperature variability, and thus changing soil moisture and irrigation-water availability for plant production in many countries, it is important that systems thinking is the basis of water planning and decision-making across scale. Increasing demands for water, both within and beyond food systems, will require careful balancing of trade-offs.

This systems thinking will demand innovation at all scales to ensure plant production and other water-use sectors can function. At the very local field scale, managing the biophysical factors that influence productivity with changing input resources will be important, while at the farm and irrigation-system scale, there will be need to control agronomic practices and infrastructure investment. At the large scale (catchment/basin or even country and regional scales) spatial hydroclimatic variability, upstream/downstream interdependencies, and the roles of other sectors with their demands become increasingly important. With growing water insecurity taking place alongside that of food insecurity, nexus thinking will be critical across scales and sectors.

References

AICCRA (CGIAR). 2022. Aiccra Zambia announce accelerator program finalists. In: *Accelerating Impacts of CGIAR Climate Research for Africa*. Cited 14 March

2023. https://aiccra.cgiar.org/news/aiccra-zambia-announce-accelerator-program-finalists

FAO & Earthscan. 2012. State of Land and Water Resources (SOLAW). ISBN 978-92-5-106614-0.

Ngoma, H., Lupiya, P., Kabisa, M. & Hartley, F. 2021. Impacts of climate change on agriculture and household welfare in Zambia: an economy-wide analysis. *Climatic Change*, 167: 55. https://doi.org/10.1007/s10584-021-03168-z

Rosa, L., Chiarelli, D.D., Sangiorgio, M., Beltran-Peña, A.A., Rulli, M.C., D'Odorico, P. & Fung, I. 2020. Potential for sustainable irrigation expansion in a 3 °C warmer climate. *Proceedings of the National Academy of Sciences*, 117(47): 29526–29534. https://doi.org/10.1073/pnas.2017796117

3.7 Fertilizer and soil health – two sides of the same coin?

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Small-scale farming systems in sub-Saharan Africa need to intensify to tackle the many challenges farmers and society are facing. Sustainable intensification aims at increasing system productivity while maintaining or improving other ecosystem services and increasing the adaptive capacity of farmers to reduce exposure to climate-change-related hazards. Current production systems are largely based on nutrient mining and result in low crop productivity and ever-increasing soil degradation. It is imperative to adopt systems that respect sustainable intensification principles. By focusing on increasing crop productivity and deploying the extra biomass to gradually restore soil health, internal returns on investment under appropriate socioeconomic conditions can be provided. However, this will require external incentive schemes for farmers, since the delivery of returns on investment takes time.

In the absence of incentive schemes, as is the case in most of sub-Saharan Africa, the path focusing on improving productivity will require the use of fertilizers. Increased fertilizer inputs can result in increased soil carbon content, a key indicator of soil health. However, fertilizers need to be used efficiently for economic and environmental reasons. Integrated soil fertility management (ISFM) is formulated around maximizing the agronomic efficiency of applied fertilizer nutrients through the following advice: (1) apply fertilizers wisely; (2) use improved/adapted varieties; (3) combine fertilizers with organic inputs; (4) apply good agronomic practices; and (5) address local constraints. These accompanying practices enhance the response of crops to fertilizer and the build-up of soil carbon derived from the increased availability of crop roots and residues. ISFM also recognizes the need to adapt recommendations to the highly variable production conditions, enabled by recent innovations in data science, remote sensing, sensor technology and analytics. The recently launched Excellence in Agronomy Initiative of CGIAR builds on these advances towards the delivery of locally relevant recommendations at scale towards the sustainable intensification and climate change adaptation of small-scale farming systems in the Global South.

In summary, fertilizer is an essential input for the sustainable intensification and climate adaptation of small-scale farming systems, but requires complimentary practices and amendments to deliver on potential impacts. Moreover, rehabilitating soil health is a long-term investment with limited to no short-term benefits to small-scale farmers and should thus be supported by incentive schemes for farmers until improved soil health generates visible, short-term benefits.

References

Nziguheba, G., Adewopo, J., Masso, C., Nabahungu, L.N., Six, J., Sseguya, H., Taulya, G. & Vanlauwe, B. 2021. Assessment of sustainable land use: Linking land management practices to sustainable land use indicator. *International Journal of Agricultural Sustainability*, I 20(3): 265–288. https://doi.org/10.1080/14735903.2021.1926150

Vanlauwe, B., Bationo, A., Chianu, J., Giller, K. E., Merckx, R., Mokwunye, U., Ohiokpehai, O., Pypers, P., Tabo, R., Shepherd, K., Smaling, E., Woomer, P.L. & Sanginga, N. 2010. Integrated soil fertility management: Operational definition and consequences for implementation and dissemination. *Outlook on Agriculture*, 39: 17–24. http://doi.org/10.5367/000000010791169998

Vanlauwe, B., Coyne, D., Gockowski, J., Hauser, S., Huising, J., Masso, C., Nziguheba, G. & Van Asten, P. 2014. Sustainable intensification and the smallholder African farmer Current Opinion. *Environmental Sustainability*, 8: 15–22. https://doi.org/10.1016/j.cosust.2014.06.001

Vanlauwe, B., Descheemaeker, K., Giller, K.E., Huising, J., Merckx, R., Nziguheba, G., Wendt, J. & Zingore, S. 2015. Integrated Soil Fertility Management in sub-Saharan Africa: Unravelling local adaptation. *SOIL*, 1: 491–508. https://doi.org/10.5194/soil-1-491-2015

Vanlauwe, B., Hungria, M., Kanampiu, F. & Giller, K. E. 2019. The role of legumes in the sustainable intensification of African smallholder agriculture: Myths, lessons, and challenges for the future. *Agriculture, Ecosystems and Environment*, 284: 106583. https://doi.org/10.1016/j.agee.2019.106583

3.8 Climate-adaptive production systems

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Agricultural crop production faces high adverse impacts from climate change, and the productivity gains achieved in the last half decade are threatened because of increasing climate risks, especially for small-scale producers and vulnerable populations in sub-Saharan Africa and South Asia. The *IPCC Sixth Assessment Report* highlights that climate risks are appearing faster and will get more severe. Current observed impacts of changing climatic systems cascade through natural and human systems, often compounding with impacts from other human activities.

The global hotspots of high human vulnerability are found particularly in West, Central and East Africa, South Asia, Central and South America, small island developing States and the Arctic. The IPCC report correlates higher vulnerability with locations facing poverty, governance challenges, limited access to basic services and resources, violent conflict and high levels of climate-sensitive livelihoods such as small-scale farmers, pastoralists and fishing communities.

This confirms the value of strengthening the adaptive capacity in production systems for increasing resilience to climate risks. The good news is that there are now a wide range of validated climate-smart innovations and advisory services available that can be rapidly scaled for quick impact. There are additional successful efforts to characterize, bundle and validate needed solutions for scaling. The challenge for building adaptive production systems remains in providing small-scale farmers with innovative tools, strategies and access to financing to rebuild climate-weakened food systems and reduce their vulnerability to external shocks.

Efforts to scale will require addressing gender and social-inclusion considerations, bundling packages, comprehensive regional data systems and linking to technology-transfer systems that improve access for food-system actors. Additional domestic support for climate adaptation is required, as is a stronger local lens for investments to respond to local, contextual adaptation needs and priorities.

References

Pörtner, H.O., Roberts, D.C., Adams, H., Adler, C., Aldunce, P., Ali, E. & Birkmann, J. 2022. Climate change 2022: Impacts, adaptation and vulnerability. *IPCC Sixth Assessment Report*, 37–118.
CPI (Climate Policy Initiative), 2021. Global Landscape of Climate Finance 2021.

Steiner, A., Aguilar, G., Bomba, K., Bonilla, J. P., Campbell, A., Echeverria, R., Gandhi, R. *et al.* 2020. *Actions to transform food systems under climate change*. Wageningen, Kingdom of the Netherlands, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Thornton, P. K., Chang, Y., Loboguerrero, A. M., & Campbell, B. 2022. *The price tag for transforming food systems under climate change: How transforming food systems under climate change will cost trillions, but inaction will cost more*. 10 pp. https://hdl.handle.net/10568/119184

3.9 Agroforestry and regenerative agriculture in coffee-growing areas with climate change

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Scientific evidence on global impacts of climate change must lead countries, economies and citizens of the world to urgently transform development models that collide head-on with delicate ecological processes in the context of climate interactions.

Agroforestry, related to a broad set of production systems that combines trees with crops, pastures or animals, is a consolidated science with important contributions on the knowledge of complex interrelationships. Agroforestry promotes conservation and sustainable production at the same time, in the same agricultural and livestock spaces.

There is a wide range of options for combining and sustainably arranging the regenerative potential of agroforestry. Their implementation involves strengthening the capacity of governments, institutions, technical personnel and farmer families to be able to collaboratively implement related actions.

At the beginning of the 2000s, CATIE began implementing a series of long-term trials with coffee to study multiple interactions. This work involved a network with universities and institutions around the world, under the support of the largest scientific platform for agroforestry in Latin America, Agroforesta (https://agroforesta.org/), coordinated jointly with CIRAD in France.

Interdisciplinary studies (Virginio Filho *et al.*, 2021) have continuously allowed the development of a mega-database on physical, biological and chemical soil interactions, fauna and flora biodiversity, pest/disease complexes and natural controllers, productivity/quality in coffee production, development of trees and interactions with light, nutrient cycling, carbon dynamics in the systems, and climatic and microclimatic information related to 20 different production systems (18 in agroforestry systems and 2 in full sun).

There is an extensive list of undergraduate and graduate theses, and more than 24 scientific articles and technical publications that are available to the public. The results, in summary, confirm that full-sun production systems, compared to various agroforestry systems, especially those based on intensive and moderate chemical management, do not allow regenerative agriculture of soil life conditions, biodiversity connectivity, microclimate regulation and links with the complexity of pests and diseases – and above all the potential for high capture and reduction of carbon emissions.

Key processes have been identified that allow the use of suitable associations of service trees (Erythrinas) with timber trees in combination with improved varieties of coffee, achieving high levels of productivity, diversification and at the same time multiple ecosystem services. Likewise, moderate conventional and organic management practices have been identified that contribute to the adaptation and mitigation of the coffee sector to climate change. The practices were validated in a wide network of farms in several countries. In Costa Rica, the lessons learned have been inputs for the design and implementation of the first nationally appropriate mitigation action (NAMA) in the World, which is the NAMA-Café Costa Rica, today a reference model for several countries.

Reference

Virginio Filho, E. de M., Somarriba, E., Cerda, R., Casanoves, F., Cordero, C., Avelino, J., Roupsard, O. *et al.* 2021. Aportes a la investigación, fortalecimiento de capacidades y formulación de políticas para el sector cafetalero en 20 años de ensayos de sistemas agroforestales con café. *Agroforestería en las Américas*, 51(2021): 107–151 (in Spanish). https://repositorio.catie.ac.cr/handle/11554/11143

3.10 Indigenous Peoples' food systems as game changers, feeding the world in a sustainable manner

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We live in an era of food crises caused by conflict, climate change and COVID-19. While approximately 20 percent of the global population suffers from obesity or is overweight, 5 percent are underweight. Additionally, the current dominant agricultural model is responsible for 30 percent of greenhouse gas emissions, uses 70 percent of the world's freshwater and causes 80 percent of the world's deforestation.

While many efforts to ensure food security focus on maximizing crop production, i.e. maximizing yields per unit of input, we also know that the problem cannot be narrowed to production, as 30 percent of the food we produce and consume gets wasted. Progress in agricultural development has tried to tackle the problem of food security by maximizing the productivity of the three main crops that account for 60 percent of people's caloric intake, i.e. wheat, maize and rice, and 25 other major crops. In an era of food-chain disruptions due to COVID-19, numbers indicate that malnourishment increased from 8.4 percent to 9.9 percent in a year. The current conflict between Ukraine and the Russian Federation is also likely to lead to increased food insecurity due to the heavy reliance on fertilizers and wheat from the region.

But are there alternative ways to ensure food security while protecting the planet and being resilient? The answer is yes. Indigenous Peoples and their food systems are game changers that can help sustainably feed the world as they have coexisted despite centuries of marginalization and discrimination. Differently from the productivity focus of conventional food systems, Indigenous Peoples' food systems are about multipurpose food generation, and they are connected to other values of identity, culture and reciprocity, and putting nature at the centre, which makes them unique and crucial for conserving the world's biodiversity.

The 476 million Indigenous Peoples representing 6 percent of the world's population inhabit more than 90 countries worldwide and preserve 80 percent of the world's biodiversity in less than 25 percent of its surface area. Indigenous People have preserved their resilient food systems and have learned to respect the seasonality of their territories, putting nature at the centre, which has allowed them to live in a broad range of environments, from the cold lands of the Artic to the arid lands in Africa or Australia that are hostile environments to many people. Importantly, Indigenous Peoples' food systems play a crucial role in supporting their food and nutrition sovereignty, and their food practices are vital to preserving biodiversity. For example, while the world generally relies on three main crops, a single Indigenous Peoples' food system can contain more than 250 food items. At least 4 000 more food plants remain unexplored. Other studies revealed that a *milpa* (maize intercropping) system is not only richer in terms of nutrition for human health but also sustainable for the environment. In the end, Indigenous Peoples and their food systems and knowledge have been undermined for centuries, and it is time to co-learn and cocreate practices that can help tackle food insecurity and transform food systems sustainably.

Conclusions

1. We need to invest in Indigenous Peoples' food systems and support them so they can share their game-changing solutions with the world, shifting the narrative of production to food generation, to shorten food chains and transform current unsustainable food systems into more sustainable food systems.
2. We need to coproduce research with Indigenous and non-Indigenous researchers on Indigenous

Peoples' food systems and practices, i.e. studying underutilized and neglected food, that can be scaled out to transform current food systems while acknowledging Indigenous Peoples' free, prior and informed consent.

3. We need to develop certification and labelling schemes to acknowledge the critical role of Indigenous Peoples in food security and the world's sustainability; this will improve their lives and benefit the world from the ecosystem services Indigenous Peoples create through their practices.

Chapter 4. Protected cropping systems

Parallel session: Optimizing production efficiencies

4.1 Improving resource use efficiency

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Protected cultivation is the modification of a plants' growing environment using different types of structures, thereby providing a fully or partially modified microclimate to the plants and protecting them against harsh climatic conditions to extend the cultivation period or provide out-of-season crop production. There are different types of protected cultivation, ranging from very simple surface covers (e.g. mulching), over low and high plastic tunnels, to simple unheated structures and sophisticated high-tech, climate-controlled greenhouses and vertical farms. Worldwide, protected cultivation is practiced on an area of over 5.6 million ha, and has increased more than tenfold during the last two decades (Tuzel and Kacira, 2021). Very simple structures are adopted in tropical and mild-winter climatic conditions, whereas high-tech structures are used in northern countries due to an increased need for climate control.

Protected cultivation offers alternatives to open-field production. Based on the type of structure, adapted protected cultivation systems have many advantages such as increased yield and quality, and year-round production resulting in higher revenues for farmers. Greenhouses not only protect plants from adverse climate conditions, but can also reduce pest and disease incidences and pesticide use, depending on the structure, location and season. One of the main advantages of production in greenhouses is the improvement of resource-use efficiency (e.g. water, land). Resource-use efficiency is expressed as the ratio between the amount of produced biomass and supplied resource. Maximizing the productivity with minimum resource inputs, such as energy, water, CO_2, land, labour, fertilizers and pesticides, contributes to the reduction of environmental impact and resource costs.

Crop water requirements in greenhouses are 20 percent to 40 percent lower compared to open-field cultivation (Nikolau *et al.*, 2019) and water-use efficiency (WUE) is higher (Gallardo, Thompson and Fernandez, 2013). WUE is the amount of production/yield per unit of water. Compared with open-field production, WUE is higher in greenhouse cultivation mainly due to reduced water loss through evapotranspiration, controlled irrigation systems, higher-yielding production systems and adoption of more efficient techniques (e.g. closed systems) (Tuzel and Kacira, 2021). A study showed that WUE on tomato in litres of water per kilogram of fresh weight is 200, 50 and 20 in open field, protected cultivation and protected cultivation with closed recirculation systems respectively (Van Kooten, Heuvelink and Stanghellini, 2008; Gruda, 2019). Another study conducted with farmers showed that up to 46 percent, 19 percent, 16 percent, 24 percent and 13 percent water savings could be provided in organic pepper, organic tomato, cucumber, French bean and eggplant production, respectively, in sensor-supported irrigation treatments (Balendonck *et al.*, 2021; Tüzel *et al.*, 2022).

Protected cultivation systems have been adopted by small-scale farmers worldwide. In greenhouses, adoption of sustainable technologies contributes to less pest and disease infestations and less use of pesticides. Only a few integrated plant production tools (e.g. insect nets, double door) were tested in a demonstration project conducted within the Near East and North Africa (NENA) region, resulting in decreased pesticide sprayings with the use of insectproof nets, the cover of entrances or the utilization of a double door (FAO TCP/INT/0165 Final Report). In Uzbekistan, yields increased 230 percent with the use of insectproof nets and double doors (Project GCP/GLO/071/ROK). Protected cultivation also makes it possible to grow cash crops in marginal lands or water-deficit areas (e.g. Arabian Peninsula, Pakistan).

Considering the impacts of climate change, the increasing population and food security issues, protected cultivation, depending on the structure type and the technology level used, can be a tool to increase the productivity, profitability and efficient use of resources, however sustainable technologies should be adapted and applied to mitigate environmental impacts.

References

Balendonck, J., Tüzel, İ.H., Tunali, U., Oztekin, G.B. & Tüzel, Y. 2021. Performance evaluation of the AquaTag, a prototype near-field RF-based soil moisture sensor. 2021 *13th International Conference on Electromagnetic Wave Interaction with Water and Moist Substances (ISEMA)*, Kiel, Germany. https://doi.org/10.1109/ISEMA49699.2021.9508292

Gallardo, M., Thompson, R.B. & Fernández, M.D. 2013. Water requirements and irrigation management in Mediterranean greenhouses: the case of the southeast coast of Spain. Chapter 6. In: W. Baudoin, R. Nono-Womdim, N. Lutaladio, A. Hodder, N. Castilla, C. Leonardi, S. De Pascale, M. Qaryouti, eds. *Good Agricultural Practices for Greenhouse Vegetable Crops, Principles for Mediterranean Areas*, FAO Plant Production and Protection Paper 217, 109–136.

Gruda, N. 2019. Increasing Sustainability of Growing Media Constituents and Stand-Alone Substrates in Soilless Culture Systems. *Agronomy*, 9(6): 298. https://doi.org/10.3390/agronomy9060298

Nikolau, G., Neocleous, D., Katsoulas, N & Kittas, C. 2019. Irrigation of Greenhouse Crops. Horticulturae, 5(1): 7. https://doi.org/10.3390/horticulturae5010007

Tuzel, Y. & M. Kacira. 2021. Recent developments in protected cultivation. *Acta Horticulturae*, 1320: 1–13. https://doi.org/10.17660/ActaHortic.2021.1320.1

Tüzel, I.H., Balendonck, J., Tuzel, Y., Oztekin, G.B. & Tunali, U. 2022. Use of a low-cost soil moisture sensor to reduce irrigation water usage in mild winter climate greenhouses. *31st International Horticultural Congress* (IHC2022), 14–20 August 2022. Angers, France.

van Kooten, O., Heuvelink, E. & Stanghellini, C. 2008. New developments in greenhouse technology can mitigate the water shortage problem of the 21st century. *Acta Horticulturae*, 767: 45–52. https://doi.org/10.17660/ActaHortic.2008.767.2

4.2 The evolution of Jamaica's protected agriculture value chain: a possible route for others

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Caribbean islands are expressing greater interest in protected agriculture (PA) and non-traditional growing systems, as it has become more evident that current methods of growing certain crops are not sustainable.

This new thrust by small island developing States focuses on the challenges that make them more vulnerable to food insecurities. These include, but are not limited to, small land masses and populations, lack of arable land, large food import bills and climate change.

Access to arable land and sufficient good quality water are two of the greater challenges. Governments must choose which sector will get the greater share of these scarce commodities. There is active competition for land and water between the agriculture, housing, mining and tourism sectors.

Caribbean States are close to sea level and to the Equator, showing year-round, usually very high temperatures. Heat is a major concern when growing crops under passively cooled PA structures.

Despite the limitations, PA systems are well adapted to the Caribbean region and offer the possibility to grow year-round, by capitalizing on continuous sunshine. By using adequate inputs and management practices, production of high-value and nutritious crops is realized in an environment that is better protected from pest and disease pressures. The resulting reduced use of pesticides guarantees important savings for farmers and the production of safer foods.

PA structures such as greenhouses are beneficial in many ways. They mitigate some of the effects of climate change, for example, prolonged rain fall, moderate to strong winds and solar radiation. They also act as physical barriers to several species of pests which have become more invasive given the effects of climate change.

On the other hand, greenhouses within the Caribbean region are prone to destruction by storms and hurricanes, which are common and usually occur each year from 1 June to 31 November.

Despite this, farmers are still willing to continue using PA structures, based on several benefits and measurable outcomes gained from the technology.

Government intervention for development of PA as a major component of the agricultural framework has been minimal. Currently, the subsector is primarily driven by the efforts of the private sector and contributions from donor countries via various outreach programmes. A few governments have contributed to setting up research facilities, nurseries and extension services.

Far more work and significant investment is needed immediately as Caribbean islands must start producing more of their own foods, given the current economic crisis.

Intensive PA systems with emphasis on non-soil, water and nutrient recirculation must be a part of the mixed approach with traditional methods; as we transition towards more environmentally friendly and sustainable methods of agriculture that will also help to conserve scarce resources including land and water.

4.3 Adapting protected cultivation systems for small-scale farmers

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Protected cropping systems bring climate-smart technology within the reach of small-scale farmers in the Global South. In protected structures, increased carbon dioxide concentrations result in vigorous plant growth. During the rainy season, protected cultivation structures (1) help avoid or lower the intensity of raindrops on crops, thus reducing crop damage; (2) help reduce soil erosion; (3) help reduce the spread of diseases because of reduced soil splashing, which can carry disease-causing organisms; and (4) help create higher temperature conditions, which enhance crop growth. During the dry season, protected systems (1) ensure soils retain water longer, thus reducing irrigation water requirement; and (2) help create lower temperature conditions, which enhances crop growth.

As regards to pest control, pests can affect from 30 percent to 100 percent of a yield, while chemical control is often misused by farmers, causing negative effects to useful organisms (e.g. microorganisms, pollinators), humans and the environment. Protected cultivation systems allow small-scale farmers to apply safe and effective pest-control strategies. In addition, the high dependence on pesticides is reduced, as is the risk of pesticide overuse resulting in resistance development, and the risk of pesticide residues affecting market access. Potentially safer control methods, such as cultural, biological, botanical, physical, mechanical, pheromonal and semi-chemical, are not yet commonly used in the Global South. Protected cultivation brings physical protection methods, which are cheap and easy to apply, within reach of small-scale farmers.

Crops of interest can be crucifer crops (e.g. cabbage, kale, broccoli, Ethiopian mustard), solanaceous crops (e.g. tomato, capsicum, eggplant, tomatillo) and cucurbits (e.g. melons, squash, karalla). Producing seedlings under protected cultivation methods allows for uniform seedling emergence and rapid production of high-quality seedlings, reducing the nursery period by 1 to 2 weeks for certain crops, while providing a barrier to pest infestation and protecting seed beds from adverse weather conditions, pests and predators.

Protected cultivations can involve high financial investments, but some structures such as low-tunnel row covers are within reach of most small-scale farmers and, just as for bigger structures, they are reusable for several (three to five) crop seasons hence reducing cost, being easy to store and washable. Use of protected cultivation methods requires knowledge, both for farmers and labour forces to make optimal use of the investment and avoid potential risks for increased pest incidence of thrips and aphids.

4.4 A biocircular approach to soilless culture in China

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An area of over 2 million ha of land is under protected cultivation in China. Protected cultivation, mostly of high-value crops, thus plays a very important role in the supply of vegetables to urban areas, increasing grower income and rural development. One of the risks associated with growing crops under protected cultivation is soil health, especially in greenhouses where crop rotation is not practised. Soilless cultivation is an option to avoid this problem, though it can be costly. To reduce the investment cost of soilless culture, low-cost materials such as maize straw, cotton straw, sunflower straw, rice husk, peanut shells, sawdust, coir and spent substrate of edible fungi can be used as a growth medium.

A mix of straw and sterilized poultry manure contains abundant trace elements and can meet crop nutrient requirements when used as fertilizer. Organic fertilizer can gradually dissolve nutrients in water to supply the needs of plant growth and development. Generally, two or three low-cost materials are mixed for enhanced quality of physical and chemical properties of the growth medium. This technique is commonly known as ecoorganic-type soilless culture.

The soilless culture system that was first developed by the Chinese Academy of Agricultural Sciences consists of a trough, PE film irrigation tape and substrate. The trough is about 15 cm high and 50 cm wide, its length depends on the type of greenhouse. The bottom of the trough is covered with 0.1 mm PE film to prevent soil-borne pests and diseases. The organic fertilizer is a mixture of sterilized poultry manure, oil cake powder, and corn or sunflower stem powder, which are rich in organic potassium and trace elements. These materials need to be composted, and thereafter dried to a moisture content of around 17–18 percent. The total content of nitrogen, phosphorous and potassium exceeds 10 percent. Each cubic meter of substrate is mixed with 10 kg of organic fertilizer. One hectare needs 450 cubic metres of substrate. Beneficial microorganisms can be added at the beginning of cultivation.

Compared to soilless culture using nutrient solutions alone, ecoorganic-type soilless culture systems decrease the initial investment by up to 80 percent, fertilizer cost by up to 60 percent, and greatly simplify the rule of operation and improve the quality of vegetables. This method introduces organic agriculture into soilless culture with low cost, high yield and good quality. It is an organic, sustainable agricultural method, which has been adopted in various areas in China. At present, ecoorganic type systems account for over 60 percent of the total area of soilless culture in China, and have been a distinctive feature of soilless culture in the country.

Dong Ruifang, a farmer devoted to growing vegetables using this system for around 10 years, reported that “this is a very easy and attractive technology. I use this technology in the desert area of Xinjiang Province to grow all kinds of vegetables using very little water. I also use this technology in Tianjin, which is nearby Beijing, to grow high-sugar tomatoes for a higher price and better income. The tomato quality can be greatly improved by reducing moisture and increasing organic matter content in the controllable artificial soil. This technology can also be used in urban agriculture. Children can plant vegetables on their balcony or on the roof of a building using this artificial soil.”

References

Gao, Y., Yu H., Liu P., Ma C., Li Q. & Jiang, W. 2018. Ending composting during the thermophilic phase improves cultivation substrate properties and increasing winter cucumber yield. *Waste Management*, 79: 260–272. https://doi.org/10.1016/j.wasman.2018.07.048

Wang, Q., Yan, F., Hua, J., Wang, Z., Bian, K., Zhang, W. & Xia, Y. 2022. Effects of Different Organic Ecotypes Soilless Cultivation on Substrate Characteristics and Watermelon Yield and Quality. *China Vegetables*, 8: 92–95.

Wei, S. 2021. Effects of Four Kinds of Eco-organic Substrate for Soilless Cultivation on the Quality and Benefit of Tomato. *Vegetables*, 2: 20–25.

Zhang, S., Yu, H. & Jiang, W. 2015. Seedling effects of corncob and bagasse composting substrates in cucumber. *Transactions of the Chinese Society of Agricultural Engineering*, 31: 236–242.

Zhang, Y., Yu, H., Yang, X. & Jiang, W. 2013. Favorable conditions of cotton straw composting using as soilless culture substrate. *Transactions of the Chinese Society of Agricultural Engineering*, 29: 210–217.

4.5 Evaluating greenhouse production systems based on the Sustainable Development Goals

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This presentation is based on a review that evaluates the sustainability of tomato production in four greenhouse systems: high-tech (Kingdom of the Netherlands) and low-tech (Spain) combined with two ways of cultivation (conventional or organic).

We used the SDGs as a lens to assess the sustainability of different greenhouse plant production systems. In total, seven SDGs, including 14 targets, were assessed through 12 quantitative and two descriptive indicators. Conventional, high-tech greenhouse systems showed the greatest potential for positive contributions towards four of the SDGs. However, their relatively high energy use makes it difficult to achieve SDG 7 on affordable and clean energy, whereas low-tech systems performed comparatively better due to lower energy use from relatively cleaner sources.

Lower water-use efficiency and higher nutrient losses in all soil-based cultivation systems were barriers to achieving some targets under most of the selected SDGs.

Organic cultivation systems showed relatively high water and land use, based on the limited data available. Our review highlights the existence of substantial synergies, but also considerable trade-offs between SDGs. This needs to be considered when making policy, investment and management decisions related to greenhouse crop production.

References

Zhou, D., Meinke, H., Wilson, M., Marcelis, L.F.M. & Heuvelink, E. 2021. Towards delivering on the sustainable development goals in greenhouse production systems. *Resources, Conservation and Recycling*, 169: 105379. https://doi.org/10.1016/j.resconrec.2020.105379

Parallel session: Transforming urban horticulture

4.6 Protected horticulture: a way forward to sustainable agriculture in arid regions

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Climate change is of global concern, and the increase in temperature is causing drought and saline conditions that are increasing land aridity in certain regions (Overpeck and Udall, 2020). At present, about 30 percent of the world's total area consists of arid and semi-arid regions, hosting approximately 20 percent of the world's population. Nearly all continents have arid and semi-arid regions, and about 24 percent of people in Africa, 23 percent in Asia, 17 percent in America and the Caribbean, 11 percent in Europe and 6 percent in Australia and Oceania are living in these areas. These arid regions receive low annual precipitation and have high evapotranspiration. The arid countries of the Middle East and North Africa are suffering from chronic water shortages and are consuming 80 percent of their freshwater for agriculture. People of low-income countries are facing malnutrition due to the unavailability of sufficient food.

At present, protected agriculture is a rising trend in arid regions due to its potential to grow food in a controlled environment and to meet demand for production in regions experiencing an increase in population, food security issues, and a decline in freshwater availability. Protected cultivation addresses climate-related issues of arid regions such as high temperature and wind speed, along with soil fertility problems, and provides opportunities to grow high-value horticultural crops in these regions (Golla, 2021). Further, lower humidity levels in arid regions reduce insects and disease incidence in protected structures.

Worldwide, there are certain conventional and modern protected cultivation structures, such as shade net houses, ventilated greenhouses, low tunnels, walking tunnels, high tunnels, as well as hydroponic and aeroponics units, that are utilized to get year-round production of high-value fruit and vegetables (Khan *et al.*, 2020). However, knowledge about the structure, design, function and modification of structures according to season, crop behaviour and knowledge of cultural practices is necessary for farmers to achieve maximum yield.

The availability of local foods can make cities self-sufficient and reduce transport costs. Moreover, local foods are fresh, cheaper, more nutritious, good in taste and have potentially less pesticide residue. Keeping in mind the potential of protected cultivation, this offers enormous opportunities for increasing farmers' income in arid and semi-arid regions by promoting protected cultivation of crops through innovative techniques.

References

Golla, B. 2021. Agricultural production system in arid and semi-arid regions. *International Journal of Agricultural Science and Food Technology*, 7(2): 234–244. https://doi.org/10.17352/2455-815X.000113

Khan, M.M., Akram, M.T., Janke, R., Qadri, R.W.K., Al-Sadi, A.M & Farooque, A.A. 2020. Urban Horticulture for Food Secure Cities through and beyond COVID-19. *Sustainability*, 12: 9592. https://doi.org/10.3390/su12229592

Overpeck, J.T & Udall, B. 2020. Climate change and the aridification of North America. *Environmental Sciences*, 117(22): 11856–11858. https://doi.org/10.1073/pnas.2006323117

4.7 Plant factory innovations towards inclusive and sustainable societies

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There has been an increasing global interest in plant factories, also referred to as indoor vertical farms or plant factories with artificial lighting (PFALs), as a novel plant production system that could concurrently contribute to the solution of significant global challenges, including food security, environmental conservation, resource saving and quality of life. PFALs are a closed plant production system with almost airtight and well-insulated structures, with the potential to enable production of high quantities of high-quality plants year-round, while achieving high resource-use efficiency. The goal of PFALs is to maximize plant yields with highest economic value, minimum resource use and minimum emissions under given climate, social and economic conditions, and to provide stakeholders with a higher quality of life.

In recent years, a great number of dynamic opportunities have emerged, as PFALs have been attracting attention worldwide. Particularly since 2015, an increasing number of people and organizations with diverse backgrounds have become involved in business, system development and research relevant to PFAL. In fact, more PFALs are being developed and commercially operated in many areas in the world, including Japan and other countries in Asia, North America, Europe and the Middle East.

Since cultivation rooms of PFALs are highly airtight and well-insulated, there are factors ensuring the evolutional characteristics of a PFAL, bringing about successive improvement of productivity, including high observability with sensors, high traceability with databases, high controllability with actuators, high reproducibility based on analysis and high predictability with models (e.g. mechanistic, multivariate statistical, behaviour and artificial intelligence models).

However, research and development challenges remain for the next-generation of sustainable PFALs with forthcoming technologies, including PFALs consisting of one or more cultivation system modules, phenotyping individual plants for cohort research, controlling three-dimensional environmental factors within a plant canopy, and production systems of fruit, roots, head vegetables and medicinal plants including herbs, among others.

To further advance PFALs, it is essential to improve productivity. Plant phenotyping plays an integral role in understanding how the surrounding microenvironment of individual plants, management factors and genotype affect variations in the phenotype of individual plants. In plant cohort research, the life cycle phenome history of individual plants can be captured noninvasively and continuously, and then analysed throughout, from seed sowing to harvesting, with phenotyping units, along with time series data on environment, management and resource inputs/outputs in PFALs (Kozai *et al.*, 2018). Using the time series data sets in the data warehouse, plant cohort research could help to identify optimal set points of environmental factors for maximizing multiobjective functions in parallel with improving plant productivity, selection of seedlings for grading and breeding of new cultivars in PFALs (Kozai *et al.*, 2018). Towards inclusive and sustainable societies, it is crucial to integrate and create the shared value of PFALs, incorporating fields such as science, engineering, design and art all together, to achieve the SDGs, including SDG 1: No Poverty.

References

Hayashi, E., Amagai, Y., Maruo, T. & Kozai, T. 2020. Phenotypic Analysis of Germination Time of Individual Seeds Affected by Microenvironment and Management Factors for Cohort Research in Plant Factory. *Agronomy*, 10(11): 1680. https://doi.org/10.3390/agronomy10111680

Hayashi, E., Amagai, Y., Kozai. T. Maruo, T., Tsukagoshi, S., Nakano, A., Johkan, M. 2022. Variations in the Growth of Cotyledons and Initial True Leaves as Affected by Photosynthetic Photon Flux Density at Individual Seedlings and Nutrients. *Agronomy*, 12(1). https://doi.org/10.3390/agronomy12010194

Kozai, T. *et al.* 2018. Plant Cohort Research and Its Application. In: T. Kozai, ed. *Smart Plant Factory*. Springer, Singapore. https://doi.org/10.1007/978-981-13-1065-2_26

Kozai, T., Niu, G. & Masabni, J. 2022. *Plant Factory Basics, Applications and Advances*. Elsevier. https://doi.org/10.1016/C2020-0-01628-2

Kozai, T. & Hayashi, E., eds. 2023. *Advances in Plant Factories: New technologies in indoor vertical farming*. Cambridge, UK, Burleigh Dodds Science Publishing Limited.

4.8 Urban farming and water conservation

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Increasing scarcity of clean water in and around many urban areas has led to intense competition for its use. Municipal water supplies have typically been treated to drinking-water standards, and are much more expensive than agricultural water supplies. Water-efficient practices and the use of appropriate irrigation technologies can save substantial amounts of water.

These practices can include the promotion of healthy soils, as adding organic matter to soil increases soil nutrition and its water-holding capacity, which helps plants produce higher-quality yields and reduces a crop's need for water by 30 percent on average. Mulching keeps soil cool, preserving moisture and reducing weed germination (Kaplan and Blume, 2011).

Several tools are needed to measure soil moisture and to help pilot water irrigation (Ragab *et al.*, 2017). Drip irrigation and subirrigation can reduce weed growth, help control mildew, reduce fungus problems and save water. Rainwater catchment systems, e.g. from roofs (Lancaster, 2011), and reuse of greywater allow for reduced consumption of municipal water (Lupia and Pulighe, 2015; Hirich and Choukr-Allah, 2013)

Water savings can be realized through irrigation with drip subsurface irrigation systems and partial root drying techniques, where only one half of the vertical root zone is irrigated at a time in alternation with the other half (Ragab *et al.*, 2017). Water savings are significant at around 40 percent, which means 40 percent more food can be produced (Afzal *et al.*, 2016).

Conservation tillage and soil organic amendments reduce soil evaporation, soil erosion, salt concentration and use of agrochemicals, while they increase water availability, soil organic matter and nutrient availability (through recycling crop residues) (Seitz *et al.*, 2019).

In conclusion, water conservation technologies create savings for water and fertilizers, improve production in quantity and quality, and protect the environment.

References

Afzal, M., Battilani, A., Solimando, D. & Ragab, R. 2016. Improving water resources management using different irrigation strategies and water qualities: Field and modelling study. *Agricultural Water Management*, 176: 40–54. https://doi.org/10.1016/j.agwat.2016.05.005

Hirich, A. & Choukr-Allah, R. 2013. Wastewater reuse in the Mediterranean region: Case of Morocco. *13th edition of the World Wide Workshop for Young Environmental Scientists (WWWYES-2013) - Urban waters: resource or risks?* Arcueil, France.

Kaplan, R. & Blume, R. 2011. *Urban Homesteading: Heirloom Skills for Sustainable Living*. Skyhorse Publishing, New York, USA.

Lancaster, B. 2011. Rainwater Harvesting for Drylands and Beyond: Volume 1. Rainsource Press.

Lupia, F. & Pulighe, G. 2015. Water use and urban agriculture: estimation and water saving scenarios for residential kitchen gardens. *Agriculture and Agricultural Science Procedia*, 4: 50–58. https://doi.org/10.1016/j.aaspro.2015.03.007

Ragab, R., Evans, J. G., Battilani, A. & Solimando, D. 2017. Towards Accurate Estimation of Crop Water Requirement without the Crop Coefficient Kc: New Approach Using Modern Technologies. *Irrigation and Drainage*, 66: 469–477. http://doi.org/10.1002/ird.2153

Seitz, S., Goebes, P., Loaiza Puerta, V., Pujol Pereira, E.I., Wittwer, R., Six, J., van der Heijden, M.G.A., & Scholten, T. 2019. Conservation tillage and organic farming reduce soil erosion. *Agronomy for Sustainable Development*, 39: 4. https://doi.org/10.1007/s13593-018-0545-z

4.9 Life cycle environmental impact of urban horticulture

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Due to rapid urban population growth during the past several decades, food supply has become one of the key resource flows in cities. Since food production contributes to a variety of impacts, such as greenhouse gas emissions and deforestation (Foley *et al.*, 2011), urban agriculture is expected to help reduce these impacts while contributing to a variety of economic and social benefits (Despommier, 2013; Kortright and Wakefield, 2011; Lovell, 2010; Müller and Sukhdev, 2019; Thomaier *et al.*, 2015; Zezza and Tasciotti, 2010). From an environmental perspective, urban horticulture, commonly referred to as urban agriculture (UA) can reduce transport emissions while releasing pressure from agricultural land (Specht *et al.*, 2014). For UA to generate these benefits, an understanding of a city's potential to supply different types of food is needed. Not only is UA meant to meet the dietary requirements of urban populations, but also to accomplish this goal at the lowest environmental cost.

Because UA can be expressed in multiple forms, there are several classifications available in the literature. One classifies the current institutional definitions of UA into different components: spatial, origin, functional, actor, stakeholder, market, motivation and process. On the other hand, and with a multiparameter classification, other researchers propose a division between soil and building-based UA.

In this presentation, which is part of a larger study funded by the European Bank for Reconstruction and Development and the FAO Investment Centre, we covered how UA can be expressed in different forms, giving a sense of dynamism to the concept. We argue that the variety of UA systems and their specific features (artificial lighting, hydroponics, protected cultivation in greenhouses, heating and ventilation, etc.) have a direct impact on the life cycle environmental profile of the system, although individual analyses are recommended when designing mitigation strategies. Two examples to illustrate this were provided in the presentation.

A final message relates to the unique opportunity that UA offers to reuse and recirculate residuals flows within urban limits, not only within the system itself, but with other more established and interlinked systems such as wastewater treatment plants or industrial composting plants.

References

Despommier, D. 2013. Farming up the city: The rise of urban vertical farms. *Trends in Biotechnology*, 31: 388–389.
https://doi.org/10.1016/j.tibtech.2013.03.008

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D. *et al.* 2011. Solutions for a cultivated planet. *Nature*, 478: 337–342.
https://doi.org/10.1038/nature10452

Kortright, R. & Wakefield, S. 2011. Edible backyards: A qualitative study of household food growing and its contributions to food security. *Agriculture and Human Values*, 28: 39–53.
https://doi.org/10.1007/s10460-009-9254-1

Lovell, S.T. 2010. Multifunctional Urban Agriculture for Sustainable Land Use Planning in the United States. *Sustainability*, 2(8): 2499–2522.
https://doi.org/10.3390/su2082499

Müller, A. & Sukhdev, P. 2019. *Measuring what matters in agriculture and food systems*. Geneva, Switzerland, The Economics of Ecosystems and Biodiversity.

Specht, K., Siebert, R., Hartmann, I., Freisinger, U.B., Sawicka, M., Werner, A., Thomaier, S., Henckel, D., Walk, H. & Dierich, A. 2014. Urban agriculture of the future: An overview of sustainability aspects of food production in and on buildings. *Agriculture and Human Values*, 31: 33–51. https://doi.org/10.1007/s10460-013-9448-4

Thomaier, S., Specht, K., Henckel, D., Dierich, A., Siebert, R., Freisinger, U.B. & Sawicka, M. 2015. Farming in and on urban buildings: Present practice and specific novelties of Zero-Acreage Farming (ZFarming). *Renewable Agriculture and Food Systems*, 30(1): 43–54. https://doi.org/10.1017/S1742170514000143

Zezza, A. & Tasciotti, L. 2010. Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries. *Food Policy*, 35(4): 265–273. https://doi.org/10.1016/j.foodpol.2010.04.007

4.10 Ecosystem services in urban agriculture in Quito

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Since 2002, the Municipality of the Metropolitan District of Quito, Ecuador, through the Economic Promotion Corporation, CONQUITO, has implemented the AGRUPAR project, a participatory urban agriculture initiative, to promote agroecological production, social, climate and gender equity, responsible consumption, as well as greater resilience and sustainability.

The main impacts of this project have been the improvement and availability of healthy food for the inhabitants of poor urban areas, increased economic opportunities, ecosystem benefits and significant changes in consumer behaviour through the creation of 2 200 gardens covering 65 hectares. The gardens are a multifunctional, nature-based contribution to the city's green infrastructure.

The intervention focuses on the areas of greatest poverty and chronic child malnutrition in Quito, with the participation of more than 4 500 farmers each year, the majority of whom are women heads of household (84 percent).

The incorporation of agroecosystems in cities represents a significant paradigm shift in urban planning and design. Gardens provide a series of ecosystem benefits to cities that compensate for part of the damage caused by urban systems where cement and asphalt prevail.

The services provided by urban agriculture include: support to quality of life by being immersed in the urban green network; regulation of climate, water resources and soil quality; erosion control; habitat creation for wild species; seed dispersal and pollination; noise reduction; biological control; and food services contributing to food security. The cultural services of leisure and recreation, environmental education and knowledge recovery, contribution to the landscape, natural and cultural heritage, tourism, spirituality, sense of belonging and cultural identity, create a platform for ecological commitment and ecoactivism.

Urban agroecology includes activities such as waste separation for composting or humus production, reuse of materials, water optimization, crop rotation and association, soil conservation and prevention of food loss and waste.

The orchards contribute to carbon sequestration, nitrogen fixation, rainwater infiltration, reduction of heat islands and alveolus effects, increase of biodiversity, reduction of transportation, packaging, refrigeration and storage needs.

Regulating services have direct implications on climate adaptation and mitigation. Cultural services, on the other hand, influence human beings and their environment in a particular geographic and cultural context. The garden becomes the space for sharing, conversing, remembering, recovering and building lives and communities.

Urban agriculture has a strong influence on the construction of healthy food environments, adoption of sustainable diets and planetary health diet, ensuring food for farming families and their immediate environment, the gardens can generate about 105 types of fresh food and artisanal food processing.

Urban agriculture contributes to food sovereignty, improves income, generates entrepreneurship, restores and regenerates ecosystems. Its contribution in times of crisis is irrefutable, given the increase of food resilience at the neighbourhood scale, contributing to healthy and environmentally sustainable nutrition.

Chapter 5. Natural resource management

Parallel session: Maximizing resource-use efficiency

5.1 Towards a circular bionutrient economy linking sanitation and agriculture

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Modern sanitation and modern agriculture are both enormous human achievements that have come with huge costs. Contemporary crises of soil depletion, water pollution, food insecurity and climate change call for new approaches to management of the nutrients upon which our food systems depend. The rising price of synthetic fertilizers has brought new attention to the "old but bold" idea of recovering the nutrients and carbon from human excreta for use in agriculture. This is an area of innovation for a small but lively community, with distinct approaches being taken depending upon context. At the household or neighbourhood scale, nutrients in urine can be used directly as a crop fertilizer, while processing is needed to enable longer-range movement of the nutrients in excreta. Work on the use of crop residues, biochar and excreta to produce agronomic substrates for urban gardening were presented, as well as strategies for producing carbon-rich fertilizers based on organic underutilized resources.

5.2 Optimizing water use: lessons from around the globe

Marco Arcieri
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Mostly due to climate change, farmers all over the world are increasingly facing challenges such as recurrent droughts, changes in precipitation and other changes in the environment affecting agricultural production. The overall challenge is the need to produce up to 50 percent more food by 2030, and to double production by 2050. This will also have to be achieved with less water and with less land, mainly because of pressures deriving from increasing urbanization, higher rates of industrialization and changes in the dietary habits of populations. Most of the world's population growth will occur in low-income countries, where water shortages are already critical, many residents are resource-poor, and food production may soon be limited by water availability. Presently, agricultural water use is not sustainable in many areas around the world, due to environmental constraints such as soil salinization, groundwater overexploitation and the over-allocation of available surface water supplies. Farmers will need to achieve higher efficiency in irrigation, while improving their overall water and natural resources management, adopting different strategies and solutions.

On the supply side, **water managers** and **service providers** need to minimize losses in distribution networks, from the source to the end users, and ensure that distribution is efficient and equitable, to achieve economically, socially and environmentally sustainable management of water resources. This means, for instance, allowing timely and efficient irrigation by ensuring that water supply is spread over the production seasons, sound water management in rain-fed agricultural areas, proper drainage and prediction of extreme events such as floods and droughts, and ecosystem conservation, with respect of associated cultural and recreational values. Research and development (**R&D**) programmes need to find appropriate solutions for irrigation methods, cropping patterns and cultural techniques, providing farmers more autonomy, flexibility and long-term solutions adapted to their needs, and leading the way to more resilient farming systems. However, efficient and effective water-resource management should not rely only on the introduction of new technologies.

Many studies have shown that to improve irrigation management, efforts must focus on the empowerment of water users, and increase their involvement in the adoption of innovative approaches. Therefore, as **farmers** are the primary actors in the agricultural sector, it is necessary to raise their competence and awareness to improve efficiency and productivity of irrigated agriculture, especially when it comes to irrigation scheduling on the farm, one of the most prevalent causes of water wastage. Encouraging results are achieved in some countries, where so called "expert systems" have been developed to support farmers in their irrigation-scheduling activities. More pervasive agricultural extension services, such as newly conceived training and education programmes, especially those regarding monitoring and prediction of extreme climate events, can be of great help in improving farmer resilience, by providing them with proper, often timely information, and raising their confidence in the adoption of advanced solutions.

Thus, the role of **farmers** in the sustainable management of water resources is at least as crucial as compared to that of irrigation-service providers, academics, researchers and other stakeholders.

Another important aspect to consider is the implementation of adequate water-management **policy** measures. It is nowadays crucial to ensure that charges for water supplied to agriculture reflect full supply costs. In many countries, farmers are only covering the operation and maintenance costs, with little recovery of the capital costs necessary for infrastructure. Where countries have raised the issue of water charges, the available evidence indicates that charges have improved water-use efficiency rather than reduced the outputs. Also, the over-exploitation of on-farm water resources, mainly groundwater, which usually involves licences and other regulatory instruments, needs to be addressed with a new approach. Today, because of the high transaction costs necessary to enforce compliance, in many countries the degradation and the illegal pumping of groundwater remains a dramatic challenge. To achieve sustainable groundwater use, more efforts will be required to enforce regulatory measures and to develop mechanisms for quantitative management and charging, especially where water stress is a major issue.

References

ICID (International Commission on Irrigation and Drainage). 2014. Food Security by optimal use of water: Synthesis of Theme 2.2 of the 6th World Water Forum, March 2012. Marseilles, France.

EIP-AGRI Service. 2020. *Sustainable and resilient farming. Inspiration from agro-ecology*. European Commission. 8 pp. https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_brochure_agro-ecology_2020_en_web.pdf

OECD. 2010. *Sustainable Management of Water Resources in Agriculture*. Paris, OECD Studies on Water, OECD Publishing. https://doi.org/10.1787/9789264083578-en

5.3 Improving nutrient management to increase crop productivity and sustainability

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Managing nutrients in a sustainable manner is key to sustainable crop production. As one of the essential inputs for food production, chemical fertilizers play an important role in increasing productivity. China has managed to feed its growing population with less than 9 percent of the world's arable land – the effectiveness of chemical fertilizers is beyond doubt. This achievement was however accomplished with huge costs to the environment, such as water eutrophication and soil acidification due to the overuse of chemical fertilizers. Developing and implementing effective nutrient-management practices in crop production became a priority in order to maintain a sustainable food supply. After years of experiments on multiple sites, along with the science and technology backyards (STB) approach (Zhang *et al.*, 2016), we established an integrated soil–crop system management (ISSM) for intensive farming systems. One feature of ISSM is that it matches the nutrient supply in the root zone of the soil with the temporal and spatial demands of the crops. The three key practices of ISSM are: (1) taking all possible sources of nutrients into consideration during crop production; (2) matching nutrient supply with the temporal and spatial demands of the crops; (3) increasing crop yield significantly by integrating the best varieties and agronomy practices. ISSM was tested across various ecological zones in China. The results indicate that this approach can increase crop yield by 30 percent, while simultaneously reducing greenhouse gas emission by 50 percent (Chen *et al.*, 2014; Cui *et al.*, 2018).

Besides the novelty of nutrient-management technologies, knowledge transfer is another key point for sustainable crop production. A new approach called "science and technology backyards" (STB) was developed, where professors and graduate students worked together with small-scale farmers in villages across China. Graduate students live in the villages and serve as technology consultants whenever farmers are not certain of best practices. One of the most prominent characteristics of STB is the direct engagement between scientists and farmers. In order to scale up adaptive technologies at a regional level, onsite graduate students hold field training programmes for farmers. They also maintain a series of field trials for long-term demonstration. In this process, the coinnovation and colearning between scientists and small-scale farmers were the key steps to empower farmers with adaptive technologies for sustainable crop production. Beyond the village scale, farmers and academics in STB work closely with local government, extending the influence of STB to the county level, realizing a large-scale green and sustainable transformation of traditional intensive agriculture. The STB approach has been acknowledged and advocated by the Chinese government as an effective model of green development. The STB approach therefore is a successful example to achieve food security and environmental sustainability at the same time, with wide adoptability in China and other economies with similar issues in the world.

References

Cui, Z.L., Zhang, H.Y., Chen, X.P., Zhang, C.C., Ma, W.Q., Huang, C.D., Zhang, W.F. *et al.* 2018. Pursuing sustainable productivity with millions of smallholder farmers. *Nature*, 555: 363–366. https://doi.org/10.1038/nature25785

Zhang, W.F., Cao, G.X., Li, X.L., Zhang, H.Y., Wang, C., Liu, Q.Q., Chen, X.P. *et al.* 2016. Closing yield gaps in China by empowering smallholder farmers.

Nature, 537: 671–674.
https://doi.org/10.1038/nature19368

Chen, X., Cui, Z., Fan, M., Vitousek, P., Zhao, M., Ma, W., Wang, Z. *et al.* 2014. Producing more grain with lower environmental costs. *Nature*, 514: 486–489.
https://doi.org/10.1038/nature13609

5.4 How making food from forgotten desert trees can strengthen both food security and biodiversity

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When we look at drylands such as the Sahara and the Sahel, we typically see dry landscapes of unimpressive scrubs that seem to be of little value. In the search for human development, we clear them to make way for agriculture, so that we can produce real food. What we often fail to realise is that this natural vegetation that we are destroying or supressing often contains a large number of highly valuable forgotten food plants, such as *Boscia senegalensis, Maerua crassifolia, Balanites aegyptiaca, Ziziphus mauritiana, Sclerocarya birrea* and more. They produce food that contains very good nutritional properties, being rich in proteins (including all eight essential amino acids), unsaturated fats, carbohydrates, vitamins and various essential minerals. Their productivity is often higher than that of the annual cereals supplanting them. For example, the productivity of *Boscia senegalensis* is over two times as high as the average yield for rainfed cereals in Niger, providing an average of 100 g of dried grains per occupied square meter. In other words, when clearing out these crops from the fields, we are not removing unproductive vegetation to better produce food crops, but we are removing rich sources of potential food to produce a narrower and less productive set of human foods. By bringing these forgotten foods back to more modern use, new markets can be created, developing inclusive value chains that offer opportunities to food-insecure communities with few economic prospects. This in turn engages rural small-scale farmers in tree protection and propagation activities, accelerating the regreening efforts and the fight against desertification taking place in the Sahel.

References

Garvi, J. & Garvi-Bode, R.D. 2020. Using market incentives to drive regreening: the case of Sahara Sahel Foods in Niger. *ETFRN News*, 60: 103–110.

Maman Mato, H. 2014. Evaluation de la capacité de la productivité du « hanza » dans la région de Zinder. Zinder, Niger, University of Zinder. Thesis dissertation (in French).

5.5 Cocreation of knowledge between farmers and researchers

Chukki Nanjundaswamy
International Planning Committee for Food Sovereignty (IPC)

This presentation is not based on formal analyses or critiques but starts from on-farm reports.

We are at a very important junction in human history, as shown by nature's call for emergency. For example, in Karnataka state in southern India, climate change has had a severe impact on peoples' livelihoods during the past few years. Last year, the state lost 40 percent of its agricultural produce. This year, people have reported to have not experienced a summer season, only a monsoon season, and while residents should usually be entering the drier winter by now, they are still receiving rains. In one district, where farmers practice rainfed farming, mostly growing maize and cotton, 118 farmers have committed suicide due to crop losses, increased debts and other factors.

Cocreation of knowledge requires an inclusive approach to agriculture, recognizing the interlinkages of specializations, such as soil health, climate change and plant production. Our approach to agriculture should be based on this holistic approach and be in harmony with nature. In the Global South, most farmers are small-scale producers, fishers and pastoralists, some of them landless. These are the people who are most significantly and most directly affected by the detrimental impacts of climate change.

We need to be honest and transparent in our communication and approach to food production. While the Sustainable Development Goals (SDGs) highlight the importance of food security, social and farmer movements, such as La Via Campesina, urge people to strive for food sovereignty based on decisions about what and how one wants to grow crops and produce food in a decentralized manner.

Since agroclimatic zones are decentralized, they cannot be managed by one corporation, or one organization, alone. Researchers and farmers must come together and learn to co-create knowledge, especially generations of farmers farming before the green revolution. The green revolution has brought immense contributions to food security. However, it has also led to a loss of crop and farm-system diversity. This historical event has contributed to the present existential crisis, requiring us to learn from our ancestors and Indigenous Peoples to co-create knowledge with those who lived in harmony with nature for many years. We need to foster co-creation of knowledge, beyond inclusion of academics, researchers and farmers alone.

Parallel session: Ecosystem approaches to resilience

5.6 Multifunctional landscapes

Lucas Garibaldi
Director, IRNAD, Professor, UNRN, Senior Researcher, CONICET, Argentina

International agreements aimed to conserve 17 percent of the Earth's land area by 2020, but included no area-based conservation targets within the working landscapes that support human needs through farming, ranching and forestry. A review of country-level legislation found that just 38 percent of countries have minimum area requirements for conserving native habitats within working landscapes. Increasing native habitats to at least 20 percent of working landscape area, where it is below this minimum, is recommended. Such a target has benefits for food security, nature's contributions to people, and the connectivity and effectiveness of protected area networks in biomes in which protected areas are underrepresented. Maintaining native habitat at higher levels, where it currently exceeds the 20 percent minimum, is also recommended. Another literature review showed that more than 50 percent of native habitat restoration is needed in certain landscapes. The post-2020 Global Biodiversity Framework is an opportune moment to include a minimum habitat restoration target for working landscapes that contributes to, but does not compete with, initiatives for expanding protected areas, the United Nations Decade on Ecosystem Restoration (2021–2030) and the SDGs.

Knowledge of the role of native habitats within working landscapes in providing nature's contributions to people has accumulated in recent decades, offering numerous successful examples of restoration and multiple associated benefits. However, implementation of native-habitat restoration, especially through policy, remains limited, and those habitats continue to be degraded and eliminated. The time has come to reverse this trend. Including a native-habitat restoration target offers an unrivalled opportunity to simultaneously enhance biodiversity, food security and quality of life.

References

Garibaldi L.A., Oddi, F.J., Miguez, F.E., Bartomeus, I., Orr, M.C., Jobbagy, E.G., Kremen, C. *et al.* 2021. Working landscapes need at least 20% native habitat. *Conservation Letters*, 14(2): e12773. https://doi.org/10.1111/conl.12773

5.7 Efficient production for resilience in small-scale systems

Arjumand Nizami
Country Director, Helvetas Swiss Intercooperation, Pakistan

The number of people affected by hunger globally rose to 828 million in 2021, an increase of about 46 million since 2020, and 150 million since the outbreak of the COVID-19 pandemic, jeopardizing the achievement of the SDGs. Producing more food with less environmental impact, while diversifying food systems, is of crucial importance in Pakistan, where food insecurity consistently remained high over the years and gaps further widened due to frequent disasters such as floods in 2022, engulfing over 3.8 million hectares of productive land. Farmers are particularly affected due to their frequent exposure to disasters, inability to cope with risks, limited access to land and water resources, and fluctuating markets for essential agricultural inputs. Poor governance of already scarce water is adding to the problem, especially for small-scale farmers and tail-end farmers in a catchment. On the consumer side, quality food is unaffordable for the poor, affecting their nutrition status. There are multiple pathways for addressing these complex issues. Two examples have been demonstrated through projects by Helvetas Swiss Intercooperation, with highly successful results for small-scale farmers.

Vertical-bag vegetable gardening improved productivity for small-scale farmers, particularly women. The tested technology is highly resilient to extreme weather events such as hailstorms, intense rain and windstorms. The technology reduces the labour effort and improves the productive potential of land, water and external inputs. A nearly four-times production increase was noted per unit of land when compared to a conventional method. Improved vegetable production can enhance nutrition and incomes of poor households. Due to resource efficiency, it has a low carbon footprint. Vegetables produced have improved harvest quality and an extended picking period. In the recommended design for a vertical farm (i.e. 110 square metres of land per farm unit), initial costs are involved. However, in a business model, these costs are recovered in one year depending on the farmers' ability to make the most of the technology. The technique received an excellent response from women. Replication potential looks bright.

The second example comes from Punjab's rice fields. Alternate wetting and drying (AWD), a method of rice cultivation with reduced water input, has proven to be the lifeline for tail-end farmers. Nearly 60 percent of irrigation needs are met from groundwater, which is costlier than government-managed canal irrigation systems due to fuel prices incurred from pumping. AWD is managed through perforated tubes in farm fields. The tubes indicate the water level and thereby guide farmers on when to irrigate fields. The use of AWD tubes for water management can reduce irrigation demand by 30–40 percent, and thus provides a very important tool for saving water in rice cultivation without affecting yield. In a project called WAPRO, Helvetas induced private-sector investment and participation to contribute to popularizing this method and market it in Europe.

In both examples, we have worked closely with government-led extension services to achieve upscaling potential. The costs of both technologies are comparatively small, and responses are noticeable. Similar simple and affordable techniques at farmer level are helpful in achieving efficient food production in small-scale systems to improve farmers' resilience, economic status and well-being.

References

Ali, J., Zulfiqar, M. & Nizami, A. 2019. Does improved water productivity matter for the farmers? A case of water-efficient rice production from Pakistan. *Journal of Developing Country Studies*, 9(9): 58–65. https://doi.org/10.7176/DCS/9-9-07

Government of Pakistan. 2021. Pakistan Updated Nationally Determined Contributions 2021. Government of Pakistan. Islamabad. https://unfccc.int/sites/default/files/NDC/2022-06/Pakistan%20Updated%20NDC%202021.pdf

IRRI (International Rice Research Institute). 2021. Nutrient content of organic materials. In: Rice knowledge Bank. Manila, IRRI. Cited 13 August 2022. http://www.knowledgebank.irri.org

von Grebmer, K., Bernstein, J., Wiemers, M., Schiffer, T., Hanano, A., Towey, O., & Ekstrom, K. 2021. *Global Hunger Index 2021. Hunger and Food Systems in Conflict Settings*. Concern Worldwide and Welt Hunger Hilfe. https://www.globalhungerindex.org/ranking.html

5.8 Australian perspectives on farmer-led regeneration of agricultural ecosystems health

Walter Jehne,[1] Ben Fox[2]
[1]Climate Scientist, Microbiologist and Founder of Healthy Soils Australia
[2]Public advocate of creativity

The global trend towards industrial agriculture over the past century has raised gross food outputs, but also raised externalized costs. These costs, often hidden, come from the degradation of soils, water bodies and biosystems, impacting the overall health of populations. We now depend on and are vulnerable to global agricultural inputs and subsidy fluctuations.

These dependencies and vulnerabilities bring into question global industrial agriculture's viability and risks to the health, sovereignty and survival of nations and regions. For example, the dangerous hydrological climate extremes we now witness and that are intensifying and endangering populations around the planet, are caused by the effects of human practices on the environment leading to the degradation of soils, hydrologic systems and biosystems that we live in.

We urgently need to strengthen and enhance the resilience of complex self-adapting biosystems to buffer, survive and ultimately regenerate and thrive in these extremes. We fundamentally rely on our agroecosystems for food, fibre and water. However, at a deeper level, biosystems are our homes, schools, villages, cities, workplaces, rivers, hills, forests, pastures, mountains, lakes and seas – ultimately our livelihoods.

In the Australian context, ancient ecosystems have developed on nutrient-deficient soils. As a result, ecosystems have coevolved to harbour highly beneficial soil microbes and have resulted in the establishment of symbioses enabling ecosystems to grow and survive. These processes underpin Australia's highly resilient and productive natural biosystems, and natural capital values. Experience with these systems has forced Australian ecoagriculture specialists to become adept at resilience design and ecosystem management on marginal farmlands with minimal inputs.

Case studies in Australia and Andhra Pradesh, India, confirm the scientific veracity and potential of new agroecological farmer-led approaches to meeting future food needs, while enhancing nutritional values and natural capital regeneration. We can act now to shape our home/biosystems to ensure the future is a welcoming, hospitable and secure place.

5.9 Building resilience through agroecological innovation in arid and semi-arid lands

Paulo Petersen
Executive Coordinator, AS-PTA – Family Farming and Agroecology, Brazil

Farming is the economic sector that most closely connects society to living nature. The natural resources used in agriculture cannot be viewed as an endless reservoir to be exploited indefinitely. Any perspective of agricultural sustainability must be based on the principle that natural resources need to be reproduced, regenerated and developed as elements of living nature.

Furthermore, living nature, not being completely predictable and controllable, repeatedly confronts farmers with surprises. Attempts to control the dynamics of living nature so that agriculture operates as a mass production economy result in increased vulnerability. In this sense, building agricultural resilience requires reconciling economic production with ecological reproduction. The agroecological approach to agricultural innovation articulates both dimensions, representing food systems as economic–ecological systems. In this sense, from an agroecological perspective, resilience is a socioecological issue. It is directly related to the web of economic–ecological flows, configured to enhance and convert local natural resources in economic values. These webs gain materiality both in biophysical (ecological) flows and in social (economic) relationships.

Resilience is the result of the diversification and densification of economic–ecological flows, both at the scale of agroecosystems and at the level of territorial food systems. Water is a critical resource in arid and semi-arid lands. In these environmental contexts, strategies of agroecological innovation combine three integrated fronts: (1) capturing and storing rainwater for the production of biomass with economic value (i.e. use and exchange values); (2) structuring of biodiverse agroecosystems, with various production subsystems integrated with each other through economic–ecological flows; (3) structuring and networking collective action devices as mediators of economic–ecological flows between agroecosystems, and between them and consumers in a given territory.

These principles for sociotechnological innovation were applied in the Brazilian semi-arid region through the implementation of a set of public policies aimed at family farming over the past 20 years. As a result, higher levels of agricultural resilience and lower rates of poverty and food and nutrition insecurity were identified.

References

Petersen, P., Monteiro, D., Del Arco, C., Mattos, C., Telles, L., Silveira, L. & Ferreira Neto, P.S. 2022. [Lights in the Sertão; trajectories of Social Emancipation in Family Farming in the Semi-Arid Region of Bahia, Brazil – Effects of the Pró-Semiárido Project according to the Lume method]. Salvador, Brazil, Pro-Semiarido. 164 pp (in Portuguese).

Monteiro, D., Silveira, L. & Petersen, P. 2022. Fartura tem demontão: Public policies and socio-ecological resilience in traditional communities of pastureland in the Sertão do São Francisco, Bahia. In: E. Sabourin, L. Oliveira, F. Goule & E. Martins, eds. *Public policies for adapting agriculture to climate change in semi-arid Northeast Brazil*. Rio de Janeiro, Brazil, E-Papers.

5.10 Regenerating the world's grasslands through holistic management

Nicholas Sharpe
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This time in history is characterized by the disintegration of ecological, social and economic systems into climactic, political and social unrest while the world gets hotter, and its inhabitants more at unease.

Land users together with corporate, charitable and institutional entities are being called upon to create systemic value – to change the nature of agriculture and their supply chains. The goal is to repurpose and channel their resources, talents and programmes directly where they are needed most: on the land, our shared sustaining source, and in the hands of those who care for it.

At the heart of the Savory Group is the Savory Institute, a non-profit organization based in Boulder, Colorado, United States of America, with 54 regional, locally owned and operated learning hubs around the globe. Founded in 2009, the Institute has trained over 16 000 farmers, ranchers and pastoralists, and influenced management on 22 million hectares of grasslands through the adoption of holistic planned grazing – a process mimicking ancestral grazing patterns of wild herbivores that coevolved with healthy grassland ecosystems. Developed by Allan Savory in the 1960s, holistic management (HM) has been proven in a wide variety of contexts to regenerate grasslands, aid soil health, increase biodiversity and sequester significant amounts of carbon while improving social and economic outcomes (Gosnell, Grimm & Goldstein, 2020). Savory's Global Network is composed of accredited professionals that work through local Savory hubs to provide HM training, resources and implementation support to local farmers, ranchers and pastoralists, as well as land monitoring and verification. With an intimate knowledge of local culture, economy, policies and environment, hubs mentor producers and help them implement regenerative practices in a culturally relevant and ecologically appropriate manner specific to a particular region.

Savory's public-benefit corporation, Land to Market, connects conscientious buyers, brands and retailers directly to farms and ranches verified to be regenerating their land, creating the world's first outcomes-based verified regenerative sourcing solution for the food and fibre industries.

Designed to rapidly grow the impact of the Savory Group, the Savory Foundation activates new global partnerships and catalyses global transformation at the intersection of regenerative finance, climate change and regenerative agriculture.

A large-scale project management arm of Savory, the Impact Landed programme was developed to leverage the Savory Institute's decades of experience and resources for impact at a truly global scale. Impact Landed engages all Savory Group programmes to build capacity with on-the-ground partners and serve the supply demand for Land to Market clients, providing channels for large-scale capital investments and programmes seeking solutions at the same scale as problems.

Together, Savory Group's programmes provide farmers with a range of tools and mechanisms to regenerate their lands, livelihoods and communities by providing a holistic framework for decision-making amid the challenges and opportunities they face in a rapidly evolving and complex world.

References

Gosnell, H., Grimm, K. & Goldstein, B.E. 2020. A half century of Holistic Management: what does the evidence reveal? *Agriculture and Human Values*, 37: 849–867. https://doi.org/10.1007/s10460-020-10016-w

Savory Institute. 2023. Science Library. In: *Savory Institute*. Boulder, USA. Cited 14 March 2023. https://savory.global/science-library/

Chapter 6. Integrated pest management

Parallel session: Challenges in plant pests and diseases

6.1 Climate change, plant pests and pathogens

Daniel Bebber
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Global food security is threatened by climate change, both directly through responses of crop physiology and productivity (Jägermeyr *et al.*, 2021), and indirectly through responses of plant-associated microbiota including plant pathogens (Bebber, 2015). While the interactions between host plants, pathogens and environmental drivers can be complex (Fones *et al.*, 2020), recent research is beginning to indicate certain overall patterns in how plant diseases will affect crop production in the future (Raza and Bebber, 2022b).

This presentation reviewed the results of three methodological approaches: large-scale observational studies, process-based disease models and experimental comparisons of patho-systems under current and future conditions (Raza & Bebber, 2022b). Observational studies have tended to identify rising temperatures as the primary driver of disease impact. Process-based models suggest that rising temperatures will lead to latitudinal shifts in disease pressure, but drying conditions could mitigate disease risk. Experimental studies suggest that rising atmospheric CO_2 will exacerbate disease impacts. Plant diseases may therefore counteract any crop yield increases due to climate change.

Finally, a new approach to understanding potential crop disease impacts is introduced, namely the analysis of field trials of crop varieties in which fungicide-treated and untreated yields are compared (Raza and Bebber, 2022a). Field trial data from the United Kingdom of Great Britain and Northern Ireland show that winter and spring varieties of wheat and barley will be differentially affected by climate change, with winter varieties increasingly vulnerable to disease due to wetter spring weather, and spring varieties benefitting from drier summers. Similar analyses of trials should be conducted in other regions to reveal the global impact of climate change on fungal disease pressure.

References

Bebber, D.P. 2015. Range-Expanding Pests and Pathogens in a Warming World. *Annual Review of Phytopathology*, 53(1): 335–356. https://doi.org/10.1146/annurev-phyto-080614-120207

Fones, H.N., Bebber, D.P., Chaloner, T.M., Kay, W.T., Steinberg, G. & Gurr, S.J. 2020. Threats to global food security from emerging fungal and oomycete crop pathogens. *Nature Food*, 1(6): 332–342. https://doi.org/10.1038/s43016-020-0075-0

Jägermeyr, J., Müller, C., Ruane, A. C., Elliott, J., Balkovic, J., Castillo, O., Faye, B. *et al.* 2021. Climate impacts on global agriculture emerge earlier in new generation of climate and crop models. *Nature Food*, 2(11): 873–885. https://doi.org/10.1038/s43016-021-00400-y

Raza, M. M. & Bebber, D. P. 2022a. Climate change, biotic yield gaps and disease pressure in cereal crops (p. 2022.08.12.503729). *BioRxiv*, 8(12): 503729. https://doi.org/10.1101/2022.08.12.503729

Raza, M. M. & Bebber, D. P. 2022b. Climate change and plant pathogens. *Current Opinion in Microbiology*, 70: 102233.
https://doi.org/10.1016/j.mib.2022.102233

6.2 Pesticide pollution – an underrepresented environmental problem

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The environmental impacts and footprints of the global food system have been extensively assessed in the past few decades, with the majority of studies focusing on greenhouse gas emissions, land use, water resources, nitrogen pollution and biodiversity loss. In contrast, pesticides, one of the main inputs of intensive agriculture, receive relatively less attention in the global-scale assessments, potentially hindered by the lack of a comprehensive geographic quantification of active ingredient use and residues.

To fill in this gap, the geographic- and crop-specific application rates of various active ingredients were estimated at the global scale (Maggi *et al.*, 2019). The estimated application rates were then used together with a spatially explicit environmental model to assess the risk of pesticide pollution in global agricultural land (Tang *et al.*, 2021). The assessment shows that about 74 percent of global agricultural land is at some risk of pesticide pollution, and about one third is at high pollution risk, with 34 percent of high-risk areas located in high-biodiversity regions and 19 percent in low- and lower-middle-income countries.

By coupling the spatially explicit environmental model to a multiregion input–output (MRIO) model that tracks more than a billion supply chains starting from first producers to final consumers, the pesticide footprints of nations were quantified to understand how international trading drives pesticide pollution (Tang *et al.*, 2022). This analysis shows that about 34 percent of the total global pesticide footprints were caused by consumption in developed countries, where approximately 18 percent of the global population resides. In developed countries, about 49 percent of the pesticide footprints were imported, meaning that the use of pesticides to satisfy the demands occurred abroad. On the other hand, only about 23 percent of pesticide footprints in developing countries were imported. High-income countries generally have a high per capita pesticide footprint.

These studies emphasise the urgent need to transition towards sustainable agriculture with low pesticide inputs and a sustainable lifestyle with reduced food loss and food waste. Strategies and policies for such a transformation should involve international cooperation and partnerships to ensure the environmental and social burdens of pesticide pollution are not transferred to other countries. To increase the robustness of global pesticide pollution assessments, it is crucial for researchers to have access to detailed and extensive datasets of pesticide use and field-monitoring measurements. Government authorities are urged to improve the collection and reporting of detailed pesticide-use data, increase investment in field monitoring campaigns and publish the data as open access.

References

Maggi, F., Tang, F.H.M., la Cecilia, D. & McBratney, A. 2019. PEST-CHEMGRIDS, global gridded maps of the top 20 crop-specific pesticide application rates from 2015 to 2025. *Scientific Data*, 6(1): 1–20.
https://doi.org/10.1038/s41597-019-0169-4

Tang, F.H.M., Lenzen, M., McBratney, A. & Maggi, F. 2021. Risk of pesticide pollution at the global scale. *Nature Geoscience*, 14(4): 206–210.
https://doi.org/10.1038/s41561-021-00712-5

Tang, F.H.M., Malik A., Li M., Lenzen, M. & Maggi, F. 2022. International demand for food and services drives environmental footprints of pesticide use. *Communications Earth & Environment*, 3(1): 1–12. https://doi.org/10.1038/s43247-022-00601-8

6.3 Biological invasions and their economic costs on agriculture

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In addition to triggering biodiversity loss, biological invasions are responsible for substantial economic losses to society, as well as monetary expenditures for their management (Pyšek *et al.*, 2020). A reliable, global synthesis of the economic costs of invasive alien species has been lacking until the recent advent of the InvaCost database – the most comprehensive synthesis of the monetary impacts of invasions worldwide (Diagne *et al.*, 2020). The first analysis of the robust subset of this database yielded invasions costs of a minimum of USD 1.900 trillion (2017 dollar value) to human society over the past five decades (1970–2020), with a consistent threefold increase per decade; up to USD 162.7 billion were estimated to have been incurred for the year 2017 (Diagne *et al.*, 2021). These costs remain massively underestimated and underreported, and their substantial increase over the past few decades does not show any sign of slowing. This financial burden of invasions is widely distributed at regional and taxonomic scales, and mostly encompasses damage from invaders rather than management expenditures.

Biological invasions cause large economic costs to agriculture, among the most affected activity sectors, but those costs have never been quantified collectively and at a global scale. Here we examined the cost to agriculture in the wide sense (including beekeeping, horticulture, viticulture, aquaculture, etc.) of biological invasions worldwide (Turbelin *et al.*, 2023). InvaCost was combined with a global database of known invasive species impacting resource-based economic sectors (the CABI invasive species compendium), and two scenarios that characterized the distribution of missing cost data to report observed costs and estimate missing costs. From 1970 to 2020, observed costs to agriculture totalled USD 509 billion (2017 dollar value), with a large cost associated with contaminants introduced unintentionally. Cost information was missing for many species listed as impacting resource-based sectors, indicating gaps in cost reporting even for well-known problematic species. Based on extrapolation, total costs to agriculture from 1970 to 2020 were estimated to be ranging from USD 516.4 billion to USD 1.4 trillion. Available data indicate that agriculture incurs the greatest reported costs from biological invasions globally and in 37 percent of the countries assessed. While the United States of America accumulated the most costs for resource-based industries (USD 365 billion), followed by China (USD 101 billion) and Australia (USD 36 billion), 20 at-risk countries that are highly economically reliant on agriculture and are more likely to suffer from the economic impact of biological invasions were also identified.

The pioneering study is a compelling call for (1) the implementation of management actions and international policy agreements aiming to reduce alien species threats over the coming decades, and (2) improving research on the consequences of biological invasions. It can be found, together with all the other studies based on the InvaCost database of the economic costs of biological invasions, here: www.invacost.fr

References

Diagne C., Leroy. B., Gozlan R., Vaissière A-C., Roiz, D., Nunninger L., Assailly C., Jaric I. & Courchamp F. 2020. INVACOST: a public database of the global economic costs of biological invasions. *Nature*

Scientific Data, 7(1): 277.
https://doi.org/10.1038/s41597-020-00586-z

Diagne, C., Leroy, B., Vaissière, AC., Gozlan, R.E., Roiz, D., Jaric, I., Salles, J.M., Bradshaw, C.J.A. & Courchamp, F. 2021. High and rising economic costs of biological invasions worldwide. *Nature*, 592: 571–576.
https://doi.org/10.1038/s41586-021-03405-6

Pyšek, P., Hulme, P.E., Simberloff, D., Bacher, S., Blackburn, T.M., Carlton, J.T., Dawson, W. *et al.* 2020. Scientists' warning on invasive alien species. *Biological Reviews*, 95(6): 1511–1534.
https://doi.org/10.1111/brv.12627

Turbelin, A.J., Hudgins, E.J., Catford, J.A., Cuthbert, R.N., Diagne, C., Kourantidou, M., Roiz, D. & Courchamp, F. 2023. Biological invasions as burdens to primary economic sectors. *Research Square*.
www.researchsquare.com/article/rs-2444595/v1
https://doi.org/10.21203/rs.3.rs-2444595/v1

6.4 Area-wide IPM in locust control: current knowledge and challenges

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Locusts and swarming grasshoppers are a unique challenge because outbreaks may occur infrequently, they are extreme, and a single upsurge can extend across many ecological and cultural contexts. Therefore, most management approaches focus at national or international levels, with limited farmer involvement, and depend predominantly on chemical pesticide and some biopesticide treatments. For species that originate in agricultural areas, however, a viable suppression programme can be led by farmers through soil fertility.

Degraded soils with low soil organic matter and nitrogen result in growth of plants with low protein and high carbohydrate contents. Locusts and grasshoppers require a lot of energy in the form of carbohydrates or lipids to fuel their migration – making low fertility fields an optimal habitat to promote outbreaks and migration. Moreover, how farmers manage their fields not only affects neighbouring farmers, but also distant communities because these insects migrate long distances en masse. Thus, programmes that promote soil health in locust- and migratory-grasshopper-prone regions also assist to keep populations of these pests at bay.

My presentation provided an overview of the biology and management of locusts and swarming grasshoppers, recent findings on their nutritional ecology in relation to land-use practices and results from a pilot-area-wide integrated pest management (IPM) programme in Senegal. Ways to engage with the Global Locust Initiative Network that co-creates and shares resources, and connects stakeholders from over 40 countries, were shared.

References

Cease, A.J., Elser, J.J., Ford, C.F., Hao, S., Kang, L. & Harrison J.F. 2012. Heavy Livestock Grazing Promotes Locust Outbreaks by Lowering Plant Nitrogen Content. *Science*, 335(6067): 467–469.
https://doi.org/10.1126/science.1214433

Le Gall, M., Overson, R. & Cease A. 2019. A Global Review on Locusts (Orthoptera: Acrididae) and Their Interactions with Livestock Grazing Practices. *Frontiers in Ecology and Evolution*, 7: 263.
https://doi.org/10.3389/fevo.2019.00263

Therville, C., Anderies, J.M., Lecoq, M. & Cease, A. 2021. Locusts and People: Integrating the Social Sciences in Sustainable Locust Management. *Agronomy*, 11(5): 951.
https://doi.org/10.3390/agronomy11050951

Word, M.L., Hall, S.J., Robinson, B.E., Manneh, B., Beye, A. & Cease A.J. 2019. Soil-Targeted Interventions Could Alleviate Locust and Grasshopper Pest Pressure in West Africa. *Science of The Total Environment*, 663: 632–643. https://doi.org/10.1016/j.scitotenv.2019.01.313

6.5 Prevention of transboundary spread of pests and pathogens is enhanced with farmer support

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More than 1 300 pests and pathogens threaten crops globally, with an estimated economic impact of around USD 540 billion annually (Paini *et al.*, 2016; Royal Botanic Gardens, Kew, 2017; Kumar *et al.*, 2021). The severe damage inflicted by introduced pests and pathogens represents a serious threat to food systems and biodiversity. Unregulated germplasm transfers and exchanges have been recognized as an essential pathway for spreading pests and pathogens through human collection and distribution activities (moving pests between geographies and introducing them into new regions where they did not exist before) (Elmer, 2001). The spread of pests has increased dramatically in recent years through agricultural trade and the unintentional movement of infected living materials (e.g. infected seed, tissue culture materials), climatic factors (e.g. wind, rainfall), and insect or other vectors (Bebber *et al.*, 2014; Santini *et al.*, 2018). Therefore, extreme care is required to ensure that the exchanged germplasm is pest-free. CGIAR has established Germplasm Health Units (GHUs) to guarantee the safe movement of plant materials, along with compliance with IPPC procedures and the International Standards for Phytosanitary Measures (ISPMs) applied by national plant protection organizations (NPPOs) to prevent the introduction and control the spread of pests along with plants or plant products (Kumar *et al.*, 2021). To safeguard countries from quarantine risks (e.g. transmission of insect pests, pathogens and weeds) associated with the movement of germplasm, ICARDA's GHU follows a regulatory and quarantine programme working in close collaboration with competent institutions where ICARDA has platforms for crop breeding, germplasm multiplication, evaluation and genetic resources. ICARDA's GHU is responsible for the monitoring, clearance and documentation of safe germplasm movement at the centre, and shares updated technology with NPPOs in host countries and farmers. To produce high-quality and healthy seed, farmers should apply the following practices at different crop stages: (1) before planting: selecting zones with minimum disease pressure, properly applying crop rotations, using certified seed, avoiding local or unknown seed sources, etc.; (2) during crop establishment: undertaking field inspections to eradicate infected plants as soon as observing abnormal symptoms, applying pesticides at the most appropriate timing to prevent pest emergence, implementing weed control, etc.; and (3) at the end of the season: using good harvesting machines and seed-cleaning techniques, applying fumigation, ensuring good storage conditions, etc. Additionally, farmers should be encouraged to collaborate by delivering samples for testing from their fields and from harvested materials to official authorities at the end of the season.

In the case of detecting new emerging pests, it is the farmer's responsibility to notify the NPPO of any unusual symptoms or signs in the field, and they should follow the instructions of the NPPO, especially in the case of eradication. Moreover, trading infected seed and keeping them as planting material for the next season should be prohibited. The farmer is the connector between the plant and the NPPO to identify any unknown symptoms or signs in the field, conduct regular field visits to observe plant health status, and act in case of any invasive new pest. To ensure reports from farmers on pest outbreaks are as timely, honest and transparent as possible, proper communication channels and support mechanisms (i.e. lowering the economic loss in case of yield losses due to pest outbreaks) need to be put in place, establishing a sense of collaboration.

References

Bebber, D.P., Holmes, T. & Gurr, S.J. 2014. The global spread of crop pests and pathogens. *Global Ecology and Biogeography*, 23(12): 1398–1407. https://doi.org/10.1111/geb.12214

Elmer, W.H. 2001. Seeds as Vehicles for Pathogen Importation. *Biological Invasions*, 3: 263–271. https://doi.org/10.1023/A:1015217308477

Royal Botanic Gardens, Kew. 2017. Plant Health – state of Research. In: K.J. Willis, ed. *State of the World's Plants* 2017. 64–71 pp. Royal Botanic Gardens, Kew. www.kew.org/about-us/press-media/state-of-the-worlds-plants-2017

Kumar, P.L., Cuervo, M., Kreuze, J.F., Muller, G., Kulkarni, G., Kumari, S.G., Massart, S. *et al.* 2021. Phytosanitary Interventions for Safe Global Germplasm Exchange and the Prevention of Transboundary Pest Spread: The Role of CGIAR Germplasm Health Units. *Plants*, 10: 328. https://doi.org/10.3390/plants10020328

Paini, D.R., Shappard, A.W., Cook, D.C., De Barro, D.J., Woomer, S.P. & Thomas, M.B. 2016. Global threat to agriculture from invasive species. *Proceedings of the National Academy of Sciences*, 113(27): 7575–7579. https://doi.org/10.1073/pnas.1602205113

Santini, A., Liebhold, A., Migliorini, D., & Woodward, S. 2018. Tracing the role of human civilization in the globalization of plant pathogens. *The ISME Journal*, 12: 647–652. https://doi.org/10.1038/s41396-017-0013-9

Parallel session: Solutions for plant pest and disease management

6.6 Coordination of digital tools for locally adapted decision support in IPM

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Numerous digital tools are being developed to provide information to aid decision-making and timing of integrated pest management (IPM) strategies. Tools can support users to identify, monitor, manage, control and predict outbreaks of pests and diseases in agricultural crops. However, the number of applications and their targeted use may provide a surplus of tools that are challenging to navigate one by one. The objective of this presentation was to share information on how digital systems can be coordinated to support each other, aiming to provide targeted and locally adapted information to end users, such as a plant health service in Malawi.

The Norwegian open-source pest-prediction platform VIPS is designed to facilitate integration with other digital services, and was originally developed to meet the needs of Norwegian farmers. Examples of such collaboration include integrations with the FAMEWS app launched by FAO, ongoing developments for integration of the Fall Armyworm Phenology Model with the IITAs Farmer Interface App, and the recently launched IPM Decisions platform (www.platform.ipmdecisions.net). As a product of the European Union–funded IPM Decisions project, the IPM Decisions platform is designed to provide farmers and advisors with access to existing pest and disease risk models of relevance for their regional conditions. The technologies, experience and web services created to provide data catalogues for decision support systems (DSSs), weather data sources and standards for data exchange are open source and will contribute to further developments in other services.

The advances and advantages achieved by coordination of internationally developed systems are generating the foundation for the establishment of an agricultural plant health service in Malawi. The main goal of the Malawi Digital Plant Health Service (MaDiPHS) project is to provide a tool for targeted and efficient pest and disease management of selected crops. MaDiPHS will build and expand on the successes achieved and data assets obtained in multiple systems, such as PlantVillage (plantvillage.psu.edu), VIPS (nibio.no/vips), PlantWise (www.plantwise.org) and IITAs Farmer Interface App (www.iita.org), contributing to a common international platform which will feed into national digital clients – with Malawi as a pilot country.

The Malawi plant health service will combine national, regional and global input data with international web platforms to feed into and create a national digital client adapted to meet local user needs. MaDiPHS will follow a coproduction approach to provide information relevant for decision support in agriculture targeted at farmers, extension agents, research scientists and agricultural decision-makers at a district or national level in Malawi. As part of this approach, users will be involved in decision-making on priorities of contents, format of information, and means of communication to ensure local ownership and sustainability of the service.

6.7 Changes in farmer perception and adoption of biological control

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Globally adopted intensive farming techniques have resulted in increased productivity per hectare but have also driven the demand for pesticides. Rising awareness of the adverse effects of broad-spectrum chemical pesticides on the environment led to their banning in many countries. Consequently, a reduction in the availability of control methods for some pests has been observed. In this scenario, biological control can foster the transition to more sustainable agriculture. The current popularity of biological control among politicians, policymakers, retailers and growers is due to many factors. In some countries, a well-defined regulatory system has facilitated the use of microbial solutions to provide alternatives to organic agriculture or to replace synthetic pesticides.

The increased number of applications for registrations of biopesticides has forced regulatory authorities to adopt procedures and legislation to meet the unique requirements of biopesticides and to speed up the registration process. These changes have brought greater diversification of new technologies, of comparatively low toxicity, to farmers.

The most significant change in recent decades was the perception by farmers that biopesticides, previously considered inefficient, are effective, measured by the high level of farmer satisfaction. There is also a greater appreciation of their environmental advantages by growers and the public. Biological control agents, previously mainly used in protected cropping systems such as greenhouses, are now being widely implemented in open fields.

Widespread adoption of biologicals for field crops and cereals is being observed in South America. With the access of many start-ups and small- and medium-sized national companies into the plant protection market, traditionally dominated by a few multinational companies, market fracturation occurred. Thus, there is great potential to reduce the dependence of low- and middle-income countries on imported chemical pesticides.

Although the global market for biopesticides is still small, the future is promising for the application of biopesticides to reach a much larger area than today and thus contribute to more environmentally friendly farming.

References

Shoham, J. & McDougall, P. 2020. The rise of biological products in the crop protection and plant nutrition markets. *Outlooks on Pest Management*, 31(3): 129–131. https://doi.org/10.1564/v31_jun_09

Arthursa, S. & Dara, S.K. 2019. Microbial biopesticides for invertebrate pests and their markets in the United States. *Journal of Invertebrate Pathology*, 165: 13–21. https://doi.org/10.1016/j.jip.2018.01.008

Barros, S. & Coffani V. 2022. Brazilian Legislation for Biopesticides – On-farm Biopesticides Production. Washington DC, United States Department of Agriculture Foreign Agricultural Service. 9 pp. https://usdabrazil.org.br/wp-content/uploads/2022/07/Brazilian-Legislation-for-Biopesticides-On-farm-Biopesticides-Production_Sao-Paulo-ATO_Brazil_BR2022-0045.pdf

6.8 Application of precision agricultural aviation technology in an ecological unmanned farm

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This presentation introduced precision agricultural aviation technology (PAAT), an on-demand pesticide-application technology.

First, prescription maps are generated according to crop information obtained through ground and aerial remote sensing technology. Then, the aerial spray system is applied based on the prescription maps, satellite position and navigation system.

This presentation also introduced the exploration and practice of the first ecological unmanned farm, built in Zibo, Shandong, China.

Digital technologies, such as the Internet of Things, big data, fifth-generation networks and artificial intelligence, have played important roles in achieving the aforementioned advances.

Based on PAAT and ecological unmanned farm technologies, labour costs are reduced by 50 percent, and pesticides and fertilizer use are reduced by more than 30 percent, providing benefits for farmers and the environment.

References

Lan Y., Chen S. & Fritz B.K. 2017. Current status and future trends of precision agricultural aviation technologies. *International Journal of Agricultural & Biological Engineering*, 10(3): 1–17.

Lan, Y., Zhao D., Zhang Y. *et al.* 2021 Exploration and development prospect of eco-unmanned farm modes. *Transactions of the CSAE*, 37(9): 312–327.

6.9 Participatory innovation platform for plant health management

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Enabling farmers to adopt sustainable practices that maintain plant health transcends knowledge extension. Change in farmer knowledge is needed, but this requires alignment with that of other relevant stakeholders. A broad framework involving multiple stakeholders and incorporating technologies and socioeconomic arrangements. This is required to create the supportive context needed for adoption by farmers and enable the shift towards sustainable management practices, creating incentives for the change.

The International Rice Research Institute and its partners in Cambodia piloted an approach for supporting innovations in IPM through adaptive learning networks (ALNs). This approach is different from current IPM approaches in that it explicitly engages a diverse range of stakeholders to enable adoption of innovations by farmers. For example, accessing IPM products, providing new service, and creating new local policies or incentive mechanisms were an intrinsic part of the learning process, alongside learning on-farm IPM techniques. The main consideration was to ease farmers from their reliance on pesticides.

The ALN approach merges learning on the farm, which is an adaptive research process with technical inputs from outside the farm. The farmers experiment with technical options and identify preferred techniques and tools. Then they integrate those new techniques and tools into their existing farm-management practices. Alongside this learning, other stakeholders, such as service providers, manufacturers and sellers of biological-control products, are engaged both informally as well as through facilitated trade fairs.

The multistakeholder learning approach led to the adaptation of the IPM tools and techniques whereby stakeholders create new products or services (added value) and new sociotechnical arrangements. The priority of the ALN method is sociotechnical learning, where varied stakeholders change the way they link to each other, create incentives for adoption and find enabling conditions for sustainable pest management.

Comparing 2016 and 2019 data, there was a significant reduction in insecticide, herbicide and rodenticide applications. The observed outcomes indicate potential to enable a wider spread of IPM technologies through adaptive learning networks.

References

Dara, S.K. 2019. The New Integrated Pest Management Paradigm for the Modern Age. *Journal of Integrated Pest Management*, 10(1): 12. https://doi.org/10.1093/jipm/pmz010

Douthwaite, B. & Gummert, M. 2010. Learning selection revisited: How can agricultural researchers make a difference? *Agricultural Systems*, 103(5): 245–255. https://doi.org/10.1016/j.agsy.2010.01.005

Flor, R.J., Maat, H., Hadi, B.A.R., Then, R., Kraus, E. & Chhay, K. 2020. How do stakeholder interactions in Cambodian rice farming villages contribute to a pesticide lock-in? *Crop Protection*, 135: 104799. https://doi.org/10.1016/j.cropro.2019.04.023

Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S. & Smits R.E.H.M. 2007. Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change* 74(4): 413–432. https://doi.org/10.1016/j.techfore.2006.03.002

Parsa, S., Morse, S., Bonifacio, A., Chancellor, T.C.B., Condori, B., Crespo-Pérez, V., Hobbs, S.L.A. *et al.* 2014. Obstacles to integrated pest management adoption in developing countries. *Proceedings of the National Academy of Sciences* 111(10): 3889–3894. https://doi.org/10.1073/pnas.1312693111

6.10 Farmer-oriented and science-driven plant health management for West Africa

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In Africa, a farmers' decision to spray their crops is most often either calendar-based or triggered by visual and conspicuous symptoms of pest infestation. This practice has led to the indiscriminate use of synthetic pesticides, with unintended side-effects on human, animal and environmental health. Although integrated pest management (IPM) was introduced about sixty years ago, by establishing an intervention threshold aiming to reduce the frequency of applications, small-scale farmers did not acquire the management skills and instead continued to use hazardous pesticides as their first control option. Nowadays, most West African farmers continue to face a widespread lack of appropriate tools to enable them to take informed decisions, and have limited access to alternatives to harmful pesticides (Deguine, Aubertot and Flor, 2021).

We are therefore proposing a new paradigm for farmer-oriented and science-driven plant health management, which is anchored on three pillars:
(1) real-time farmer access to decision-making,
(2) pest-management options relying on science-driven and nature-based approaches,
(3) the integration of genomic approaches, biopesticides and habitat-management practices (Tamò *et al.*, 2022).

The development of simple apps such as the Farmer Interface Application (FIA) illustrates progress in educating and empowering farmers to take more-informed decisions. FIA assists farmers in recognizing early stages of the presence of pests in the field, in a random manner guided by GPS coordinates to determine an intervention threshold and response. Animation videos, voice recognition and commands guide low-literacy users through the different functions of the app, addressing the needs of all genders, ages and social groups (Tepa Yotto *et al.*, 2021).

For many years, the pod borer *Maruca vitrata* has been tacitly categorized as an "indigenous" pest in Africa, with most control approaches relying on pesticide applications and improved host plant resistance. However, recent population genetic studies have revealed that this pest likely originated in tropical Asia. The finding is supported by biodiversity studies on hymenopteran parasitoids of *M. vitrata* in Asia. Studies have uncovered a large diversity of parasitoids with specifically two efficient species, *Phanerotoma syleptae* and *Liragathis javana* (Hymenoptera, Braconidae), causing field parasitism rates of up to 60 percent. In West Africa, on the other hand, indigenous natural enemies observed attacking M. vitrata are non-specific and poorly adapted to the host.

Based on the above-mentioned findings, both parasitoids were introduced from the World Vegetable Center (AVRDC) to the labs of the International Institute of Tropical Agriculture (IITA), Benin Station, as possible candidates for biological control interventions (Srinivasan, Tamò and Periasamy, 2021). After more than two years of confined testing at IITA and upon obtainment of release permits, both parasitoids were experimentally released in Benin. Encouraged by the establishment and preliminary impact data (of up to 86 percent reduction of pod-borer populations at pilot release sites), releases are continuing in Burkina Faso, Niger (recording establishment two years after first releases) and Nigeria.

This new paradigm based on technological advances, involvement of young people, gender-responsiveness and climate resilience can be a game changer in plant health management. However, it can only become effective through redeployment of public funding and stronger policy support.

References

Deguine, J.P., Aubertot, J.N., Flor, R.J., Lescourret, F., Wyckhuys, K.A.G. & Ratnadass, A. 2021. Integrated pest management: good intentions, hard realities. A review. *Agronomy for Sustainable Development*, 41: 38. https://doi.org/10.1007/s13593-021-00689-w

Srinivasan, R., Tamò, M. & Periasamy M. 2021. Emergence of *Maruca vitrata* as a Major Pest of Food Legumes and Evolution of Management Practices in Asia and Africa. *Annual Review of Entomology*, 66: 141–161. https://doi.org/10.1146/annurev-ento-021220-084539

Tamò, M., Glitho, I., Tepa-Yotto, G. & Muniappan, R. 2022 What does IPM 3.0 look like (and why do we need it in Africa)? *Current Opinion in Insect Science*, 53: 100961. https://doi.org/10.1016/j.cois.2022.100961

Tepa-Yotto, G.T., Winsou, J.K., Dahoueto, B.T.A. & Tamò, M. 2021. Assessing New Scouting Approaches for Field Sampling of *Spodoptera frugiperda* and Its Parasitoids. In: *Proceedings of the 1st International Electronic Conference on Entomology*, 1–15 July 2021. Basel, Switzerland. https://doi.org/10.3390/IECE-10397

Chapter 7. Mechanization and digitalization

Parallel session: Smart mechanization

7.1 Agricultural mechanization: where are we and where are we going

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The Green Revolution saw the spread of new high-yielding varieties of crops, supported by the application of irrigation, fertilizers, pesticides and agricultural machinery, which helped to reduce hunger and malnutrition, and freed up labour. Agricultural machinery developed in relation to equipment for water pumping, soil preparation, seeding and planting, crop protection, harvesting, threshing and transporting. In 2021, the agricultural machinery market was estimated at USD 10 billion in India and USD 150 billion globally, with a compound annual growth rate of 4–8 percent. In the Asia and the Pacific region, India and China account for more than 40 percent of the revenue share.

The average land holding size in Asia is about one hectare. In India, 85 percent of land holdings are below 2 ha and about 50 percent of the population is dependent on agriculture to sustain their livelihoods. On small farms, usage of <10Kw power tillers is commonly observed. Farmers need pull-based sustainable machinery for small farms; however, custom hiring centres of machinery are having issues with finance and service provision. More "uberization of farm machinery" is expected and TAFE, a manufacturer in India, provided related services during COVID-19–related lockdowns.

The demand for organic, diversified and nutritious food has increased, and many farmers have started adopting organic and agroecological farming practices. These changes, partly incurred by climate change, warrant more equipment for soil and water conservation and precision irrigation systems, to reduce input costs of water, fertilizers and chemicals.

By 2050, farmers must produce 70 percent more food to feed an estimated global population of 9 billion people. There will be shortages of land for human food and livestock feed. There will be a need for more technology adoption, including biotechnology, in plant-based protein production to replace animal-based protein. However, climate change has been observed to pose problems for vegetable cultivation in Europe and elsewhere.

Conservation agriculture is expected to expand, as will tools and equipment that are needed for this practice, such as for no-till seeding, residue management and intercropping. Equipment must become affordable and sustainable, and more awareness must be created on conservation agriculture as it can produce more with less inputs and is more environmentally friendly.

With increasing demand for fruit and vegetables, controlled-environment agriculture (CEA) farms will grow rapidly. Europe and Japan already produce 30 percent of nutrients in CEA, even in times of energy challenges. To be successful, CEA relies on automatization in terms of climate control, fertigation, harvesting and processing including the use of robots.

Farm mechanization is not limited to open-field cropping of cereals, but also encourages development and use of light multipurpose electrified prime movers, precision irrigation and fertigation systems that can reduce input costs. Small-scale local food processing solutions are in demand. With advances in UAV, block chain, big data and artificial intelligence, more pull-based innovations are expected to provide advisory services on designing cropping patterns, seeding/planting, managing nutrients and water, scheduling harvest and undertaking farm gate collections, and to provide efficient control systems to automate agricultural mechanization.

7.2 Digital innovations and precision agriculture – an opportunity for small-scale farming systems in sub-Saharan Africa

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Despite reported economic growth in Africa, food insecurity, malnutrition and poverty levels, especially in sub-Saharan Africa (SSA), remain high. The agriculture sector in SSA is mainly composed of small-scale farmers that play an important role in ensuring food security. Despite its vital role across households, plant production in SSA has been declining. In most countries of SSA, farmers have poor access to inputs, minimal or lack of extension and support services, suboptimal management practices and poor access to markets. Minimal standards and lack in precision use of inputs to boost productivity prevail. Most government recommendations use a "one size fits all" approach on the use of inputs, which is inefficient.

Digital innovations and precision agriculture technologies that have been tested in SSA have shown promising results. These technologies provide information that is farm-specific. They include, to name a few examples, intelligent and integrated decision-support systems for intercropping to provide diagnostic information for common crop diseases, digital soil mapping that considers soil fertility constraints to determine crop suitability for common beans in the United Republic of Tanzania, microdosing fertilizer application in millet-production systems in Niger for improved nutrient use efficiency, and use of a soil diagnostic model combined with geographic information systems to develop site-specific fertilizer recommendations for cocoa production in Ghana. Additionally, wireless sensors for real-time plant water stress detection have been used to optimize drip irrigation in Burkina Faso and Malawi, Digital Green – a development organization for extension advisory services – and UjuziKilimo have been operating in Kenya for real-time soil testing, Ghana-based Farmerline and AgroCenta mobile and web technologies have provided advisory services to farmers in remote areas with poor connectivity and low literacy, and Cameroon's AgroSpaces and Nigeria's Zenvus zPrices have provided pricing data to remove price-information asymmetry between farmers and buyers.

Implementation of these technologies, however, faces some challenges. For example, the use of certain precision-agriculture technologies depends and relies on advanced machinery and computer software that is differentially utilized depending on the socioeconomic and technological advancement of countries. Hence, certain software has been reported to be in use in, for example, South Africa and Nigeria, which are technologically advanced compared to other countries on the continent. Full technology integration, in real time, is another challenge. Other challenges include low levels of digital literacy, language barriers, norms and traditions, aggravated by inadequate extension services in most countries. Even with all the challenges mentioned, the use of these technologies in input and management practices among small-scale farmers in SSA can greatly improve productivity. Their application must aim to address farmer needs, to improve productivity and to ensure sustainable food systems. For example, the integration of remote sensing and real-time wireless sensor technologies to accelerate planning, design and construction of irrigation systems in SSA will improve irrigation water-use efficiency and increase crop yields in areas where water is a major limiting factor.

References

Bhalla, N. 2021. Africa's farmers are increasingly using digital tools but not everyone feels the benefits. In: *How We Made Africa*. Cape Town, South Africa. Cited 14 March 2023. www.howwemadeitinafrica.com/africas-farmers-are-increasingly-using-digital-tools-but-not-everyone-feels-the-benefits

Ekekwe, N. 2017. How Digital Technology Is Changing Farming in Africa. In: *Harvard Business Review*. Boston, USA. Cited 14 March 2023. https://hbr.org/2017/05/how-digital-technology-is-changing-farming-in-africa

Sodiya, A.S., Akinwale, A.T., Okeleye, K.A. & Emmanuel, J.A. 2010. An Integrated Decision Support System for Intercropping. *Integrated and Strategic Advancements in Decision Making Support Systems*, 2: 51–66. https://doi.org/10.4018/978-1-4666-1746-9.ch015

Soropa, G., Nyamangara, J. & Nyakatawa, E.Z. 2019. Nutrient status of sandy soils in smallholder areas of Zimbabwe and the need to develop site-specific fertiliser recommendations for sustainable crop intensification. *South African Journal of Plant and Soil*, 36: 149–151. https://doi.org/10.1080/02571862.2018.1517901

KALRO (Kenyan Agricultural & Livestock Research Organization). 2023. KALRO Crop Selector. In: KALRO. Nairobi, KALRO. Cited 14 March 2023. https://selector.kalro.org

7.3 Mechanization solutions for enhanced climate resilience, productivity and reduced environmental footprints in drylands of the Global South

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The world's drylands form an extensive biome, covering around 45 percent of the Earth's land surface, supporting 2.5 to 3 billion people and 1.4 billion (48 percent) of the world's livestock. Drylands are home to the majority of the world's poor, with around 16 percent living in chronic poverty. Dryland regions are also the global "hotspots" for contemporary and future climate vulnerability, with more stressed natural resources as compared to other regions. Drylands are home to many small-scale farmers, while being among the most food- and water-deficient regions of the world. It is well documented that anthropogenic climate change has already slowed down global agricultural productivity growth by 21 percent. The highest impact of climate change has been observed in dryland regions of the world, especially in Africa and South Asia, which has posed a serious threat to food and nutritional security to the livelihoods of billions in the semi-arid tropics (SAT). Moreover, in the SAT of the Global South, populations are expected to grow, which will increase pressure on already-stressed natural resources to produce food, while climate change makes challenges greater.

Small-scale farmers in SAT regions are highly vulnerable to frequent extreme weather events due to limited economic, human and institutional capacity to respond. As a result, food production in many countries in the SAT is decreasing. Without corrective measures, this decrease in food production will further compound challenges. The agrifood systems in drylands require systemic solutions that are climate-smart, regenerative, affordable and profitable, to reduce the burden of malnutrition and alleviate small-scale farmers from the negative impact of climate change in the SAT.

Immediate actions are required to fuse technologies, innovations, strategies and investments towards production of more nutritious food from less inputs while regenerating natural resources and building resilience to increased climatic variability. In a systems-thinking context, use of agricultural mechanization within a sustainability framework can bring a wide range of benefits through time efficiency speeding up operations in the food-production process, such as increased yields, reduced production costs, increased cropping intensity, increased efficiency of production inputs, reduced post-harvest losses and reduced drudgery for farm workers. However, context-specific and scale-appropriate value chain mechanization solutions are critical for: (1) increasing productivity per unit of land, time, labour and capital, and building resilience; (2) reducing environmental footprints through efficient and careful use of inputs; (3) conserving or enhancing natural resources; and (4) ensuring equity, societal benefits and reducing farmer risks. We need to develop, refine and target scale-appropriate mechanization solutions to the diversity of plant production systems. Stakeholder-driven capacity building and policy proposition, coupled with increased investments, are critical for impact at scale. Evidence-based mechanization solutions for enhanced climate resilience, increased productivity and reduced environmental footprints, as well as research gaps in drylands of the Global South, were presented.

7.4 Business models and economics perspectives of agricultural mechanization development

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This presentation highlighted key issues around business models of successful custom-hiring services in conventional and modern sustainable mechanization, and relevant policy issues. It first reviewed a typology of mechanization service models based on scientific studies and highlighted key principles of success factors and investment priorities.

The presentation then highlighted related concrete lessons from mechanization growth in Asia and emerging lessons from Africa. Demand for mechanization services can vary and affect the viability of services. Demand also depends on economic growth, industrialization and urbanization in the region. Tractor use for land preparation in Asia has grown even in extremely land-scarce countries, where small- to medium-sized tractors and combine harvesters were still accessed through custom-hiring services. Local manufacturing grew gradually, starting from spare parts, attachments, then machines. Subsidies, when needed, were provided in ways to keep distortions at minimum and to ensure market competitiveness. Credit was often provided by machine sellers, as well as commercial banks taking land-use rights as collateral. The multifunctionality of machines was fully exploited. While Africa can have different business environments for mechanization service provisions, many of these principles remain relevant for mechanization service providers operating in Africa.

While spatial heterogeneity of the agroecological environment is well-known in developing countries, recent research findings further illustrate that the adoption of tractors and agricultural equipment among small-scale farmers has been induced by yield-enhancing biological technologies, particularly improved varieties and high-yielding production systems, when these biological technologies are instrumented by agroclimatic similarity to plant breeding locations. In Ghana, for example, tractor custom-hiring service providers often travel to distant districts if those districts have sufficiently high-yielding production systems.

Scope exists for improving the efficiency of service provisions. Recent research in Nigeria shows that obtaining tractors from private markets or from private individuals is more efficient than those who receive tractors through government programmes, by providing services to a greater area at lower costs, including during off-peak seasons, and sometimes even selecting machinery types according to soil types. This suggests that African governments promoting the growth of custom-hiring service providers in mechanization can focus on enhancing their business efficiency through training.

From a policy perspective, Ghana's recent examples of adaptive public support are an important case in point. The Ghanaian government has adapted its strategies over the years in attempting to overcome market failures associated with agricultural mechanization services. For example, Ghana's AMSEC Phase II (2016 onwards), reflecting on the lessons from AMSEC Phase I, has incorporated various modifications, including improving the competitiveness of potential service providers by expanding eligibility criteria, providing greater support for maintenance, providing mobile workshop vans, strengthening spare-parts supply networks, exploiting multifunctionality of machines and promoting greater brand diversity. Similar adaptive support systems can be encouraged in other African countries.

The presentation also highlighted cases of custom-hiring services for more modern sustainable mechanization methods like zero-tillage, laser-land-levelling and precision farming, as well as potentials and challenges for emerging uber-typed tractor hiring services and mechanization application to solar-powered cold-storage in Nigeria.

References

Diao, X., Takeshima, H. & Zhang, X. 2020. An Evolving Paradigm of Agricultural Mechanization Development: How Much Can Africa Learn from Asia? Washington DC, International Food Policy Research Institute. https://doi.org/10.2499/9780896293809

Houmy, K., Rojas, M.F. & Side, C. 2021. Agri-hire in Sub-Saharan Africa: Business models for investing in sustainable mechanization. Rome, FAO. https://doi.org/10.4060/cb5071en

Takeshima, H., Diao, X. & Aboagye, P. 2020. Policies for competitive and sustainable agricultural production systems: A case study of Ghana's recent mechanization interventions. In: D. Resnick, X. Diao & G. Tadesse, eds. *Annual trends and outlook report: Sustaining Africa's agrifood system transformation: The role of public policies*. Washington DC, IFPRI. https://doi.org/10.2499/9780896293946_05

Takeshima, H., Edeh, H., Lawal, A. & Isiaka, M. 2014. Tractor owner operators in Nigeria: Insights from a small survey in Kaduna and Nasarawa states. *IFPRI Discussion Paper 1355*. Washington DC, IFPRI.

7.5 The Africa We Want: Agenda 2063: The Sustainable Agricultural Mechanization Framework – towards commercial, environmental and socioeconomic sustainability

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The African Union Agenda 2063: The Africa We Want captures a workable dream of an Africa that takes charge of its own development. A continent that has increased unity, to allow it to be a global power, capable of rallying support around its own common agenda for development and enhanced investment opportunities. The 50-year vision of the Agenda 2063 was adopted in 2013. Since then, more urgent challenges have arisen. More proactive action is needed to ensure that Africa's agrifood systems become more diverse, productive and resilient to today's shocks and stresses. Climate change, political conflicts and a war with far reaching impacts on agribusiness performance and food supply call for increased partnerships, plant productivity and sustainable intensification.

The renewed urgency is multifaceted. Fortunately, responses by the African Union Commission (AUC) in collaboration with FAO were already being actioned. Climate-smart agriculture had been under promotion for the last decade and a half, with a key realization: to rapidly apply conservation agriculture at scale, enhanced agricultural mechanization provisions and capacities are required.

In line with Agenda 2063 and heeding the rallying call of "Sending the hoe to the museums of Africa", AUC and FAO initiated an elaborate consultative process that published the Framework for Sustainable Agricultural Mechanization for Africa (F-SAMA). The framework acts as a tool for African governments to develop private-sector-led national strategies for agricultural mechanization.

Mechanization efforts and services need unique African business models that are not only climate-smart but also sensitive to small-scale farmers' needs, in terms of availability, accessibility, affordability and accountability. As it stands, Africa lacks mechanization capacity. The continent reported a paltry 0.2 kW/ha compared to India's 2.5 kW/ha in farm-power availability. Africa is a continent where there are 2 tractors per 1 000 hectares, compared to the world average of 16 tractors per 1 000 hectares (FAO, 2023; Index Mundi, 2021).

For Africa, mechanization models must be value-chain complete and farming-systems oriented. Modern-day models feature an orientation towards one-stop centres of excellence (COE) where value-chain developers and business supporters can congregate to merge efforts that help agribusinesses thrive. COEs make it possible to deliver education, technology and innovation interventions at one location, while respecting the position of the farmers as central stakeholders. In COEs, extension agents, researchers, financiers, aggregators and off-takers, market-providers, regulators and policy makers manage to keep farmer needs in perspective, while modelling and demonstrating modern-day market-linked farming and agribusiness. It is at COEs that modern-day farming skills can be developed while building competitiveness, cooperation and scale for markets to respond. From COEs, proven practices are expanded and replicated in more locations and agroecologies across the land. The goal will be Africa excelling at establishing robust and home-grown problem-solving and development capacity. Capacity to grow strong foundations to take charge of the continent's own development. To deliver in a competitive and dynamic global market. To make Agenda 2063 real and achievable.

This presentation takes the view that much more attention and resources have gone to the What and the Why of technology transfer processes, compared to the How. To help agricultural mechanization progress more rapidly, it is business models, such as those that would be nurtured in inclusive value-chain COEs that are needed. It is at perfected and replicable COEs that all value-chain practitioners can finally play a bigger role, under public–private partnerships that build sustainable change, fuelled by growing and farmer-sensitive agribusinesses.

For Africa to leap-frog its mechanization and agribusiness efforts as imagined in Vision 2063, the F-SAMA initiative has a great opportunity to support ongoing private-sector efforts that have their foundations and the makings of COEs. Such hubs of development energy, common learning, technology transfer and innovation are showing new promise, across the continent. It is the support and expansion of these one-stop value-chain hubs that potent AUC- and FAO-led networks need to be further established and advanced (AGRA, 2018; AGRA, 2020; Regenerators, 2022; Semonegna, 2017). To give these initiatives the power to leap-frog, policy makers and technocrats will need to modify approaches, to understand farmers differently, to place them in charge as prime members of the private-sector fraternity. Continental networks have worked well previously but with limited inclusion of the private sector. They have successfully mobilized institutions, teams and resources. The most memorable are the Animal Traction Network for eastern and southern Africa (www.ATNESA.org) and the Africa Conservation Tillage Network (www.ACT-Africa.org) and their national-level offshoots.

References

AGRA. (Alliance for a Green Revolution in Africa). 2018. Working Business Models for Sustainable Agricultural Mechanization in Africa. Zed Group for Alliance for A Green Revolution in Africa. Contract No. 12024, November 2017. Internal document.

AGRA. 2020. A Conservation and Climate-Smart Agriculture Capacity Building Manual for Ethiopia. Participatory Small-scale Irrigation Development Programme (PASIDP II) Project. Ministry of Agriculture and Natural Resources of Ethiopia. Project No. 2000001134. Agrimech Africa Ltd. Improved Seed and Soil Fertility Management Project. Internal document. www.AGRA.org

FAO. 2023. FAO. Cited 14 March 2023. www.fao.org

Index Mundi. 2021. Index Mundi. Cited 14 March 2023. www.indexmundi.com

KALRO (Kenyan Agricultural & Livestock Research Organization). 2023. KALRO Crop Selector. In: KALRO. Nairobi, KALRO. Cited 14 March 2023. https://selector.kalro.org

Parallel session: Digital agriculture

7.6 Digitalization in the agricultural system of southern Africa (newly released case study for the SADC region)

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The Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA) is a key player in Agricultural Research for Development (AR4D) activities. CCARDESA intends to take the AR4D agenda forward by ensuring that digitalization accelerates agricultural transformation through enhancing productivity and sustainability across all value chain actors in agriculture and food systems. Through support from the World Bank and the Southern African Development Community (SADC) – Directorate of Food, Agriculture and Natural Resources, CCARDESA facilitated a stocktaking analysis of the status of digitalization in the agricultural systems of SADC countries. The study was commissioned in 2020, at a time when the global community was grappling with the effects of the COVID-19 pandemic, which turned out to be an opportune time to witness how digital technologies could help confront the threat of disease and keep people connected.

The presentation focused on the key study findings. Among these is a map of the status of national and regional policies and regulatory frameworks of SADC countries that provide a conducive environment for agricultural digital innovations. Also presented was a verified range of agritech innovations available in SADC countries and an analysis of the extent to which the current agricultural syllabi in agricultural universities and innovation hubs facilitate digital agricultural skills development in the region. A more systematic understanding of these innovations creates the opportunity to exploit their impacts, including enhancing efficiencies in reaching farmers, increasing agricultural productivity, improving farmer incomes and food security and encouraging opportunities for employment across SADC countries.

The study focused on key actors within the digital economy for agriculture, including governments, civil society, private sector, universities and agritech innovators to provide the first of its kind, regional multicomponent baseline to understand how these actors may work collaboratively to drive digital integration and the development of a vibrant digital ecosystem made up of multiple stakeholders. The full results are presented through an interactive agrihub portal on the CCARDESA website.

Reference

CCARDESA. 2023. *Centre for Coordination of Agricultural Research and Development for Southern Africa*. Gaborone. Cited 14 March 2023. www.ccardesa.org

7.7 Research and practice of digital agriculture in China

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In China, small-scale farming is facing the challenges of low resource-use efficiency, low production efficiency, shortages of agricultural labour, low rates of agricultural mechanization and low farmer income. Digital agriculture is put forward as one way to sustainability and to help farmers reap more benefits, by improving agricultural productivity, reducing cost and increasing the efficiency of fertilizers, pesticides and water. China is making digital agriculture part of its future development direction, and digital technologies have already been widely used in crop production.

In wheat–corn cropping systems, the Beidou Global Navigation Satellite System (BD-GNSS) is used to achieve precision corn sowing, to ensure that corn is planted precisely in the soil between two rows of wheat. Crop canopy nitrogen sensing by an unmanned aerial vehicle (UAV) and Internet of Things helps farmers implement precision fertilization. Drift prevention and digital-control technology help farmers achieve precision spraying of pesticides. Big data and Internet-based agritech service platforms connect agricultural technicians, experts and farmers, and can answer farmer questions on plant production practices. Field demonstrations of digital agriculture are one of the most effective ways for technology transfer and its popularization.

There are between 230 to 250 million households engaged in small-scale farming in China. One household has on average 0.53 ha of farmland. The challenge is to develop digital agriculture solutions for small-scale farming. Farmland consolidation coupled with the development of appropriate systems for machinery use, trusteeship services and government assistance policies are all necessary for the promotion of digital agriculture.

References

Advisory Committee of Experts on Agricultural Rural Information Technology. 2020. [Report on the development of China's digital villages]. Beijing. 77 pp (in Chinese). www.moa.gov.cn/xw/zwdt/202011/P020201129305930462590.pdf

Moysiadis, V., Sarigiannidis, P., Vitsas, V. & Khelifi, A. 2021. Smart farming in Europe. *Computer Science Review*, 39: 100345. https://doi.org/10.1016/j.cosrev.2020.100345

Zhao, C., Li, J. & Feng, X. 2021. Development strategy of smart agriculture for 2035 in China. *Strategic Study of Chinese Academy of Engineering*, 23(4) 1–9 (in Chinese).

7.8 Agricultural automation for small-scale producers with applied cases on weed control in vegetables and vineyards

Ingrid Sarlandie[1] and Gaëtan Séverac[2]
[1] *Former Chief Operating Officer (COO), Naïo Technologies, France*
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In this presentation we shared feedback from farmers on the use of field agricultural robots, to show why and how agricultural robots can support sustainable agriculture while improving worker conditions, farm profitability and crop productivity.

Field agriculture robots are not a futuristic opportunity, they are instead already concretely part of the present, with hundreds of users in Europe and North America. They have the potential to solve global labour shortage issues in agriculture and support sustainable practices contributing to restoring biodiversity, soil health, chemical input reduction, CO_2 reduction and CO_2 sequestration.

To guarantee resilience in our global food production system, while facing climate change, energy crises and international conflicts, we need more diverse and local plant production. Robots can help to develop that, at a global scale.

7.9 Opportunities and challenges in digital agriculture: global patterns and policy issues on the way towards sustainable agriculture

Sarah Hackfort
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"Smart Farming", "Agriculture 4.0" or "Digital Agriculture" are to a large extent interchangeable terms used to describe the phenomenon of an increased use of data-related technologies in the farming and food-production process. These technologies, including big data–based applications, artificial intelligence and automation, digital agricultural platforms and the deployment of sensors, drones and satellite imagery, are increasingly making their way into agriculture across the globe.

Both industry and political institutions worldwide argue that digitalization offers one of the solutions to feeding a growing world population, while at the same time mitigating the negative environmental and climate consequences of agriculture (Prause, Hackfort and Lindgren, 2020).

This picture is mostly an affirmative one, generally conflict-free and with few if any downsides. However, some civil-society organizations adopt a critical attitude, drawing attention to problematic impacts, e.g. on labour issues and social injustice. These organizations see digitalization as a threat to food sovereignty and the livelihoods of small-scale farmers reinforcing devastating effects of the agroindustrial model (Mooney and ETC Group, 2018).

Academic literature presents a more nuanced picture. Studies highlight social and economic opportunities, while acknowledging that digitalization also entails challenges and risks (Hackfort, 2021).

This presentation provided an overview of recent research findings on the social impacts and distributive dimensions linked to the adoption of digital technologies in agriculture. It presented patterns of inequality in the use, adoption and distribution of the benefits of digitalization in agriculture.

It discussed the current regulatory and legal framework governing the use of data and digital technologies in agriculture in the European Union as an example and highlighted the importance of national and supranational policies for unlocking the potential of digital technology to contribute to socially and ecologically sustainable food and agricultural systems.

It argued that in order to realize this potential, the social impacts and inequalities linked to digital agriculture need to become a key concern of policy makers, especially against the background of the Sustainable Development Goals, which includes the goals of both reducing inequality and making agriculture more sustainable.

The presentation concluded, first, that agricultural data policy needs to be advanced towards technological sovereignty of farmers to prevent corporate lock-ins and to shape digital agriculture towards equal benefits. Second, more public digital infrastructure needs to be built and more investments in non-proprietary technologies need to be made – this means technology that is farmer-driven, open-access and open-source for equal access. Third, there should be more funding for digital technology development directed towards the needs of small-scale, agroecological and biodiverse farming, to strengthen "digital agroecology". But most importantly, the limits of digitalization need to be acknowledged and a broader notion of innovation should be adopted which includes "wide-tech" (Mooney and ETC Group, 2018) technology that is farmer driven and people oriented.

References

Hackfort, S. 2021. Patterns of Inequalities in Digital Agriculture: A Systematic Literature Review. *Sustainability*, 13(22): 12345. https://doi.org/10.3390/su132212345

Prause, L., Hackfort, S. & Lindgren, M. 2020. Digitalization and the third food regime. *Agriculture and Human Values*, 38: 641–655. https://doi.org/10.1007/s10460-020-10161-2

Mooney, P. & ETC Group. 2018. *Blocking the chain: Industrial food chain concentration, big data platforms and food sovereignty*. Berlin, ETC Group. 43 pp. www.etcgroup.org/content/blocking-chain

7.10 Commercialization and scaling innovations from digital agriculture start-ups through national policies

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In many farming communities where the majority of small-scale farmers still operate with small manual farm tools or animal labour, mechanization holds tremendous potential for increasing farm profitability, opening new market opportunities for small-scale farmers, attracting young people to the sector and boosting agricultural production. But mechanization is a major investment, and few individual small-scale farmers have the financial resources or the justification to purchase necessary equipment.

To feed a growing population under current circumstances, an integrated approach of efforts on several fronts is required, especially through digitalization and mechanization innovations, such as drone technology and precision agriculture.

The agricultural drone industry alone is a growing one, estimated to reach USD 5.7 billion by 2025, increasing at a 35.9 percent compound annual growth rate. The purpose of deploying drone technology is to eliminate doubt in favour of accurate and reliable data. Precision agriculture can improve agricultural management by tracking metrics using software, services and specialized equipment such as drones. The introduction of drone technology holds tremendous scalability prospects. It has so far assisted farmers in delineating and mapping their land boundaries, allowing for easier planning of planting as well as providing data when seeking financial assistance.

Assisting in the analysis of the state of land, soil fertility and crop health through satellite and multispectral imaging, the technology can greatly reduce farm-resource losses and maximize yields and productivity. Forecasting yields allows farmers to plant and harvest at appropriate periods and to target areas of their farms that require attention. In plant production, the volume of pesticides used is one of the most critical variables for sustainable agriculture. During this stage, drones provide effective and environmentally beneficial solutions, particularly for pesticide applications, due to their capacity to identify the locations to be treated. Avoiding the use of superfluous pesticides contributes to sustainable agriculture.

Digitalization in the agricultural value chain does not only help increase yields, but also helps to reduce farm expenses in the long run and improves farmer life by minimizing their exposure to otherwise harmful aerosols and giving them more time to focus on other elements of the farming value chain. Data gathered through digitalization can be used to support rapid decision-making, improve efficiency, and address climate-related issues. Digitalization provides small-scale farmers with a single platform to support many of their practices from land preparation to market distribution.

Nations are encouraged to take advantage of digitalization in mechanization to attract young people to the sector and to boost agricultural production in an efficient, innovative and sustainable manner.

Chapter 8. Farmers and Enabling Environment

8.1 Accelerating digital innovation and making big data work for small-scale farmers

Owen Barder
CEO, Precision Development (PxD)

Small-scale farmers typically harvest only 30 to 50 percent of what their land could produce. The yield gap directly induces low income, hunger and malnutrition. Higher food prices and subsequent lack of sustainability and increasing inequality are a consequence, just as indirectly induced low levels of public investment in, for example, education.

Logistical challenges may impose a burden on farmers. For example, if input prices are relatively high, or output prices low, it may not be interesting for farmers to increase yields. It takes time and effort for knowledge on new technologies to reach farmers. There may be behavioural constraints which delay adoption. Yield and net income increases may require simultaneous improvements in markets for inputs, outputs, credits, insurance and labour. Extremely poor farmers may not have social safety nets, insurance or savings to mitigate risk. Additionally, a farmer may not invest in expensive inputs that would increase yields, because of the downside risks to them in challenging years. Appropriate practices will differ by crop, geography, demand, availability of inputs, weather conditions and risk appetite. Generic advice to communities (e.g. nationwide advice to change to higher-value crops) instead of customized advice for each farmer may increase average yields or incomes, however, could leave many farmers below their potential. Some farmers lack access to key real-time information, including information on long-range and short-range weather, pests, prices and input-availability data.

Information services can help by: (1) knowledge diffusion, (2) improved market linkages, (3) risk mitigation, (4) customization, and (5) real-time information provision. Informing, reminding or nudging farmers to adopt high-value practices (e.g. use of improved seed, fertilizer microdosing) can increase adoption, yields and net income. Connecting farmers to low-cost, reliable input suppliers, enabling access to credit by improved credit scoring, establishing connections to output markets to increase bargaining power, and market shaping are examples to foster market linkages. Information services can reduce the constraint on technology adoption associated with risk by access to insurance and risk pooling. Private sector approaches to user experience and product development can improve engagement and adoption. Algorithmic targeting of highly specific advice, tailored to the needs of each farmer, based on information gathered about that farmer. Obtaining (perhaps by crowdsourcing) and distributing real-time information can increase productivity.

Precision Development (PxD) provides customized, actionable, impartial and free information. Information on input recommendations, management advice, market information and weather is real-time and customized to farmer profiles and agricultural data. Two-way information is shared through mobile phones via multiple channels, such as apps and learning platforms. PxD monitors and evaluates changes leading to increased crop yields, decreased crop losses, increased incomes and improved benefit–cost ratios. PxD is using behavioural science and human-centred design to build engaging, actionable and customized messages and services. It scales rapidly through partnerships with governments, NGOs and private companies, while remaining free to the user as a public good. Additionally, it uses experiments and data science to test, iterate and improve its functions.

The impacts of digital agricultural advisory services, based on rigorous evaluation, are 4 percent average yield gains (much higher increases per adopter), a 22 percent average increase in recommended farming practices, a 10:1 benefit–cost ratio (high return of investment for development), and large variation in impact estimates across studies. Empowering users with quality information at their fingertips.

8.2 Biovillages – Landscape-level management and governance of agroecosystems

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Agricultural Scientists, Centre for Sustainable Agriculture, India

The Centre for Sustainable Agriculture (CSA) is a non-profit trust, working with 25 000 organic farmers, 75 000 farmers in conversion and over 65 farmer producer organizations (FPOs) in India to support transition towards agroecological approaches and linkages to markets. CSA also does research to build evidence for policy change. Learning grounds have been established in Andhra Pradesh, Telangana and Maharashtra, while support services are provided to programmes and organizations in Assam, Chhattisgarh, Jharkhand, Himachal Pradesh, Karnataka, Manipur, Nagaland, Sikkim and Tamil Nadu. CSA promotes community-managed sustainable agriculture, focusing on farmers as resource persons, managed by community institutions. The farmer field school approach is adopted to build knowledge and skills of the community resource persons. CSA partners with governments for scaling up.

Continued overexploitation of natural resources and the associated impacts of climate change threaten the sustainability and biodiversity of our global agroecosystems. Similarly, changes in consumption patterns, institutions, markets and policies have disrupted food systems, which further worsens our agroecosystems. Integrated landscape approaches are governance strategies that attempt to reconcile multiple and conflicting land-use claims to harmonize the needs of people and the environment, and to establish more sustainable and equitable multifunctional landscapes. Biovillages for integrated landscape management are chosen as units to establish systems for planning, execution, management and governance. The Biovillage concept involves the conservation and enhancement of biological resources, the creation of on- and off-farm livelihoods for income generation, and the enhancement of access to healthy food and nutrition security. By integrating ecology, equity and bioeconomy, Biovillages can lay the foundation for sustainable rural development.

CSA's work on landscape-level agroecosystem management in 16 villages as part of the Andhra Pradesh Community Managed Natural Farming project has contributed to villages now reaching at least 85 percent of the farmers involved, and 85 percent of the area being converted to organic/natural farming. The transition to organic farming is influenced by socioeconomic factors and differences in willingness to change behaviour and adopt practices by farmers. Reaching the first 10–15 percent of farmers was easier than reaching up to 35–50 percent of farmers, which required intensive efforts and institutional systems. Reaching the 75–85 percent group requires input and market support. Water budgeting, harvesting and conservation and planning production systems are taken up, agrochemical use is reduced, and a diverse range of cropping and integrated farming models are adopted. Sustainability indicators include: (1) ecological indicators (e.g. efficient energy use, high groundwater level, limited agrochemical use, soil carbon sequestration, increased green cover), (2) economic indicators (e.g. nutritional security, increase in net incomes), (3) and social indicators (farmers organized, no distress).

Extension and advisory services, and business development services are being institutionalized as farmer service centres at farmer producer organization (FPO) level. While primary FPOs focus on providing services to member farmers, these FPOs are federated to facilitate access to processing and storage facilities, brand building and quality assurance and market linkages. Direct marketing under the “Sahaja Aharam” brand helps farmers realize better prices. Participatory guarantee systems are used for data management. The same data set is used for quality assurance (organic certification), ecosystem services assessment and payments (carbon credits), business planning and project management. Carbon sequestration assessment using satellite maps showed an average increase of 0.1 percent per year over four years. Carbon revenue is calculated by quantifying soil organic carbon build to establish carbon credits. New methodology using satellite imagery and ground truthing using PGS data is applied. The transition towards organic/natural farming shows that productivity increased by 10 percent, cost of cultivation decreased by 15–20 percent and price realization increased by about 10–15 percent. Integrated biodiversity conservation/revival, as well as soil and water conservation measures, take more time. FPOs also involve schoolchildren in increasing green cover in public areas.

Integrated support services to improve agroecosystems and local food systems by strengthening existing production systems increase livelihood opportunities and improve access for small-scale and vulnerable farmers, including women farmers, leading to large-scale transitions. CSA also offers these services to other programmes and organizations through season-long, participative learning for problem solving and designing interactive and inclusive solutions at the Farmer Field Schools, Kisan Business School. eKrishi-Digital services provide an integrated digital platform for small farmers and their collectives, including multiple stackable and customizable digital solutions to support farmers’ management from production to marketing. The service is available in multiple languages and offers a combination of free-for-use and affordable payment options.

8.3 Promoting access and adoption of sustainable inputs and technologies

Elizabeth Nsimadala
Director, Women Affairs, Pan Africa Farmers Organization (PAFO). Ex-President, PAFO. President, Eastern Africa Farmers Federation (EAFF)

The members of the Eastern Africa Farmers’ Federation (EAFF) are currently representing over 25 million farmers across East Africa. The EAFF vision is to achieve a prosperous and cohesive farming community in eastern Africa. The EAFF established a new Strategic Plan 2021–2028 to transform small-scale agriculture into a rewarding investment opportunity. This transformation will be realized through investment in the following five mutually reinforcing thematic areas: (1) taking aggregation to scale; (2) leveraging digital technology; (3) taking provision of economic services to scale; (4) advocating for supportive policies; and (5) improving the capacity of members to discharge their representation mandate.

The concept of a **sustainable farming system** refers to the capacity of agriculture to contribute to overall welfare over time by providing sufficient food and other goods and services in ways that are economically efficient, profitable and socially responsible, while also improving environmental quality. Thus, improving access and adoption of inputs and technologies must be seen in this context.

The most important factors for a farming site are **climate, soil, nutrients and water resources**. Over time, farmers in Africa have experienced reduction in productivity as a result of: (1) poor management of these factors; (2) poor implementation of at-times unpredictable policies; (3) low investments in low- value agriculture value chains; and (4) fragmentation of value chain partnership ecosystems. Uptake of available technologies is low due to lack of information and mismatch of technologies versus needs or high costs associated with uptake. Most of the farmer-developed technologies and inputs lack abilities to reach scale since they are not well documented and supported. The concept of sustainable inputs and technologies is also not well understood by many venture capital actors.

What is being done?

EAFF believes that access to a reliable and predictable market is key to incorporating any form of sustainable approach at any point of the value chain because it is possible to measure the impact and tailor make the intervention.

Our strategic plan has allowed us to develop an e-platform that has helped us build a partnership ecosystem along the value chain. The e-granary aggregates farmer output, input, finance, extension and mechanization markets and services.

The platform helps in improving decision-making at the farmer level based on expected rainfall, helps access certified inputs through bulk procurement, mitigates risks associated with production through agriculture insurance and targeted e-extension services, attracts technology providers to dry the grain due to the platform's scale of operation, and provides solar-powered irrigation systems using a check-off system.

The e-platform is scalable, and is being already used in Rwanda, Uganda and Kenya; however, the business model and approach is different due to variations in agricultural development and the organization of value chains as well as the capacity of farmer organizations.

This platform thus promotes climate-smart agriculture by improving decision-making, creating partnerships (and trusting in them) and reducing transaction costs associated with deployment of technologies, but also makes it possible to develop tailormade solutions.

The way forward requires:

- Inventorizing existing technologies around inputs and match them with the needs of farmers.
- Implementing approaches towards sustainable access and adoption of inputs, based on partnerships in place for the target value chain.
- Enhancing uptake but also development of fit-for-purpose technologies, via economies of scale and flow of information among and between partners.
- Communicating the EAFF concept widely to enhance the understanding of principles around it, since it requires collective effort and collective monitoring.
- Creating market incentives to generate interest and investments.
- Implementing policies that support sustainable agriculture and especially sustainable access and adoption of input technologies.

8.4 Overcoming extension gaps: increasing access to extension and advisory services

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Small-scale farmers continue to adapt and innovate in the face of challenges, such as low productivity, soil degradation, water scarcity, climate change, the COVID-19 pandemic and price increases due to the conflict in Ukraine. Extension services support small-scale farmers to operate resilient, innovative and sustainable agrienterprises. However, extension still has many gaps in terms of its characteristics that affect performance, outcomes and impact.

There are gaps in governance. In Ethiopia, Kosec and Mogues (2020) found that decentralization improved access to extension for both men and women farmers. However, men saw a greater improvement in access than women, thus decentralization increased the gender gap. In Ghana, Resnick (2021) found that devolution of extension had both positive and negative effects, enhancing accountability of local extension but undermining their provision. Local government median agricultural expenditures fell by 36 percent following devolution.

There are financing gaps. More than USD 1 trillion of development finance was dispersed between 2015 and 2018. Of this, 4.3 percent (USD 44 billion) was for the agricultural, forestry and fishing sector. Of this, only 2.4 percent (USD 1.8 billion) went into the subsectors of agriculture education, training and extension (Atteridge, Savvidou and Meintrup, 2019).

A major gap is the capacity of individual extension staff. Of roughly one million staff globally, over half have only diploma-level education or less (Davis *et al.*, 2020). A related issue is extension management through incentives. Salaries are low, and educational opportunities, rewards and promotions can help motivate staff.

There are gaps in methods. Van Campenhout, Spielman and Lecoutere (2021) found that video had a positive impact on knowledge, adoption and yields, whereas integrated voice response and short message services had no significant impacts. In Ethiopia, video-mediated extension had a wider reach than conventional extension, but other digital approaches showed no effect. Lead farmers can increase extension's reach, reduce costs and improve efficiency. While they can be effective, they lack capacity and require institutional support (Kiptot and Franzel, 2015).

There are continuing gaps in community engagement – how extension reaches marginalized groups. Numerous studies have shown that women lack access to extension and other services (Kosec, Doss and Slavchevska, 2020; Magnan *et al.*, 2020).

We must intervene at multiple levels to overcome these gaps. Public and private staff need up-skilling, and lead farmers need extensive training, follow-up and mentoring. Even if salaries are low, incentives can help attract and retain staff. In Ethiopia, incentives such as housing, electricity and transport were more attractive to women than salaries (Berhane *et al.*, 2020; Regassa *et al.*, 2021).

Digital methods must ensure that marginalized groups are not left out. For community engagement, it is important to provide information to all household members rather than just the household head, who is often a man. Providing entrepreneurship training can help attract young people to agriculture.

At the institutional level, we need more investment – research shows that supporting extension makes agricultural interventions more effective. We need implementation support for extension policies and strategies.

Finally, farmers need to be at the centre, through participatory approaches, farmer advisory committees and engagement in policy dialogues and governance structures.

References

Atteridge, A., Savvidou, G. & Meintrup, L. 2019. *Aid Atlas*. Stockholm Environment Institute (SEI). https://aid-atlas.org/about/sectors#agricultural-water-resources

Berhane, G., Ragasa, C., Abate, G.T. & Assefa, T.W. 2020. Ethiopia. K. Davis, S.C. Babu & C. Ragasa, eds. *Agricultural Extension: Global Status and Performance in Selected Countries*. Washington DC, International Food Policy Research Institute. https://doi.org/10.2499/9780896293755

Birner, R., Davis, K., Pender, J., Nkonya, E., Anandajayasekeram, P., Ekboir, J., Mbabu, A., Spielman, D., Horna, D. & Benin, S. 2009. From Best Practice to Best Fit: A Framework for Analyzing Agricultural Advisory Services Worldwide. *Journal of Agricultural Extension and Education*, 15(4): 341–355. https://doi.org/10.1080/13892240903309595

Davis, K., Babu, S.C. & Ragasa, C. (eds.). 2020. *Agricultural extension: Global status and performance in selected countries*. Washington DC, International Food Policy Research Institute. https://doi.org/10.2499/9780896293755

Kiptot, E. & Franzel, S. 2015. Farmer-to-Farmer Extension: Opportunities for Enhancing Performance of Volunteer Farmer Trainers in Kenya. *Development in Practice*, 25(4): 503–517. https://doi.org/10.1080/09614524.2015.1029438

Kosec, K. & Mogues, T. 2020. Decentralization Without Democracy. *World Politics*, 72(2): 165–213. https://doi.org/10.1017/S0043887120000027

Kosec, K., Doss, C. & Slavchevska, V. 2020. Gender and Rural Transformation. PIM Synthesis Brief. International Food Policy Research Institute (IFPRI). Washington, DC. https://doi.org/10.2499/p15738coll2.134037

Magnan, N., Love, A.M., Mishili, F.J. & Sheremenko, G. 2020. Husbands' and Wives' Risk Preferences and Improved Maize Adoption in Tanzania. *Agricultural Economics*, 51(5): 743–758. https://doi.org/10.1111/agec.12589

Regassa, M.D., Abate, G.T. & Kubik, Z. 2021. Incentivising and Retaining Public Servants in Remote Areas: A Discrete Choice Experiment with Agricultural Extension Agents in Ethiopia. *Journal of Agricultural Economics*, 72(3): 878–900. https://doi.org/10.1111/1477-9552.12432

Resnick, D. 2021. Does Accountability Undermine Service Delivery? The Impact of Devolving Agriculture in Ghana. *European Journal of Development Research*, 34: 1003–1029. https://doi.org/10.1057/s41287-021-00408-x

Van Campenhout, B., Spielman, D.J. & Lecoutere, E. 2021. Information and Communication Technologies to Provide Agricultural Advice to Smallholder Farmers: Experimental Evidence from Uganda. *American Journal of Agricultural Economics*, 103(1): 317–337. https://doi.org/10.1002/ajae.12089

8.5 Agroecological transition in Mexico: Promote the agroecological transition and face the challenges of farmers

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[2]*Director-General de Organización para la Productividad*

The Ministry of Agriculture and Rural Development is working to achieve an agroecological transition. In the past, public policy in Mexico was characterized by the seizure of public resources destined for agricultural production by corporations. The present administration decided to transform food systems in general, respecting the rights of small and medium producers. Two priority presidential programmes were established: *Sembrando Vida* (Sowing life) with 450 000 producers, and *Producción para el Bienestar* (Production for well-being) with 2 million producers, totalling almost 2.5 million people, with a combined budget of more than USD 2 billion. In addition, agricultural credits have been generated with incentives for agroecological practices, economic resources that in the past were associated with the support of technological packages called the Green Revolution.

The production of bio-inputs was proposed to replace agrochemicals, while the participatory selection of seed and the dialogue of knowledge between technicians and producers were favoured. The previous model was aimed at large producers, with technical information moving in a single direction from technician to producer through the recommendation of technological packages. Many packages did not match the realities and the physicochemical characteristics of the producer's environment (and soils). The model has shifted towards small agriculture, recognizing the knowledge of the producer. Schools were set up in farmer fields, functioning as spaces for dialogue of knowledge transmission from farmer to farmer, and from farmer to technician, and thus developing practices based on a bidirectional flow of knowledge.

The number of agroecological practices adopted by farmers increased from 3 to 12, with a potential to reach a total of 25. The use of glyphosate has been reduced and the use of bio-inputs has been increased. Bio-inputs are being produced with microorganisms that meet the characteristics of Mexico's official standards, as indicated by Mexico's national research institute for forestry, agriculture and livestock, INIFAP. Additionally, publications on production-related topics, including the use of bio-inputs, have been made available for producers and the general public. Interactive, free-access platforms have been created on the Internet. The idea is to eliminate the dependence on the government for technical support. By focusing public policy on small and medium producers, combined with the use of bio-inputs, close technical support to the communities and recognizing agroecological practices, the first link of the food system has been transformed.

With the experience it has gained, Mexico has recommended on several occasions that the United Nations and its agencies, such as FAO, take on leadership towards the search for global regulation of food systems, establishing an open-ended working group in the Committee on World Food Security (CFS). This group should work in all value chains of food systems to build international regulation, taking as an example the WHO Framework Convention on Tobacco Control (WHO FCTC). In general, it must include: (1) measures to regulate the use of highly dangerous agrochemicals, including glyphosate; (2) encourage use warning labels for food and beverage packages; (3) implementation of an international code for marketing breastmilk substitutes; and (4) promote incentives for an agroecological transition without genetically modified organisms or agrochemicals. Mexico has shown that it can be done at the national level, but the support of an international framework will make it possible to further strengthen actions.

Chapter 9. High-level ministerial segment and closing plenary session

9.1 Statement by H.E. Chalermchai Sri-on

Minister of Agriculture and Cooperatives, Thailand

Dr QU Dongyu, Director-General,
Your Excellency, Distinguished Guests,

I am extremely honoured to be invited to participate in the Global Conference on Sustainable Plant Production

The Covid-19 pandemic has posed a challenge to the agricultural and food system. Therefore, we must take urgent action to deal with hunger, malnutrition, sustainability and climate change.

The Ministry of Agriculture and Cooperatives of Thailand welcomes the development of a new FAO Strategic Framework and the Four Betters to accelerate good solutions for members for agrifood-system transformation to a healthy diet, for equitability, sustainability and resilience, also supporting rural development inclusively and for the achievement of the Sustainable Development Goals.

Thailand places significant importance on the development of science and technology, as game changers leading to the transformation towards more sustainable and resilient food and agriculture systems. We support the development of innovation and technology that is accessible and affordable, user-friendly, gender-sensitive, age-sensitive and best suited for smallholders of all ages.

I would like to emphasize that the development and selection of technologies must be focused on the needs of smallholder farmers, family farmers, young people and women, and also take into consideration the trend of an ageing agricultural workforce in association with demographic structural changes in the country. Meanwhile, the number of young farmers is declining, which may lead to challenges in maintaining the competitiveness of a country's agricultural sector, its sustainability and its food security.

The Ministry of Agriculture and Cooperatives supports farmer field schools, especially to encourage young farmers to practice agriculture more efficiently and engage in environmentally friendly farming practices leading to cost reductions and environmental conservation. We initiated intergenerational support activities, such as the Young Smart Farmer programme to promote the adoption of technology and innovation, and facilitate access to farmer field schools, markets and financial resources, and also to motivate young people to continue in, return to or enter the agricultural sector.

The Ministry of Agriculture and Cooperatives works in collaboration with academia, research organizations, and the public and private sectors to increase investments and enhance scientific and technological research and innovation to promote sustainable production in the agricultural sector while also enhancing value addition along the supply chain and providing decent income for farmers, especially by focusing on issues of food loss and waste, crop-water use efficiency, low-carbon crop production, risk assessments and early warning systems. Also, developing innovations and technologies in crop breeding that respond to climate change, through which farmers can produce their own seed, reduces production cost and generates income for farmers to make a better living and to create stability and sustainability in agriculture which is the source of food production for mankind.

Lastly, Thailand would like to support FAO and its Members. To access knowledge and innovation for sustainable plant production, I offer my thanks to FAO for organizing this meeting. It was a good opportunity for us to exchange ideas for sustainable plant production.

Thank you.

9.2 Statement by H.E. Víctor Manuel Villalobos Arámbula

Secretario de Agricultura y Desarollo Rural, Mexico

Dr QU Dongyu, FAO Director-General, Ministers and Secretaries of Agriculture present at this event, Excellencies and Permanent Representatives to FAO, friends,

All of us present here, and those accompanying us thanks to virtual channels, agree on the grave severity of the historical moment we are living, whose deepest manifestations are reflected in the lack of food for more than 800 million of our brothers and sisters, in the rapid loss of our biodiversity and in the acceleration of catastrophic climatic events caused by the intensification of climate change. Likewise, we all agree on the urgent need to rectify the path and find sustainable solutions that ensure a prosperous future for future generations, for those of our children and our grandchildren.

Despite the seriousness and complexity of this crossroads, it seems that we are not able to join forces and propose common alternatives to reverse these trends. On the contrary, it seems, according to multiple projections, that hunger will continue to grow in the face of escalating crises and conflicts.

I am convinced that our sector, agriculture, holds many of the solutions to face these problems, and that is why I want to congratulate FAO and its Director-General for having called this conference, which has already given us, and I hope will continue to generate, some alternatives to move from reflection to action and transform our food systems to achieve greater productivity, inclusion and sustainability; making the proposal a reality to achieve the four betters defined in the strategic framework of this important organization.

I would like to use my remaining time to briefly share with you my vision on the importance of science, technology and innovation in transforming the way we produce, market and consume food, and also share some of the experiences that, as Secretary of Agriculture of my country, Mexico, we have been promoting in favour of this transformation.

The promotion of sustainable agriculture, through which more food can be produced, without generating additional pressures on the environment, natural resources and biodiversity, seems an impossible task to fulfil under current paradigms. This change will only be possible if we recognize that food production is the end result of a complex series of interactions of biological processes that take place in a given ecosystem and that are influenced by cultural, social and economic factors. Science and innovation must be carried out with this systemic vision and use participatory approaches to meet the particular conditions of the territory, breaking with old styles of knowledge generation.

The sustainability of plant production systems can only be a reality when the system is considered as a whole, simultaneously integrating the plant, soil, water and biodiversity.

Soil and water, which are two pillars of agriculture, are becoming more relevant today because we have realized that, over at least the past 30 years, we have not only forgotten them, but accelerated their process of degradation and pollution. Their loss will be irreversible, and without them agriculture will not be possible. Therefore, the food security of future generations depends on the health of our soils and the wise use of our water resources.

Simultaneously, we have to advance in the development of new varieties of crops for which it is necessary to be at the frontier of knowledge, and ethically use the advances of science to generate new varieties. At the same time, it is urgent to redouble efforts to recover species we have forgotten, rescuing traditional food systems, which can help us transform the way we eat and offer real alternatives to millions of people in the world.

Aware of these challenges and during the last four years that I have had the privilege of serving as the Secretary of Agriculture of Mexico, under the administration of President Andrés Manuel López Obrador, we have been promoting changes to transform national agriculture and give priority attention to those who need it most, leaving no one behind.

Within these efforts, I would like to highlight the priority attention we have given to soil. We have established a national policy of sustainable improvement and recovery of our soils, encouraging Mexico's participation in international fora on the subject, notably in the Global Soil Partnership, and we are using the fertilizer for well-being programme, through which we expect, in 2023, to reach 2 million small producers with land extensions of less than 2 hectares, to sensitize them and jointly build management alternatives. I take this opportunity to announce the first inter-American congress on water, soil and biodiversity that will take place in Ciudad Obregón, Sonora, Mexico, from 23 to 25 November 2023, to which we invite all of you.

On climate change, we have reaffirmed our commitment to address the vulnerability of food systems through actions that simultaneously promote adaptation and mitigation in agriculture, livestock and fisheries-based systems. For this, we have established a Strategic Plan for Climate Change for the Agrifood Sector.

We have also, in collaboration with the environmental sector of our country and producers and innovation institutions, established a law on the protection and use of biodiversity and another on the protection of pollinators. Pollinators are of high relevance for Mexican agriculture because products as emblematic as tequila and mezcal depend on them, and their conservation is a priority for the future of our agriculture.

In terms of plant production, we have strengthened programmes for the production of national seeds in strategic crops, and we have promoted the recovery of the production systems for beans, wheat and rice, among others.

A special case is made for corn, because Mexico is the country of corn, and this crop is intimately linked not only to our food, but to our history, culture and traditions. Hence the importance that we, from the government, place on the crop. We have strengthened conservation and protection programmes for our native varieties and articulated programmes to ensure that native seeds remain in the hands of their traditional caregivers: our native peoples. We have also been promoting a unique initiative in its approach that we call "Corn for Mexico" and that aims to achieve self-sufficiency in corn production by 2024. In this effort, all actors in the maize chain have agreed on actions to increase production, ensure the commercialization of national crops and gradually transform the way of producing towards systems that use fewer chemical inputs and are more sustainable.

Let me conclude by reflecting on the important role that FAO must play in advancing the urgent task before us. FAO must continue to advance in the process of transformation that it has already begun and manage to become an institution of the twenty-first century, strengthening its actions in the implementation of its strategies of "Science and Innovation" and "Climate Change". We must, as Members, redouble our support for this noble organization.

Mexico reiterates its commitment to advance these goals and to strengthen collaboration with all the countries of the Earth to achieve a fairer, more sustainable and more productive agriculture.

Thank you.

9.3 Statement by H.E. Mohammad M. Abubakar

Minister for Agriculture and Rural Development, Nigeria

I am delighted to be here with you today, participating online, on this very important occasion of the Global Conference on Sustainable Plant Production (GPC) and to contribute to the dialogue on innovations to create efficient plant production systems.

This is a very important engagement for us considering the contribution of the crop subsector to national food security and gross domestic product, and the various threats confronting agriculture and food systems.

As you are aware, the entire world is facing challenges resulting from various shocks suffered over the past two years, causing unprecedented food price inflation.

Nigeria has also grappled with challenges ranging from the high cost of production and lack of access to farmlands on the account of insecurity and floods.

This has had a negative impact on food production, incomes and livelihoods of smallholder farmers who produce the bulk of what we consume.

Our mandate is to ensure food security, employment generation and wealth creation through improved commodity value chain activities and rural infrastructure development.

In recent times, the entailing frameworks of the Agriculture Promotion Policy (2016–2020), the Economic Recovery and Growth Plan (2017–2020) and the Economic Sustainability Plan (2020–2021) focus on laying a foundation for rapid agricultural development using comparative advantage, climate change adaptation, nutrition-sensitive agriculture, agroenterprise promotion and market access linkages.

As a result, massive investments were attracted into agriculture, making Nigeria closer to food self-sufficiency, particularly in rice and poultry production.

Accordingly, the ministry developed a National Agricultural Technology and Innovation Policy (NATIP) (2022–2027) for the entire agricultural sector, in line with the aspirations of the current administration, that harness the economy, food-system transformation pathways, the achievement of the SGDs and the changing global food system and supply chains. Using a systemic approach, the policy will operate in alignment with other policies and strategies of relevant agencies, regional and global bodies, ensuring synergy and better coordination in transforming the agriculture and food system to be inclusive and sustainable.

Along with the policy, risk and capacity-gap analyses were done to ensure evidence-based interventions for adjustment for optimum implementation.

This policy is not unaware of the security challenges that threaten the supply of production inputs and food. Hence, the coordinated response has been carefully crafted to mobilize critical stakeholders and to restore the peace and security necessary to increase agricultural performance.

Equally, the policy picked important lessons from the COVID-19 pandemic, which further reinforced the government's resolve to pursue policies and programmes that would make Nigeria food secure and competitive in the global food chain.

On research, development and markets for inputs, including legislation, the National Fertilizer Quality Control Act 2019 and the World Fertilizer Registration Guideline, address issues of quality, availability, higher revenue and yield, good health, environmental sustainability and general economic development.

With the support of the African Development Bank, we are going to implement our national emergency food security intervention, which is aimed at reaching smallholder farmers with agroinputs for improved production.

The ministry is also promoting the adoption of different climate-smart varieties of crops such as:

- short-duration and drought-tolerant sorghum;
- high-yielding, flood-tolerant rice varieties (Faro 66 and Faro 67), which were developed by the Africa Rice Centre (AfricaRice) for flood-prone areas;
- pod-borer-resistant (PBR) cowpea against *Maruca vitrata*, an insect that can cause up to 80 percent yield loss, developed by the Institute for Agricultural Research in Nigeria; and
- the use of organic soil amendments to replenish the soil and obtain optimal productivity.

We are also promoting nutrition-sensitive agriculture through the development of provitamin A cassava, orange flesh sweet potato and quality protein maize varieties, as well as aflatoxin contamination reduction in susceptible commodities.

Plans are in an advanced stage to improve access to mechanization through our private sector-driven cooperation with Brazil, termed as "Green Imperatives".

We have been releasing grains from our reserves to the most vulnerable households to produce products against hunger and malnutrition.

The government has also made a consulted effort through development finance to structure suitable loans for agriculture and trade.

We recently have launched special agroindustrial processing zones in eight states in Nigeria, which will be centres of excellence that will integrate production, aggregation, processing and end market for crops to drive needed development in the crop subsector. We eventually intend to have this in all the 36 states of the country.

In conclusion, I wish to assure you that the government of Nigeria is doing everything possible to drive agriculture and food-systems transformation that is climate-smart and that will work for all in a sustainable manner, and is looking forward to partnering with organizations that can help the achievement of this vision.

Thank you.

9.4 Statement by H.E. Chavonda Jacobs-Young

Under Secretary for Research, Education and Economics, United States of America

Deputy-Director Bechdol,
Ministers and Distinguished Guests,

I would like to thank FAO for hosting this event. I am pleased to be here on behalf of United States Secretary of Agriculture, Tom Vilsack.

We congratulate FAO for convening this global conference on sustainable plant production. The concepts of innovation, efficiency and resilience must be central to our efforts to enhance the sustainability of agriculture and food systems.

Agriculture is facing the challenge of meeting a growing global population, while addressing the climate crisis, conserving natural resources and enhancing resilience to changes that are already in motion.

The current global situation underscores the need to unite behind common principles and take action to end hunger and poverty, face the challenges of climate change head on, and build more sustainable, equitable and resilient agriculture and food systems.

Sustainability, climate change and food security are top of mind for the Biden Administration, and especially for the United States Department of Agriculture (USDA).

As USDA's Chief Scientist and Under Secretary for Research, Education and Economics, I have the honour of overseeing USDA's science and research enterprise.

USDA's voluntary and incentive-based approach is grounded in science and data, and supports farmers, ranchers and forest landowners in responding to the many challenges they face.

And open markets and science-based regulatory regimes are critical to the development and deployment of innovative technologies.

Only by leveraging science and innovation can we provide farmers, foresters and other producers with the tools they need to improve productivity, sustainability and resilience.

Sustainably increasing agricultural productivity is essential to meeting the needs of the growing global population.

To produce more, while minimizing environmental and climate impacts, we need to foster new ways of doing things.

Equity and environmental justice are integral to all we do at USDA.

We are working to ensure that the programmes we support and the investments we make are available to everyone, and that investments fairly and equitably benefit communities disproportionally distressed and historically underserved.

And just recently, USDA and our partners at the United States Agency for International Development (USAID) launched the United States Global Food Security Research Strategy, which outlines the critical role research plays in sustaining and improving agricultural productivity, profitability and resilience of agriculture and food systems.

The new research strategy focuses on three areas where science and innovation are essential to progress:

- climate-smart agricultural innovations;

- improved nutrition through high-quality, affordable diets; and
- genetic improvement of resilient crops and livestock.

This global conference on sustainable plant production could not have come at a better time. The conference themes you will explore all have important elements I hope you will consider.

Regarding seed systems, we need investments in research and development to support improved varieties that can grow with reduce inputs and tolerate drought, heat, floods and other environmental stresses, to contribute to reduced carbon emissions and increased yield.

On field cropping systems, we need so many innovations: precision agriculture, hydronics, genetics, cell culture, robotics, to name just a few. Soil and leaf sensors to improve irrigation for water conservation, auto-guided tractors to improve equipment efficiency, enhance yield and reduce the application of inputs, etc.

On protected cropping systems, investing in urban agriculture innovations helps us build more transparent and efficient food systems and promote equity by increasing food and nutrition security as well as economic opportunity in underserved communities.

To enhance natural-resource management, in addition to tried-and-true conservation approaches and improved nutrient-management practices, agricultural biotechnology is one of the many tools available to improve yields and make more efficient use of natural resources, build resilience while sequestering carbon and reduce demands on natural areas that promote ecosystem services and conserve biodiversity.

In the realm of mechanization and digitalization, digital technologies such as sensors and drones are bringing tremendous value to individuals, businesses and farming communities.

And finally, on farmers and enabling environment, farmers need access to the best decision-making tools to estimate how production decisions influence farm productivity and environmental impacts.

We are investing in open data to ensure high-value services and systems are available any time, on any device, anywhere, including small farms – to assist farmers in making science-based and data-driven decisions.

These are just a few examples of innovations that will make agriculture more sustainable and improve lives around the world.

The United States of America recognizes that joint international action is key to ensuring global food security while enhancing agriculture's climate resilience and reducing its climate impacts.

In support of these goals, we are leading several major initiatives that bring together governments, NGOs and industry from across the world.

A few examples include: the Coalition for Sustainable Productivity Growth, which seeks to accelerate sustainable productivity growth to advance progress on environmental, social and economic objectives, and the Agriculture Innovation Mission for Climate (AIM for Climate).

For those who may not be familiar with the initiative, AIM for Climate partners intend to catalyse greater investment in and other support for climate-smart agriculture and food-systems innovation to help raise global ambition.

We encourage all to consider joining these two important initiatives.

And the United States of America is looking forward to the twenty-seventh session of the Conference of the Parties of the UNFCCC (COP27), in just a few days, where AIM for Climate will highlight accomplishments to date and announce plans for the year ahead.

FAO and its Members have an important role to play in enhancing agricultural productivity growth, promoting sustainable and resilient food systems, and providing farmers the tools to succeed.

We look forward to the rapid implementation of FAO's strategies on climate change and science and innovation, which will further assist countries in adapting to climate change, producing more with fewer resources, and improving food and nutrition security and livelihoods.

Together we can build more sustainable food systems, empowering agriculture to rise to the challenge of feeding a growing global population while taking action to combat the climate crises and conserve natural resources.

Thank you for a productive conference.

9.5 Statement by Mr Ayhan Baran

Alternate Permanent Representative, United Nations Agencies in Rome, Türkiye

Honourable Ministers, Ambassadors,
Ladies and Gentlemen,

I want to thank FAO for organizing the Global Conference on Sustainable Plant Production (GPC).

I am pleased to greet all those attending this conference and I have the honour to provide you with a brief overview of Türkiye's National Strategies towards sustainable food systems.

Since the early 2000s, significant efforts have been made in Türkiye to build a strong national and rural development strategy to provide healthy diets for all, mitigating climate change, protecting biodiversity and improving the food chain by protecting smallholders in a sustainable manner.

In Türkiye, the total utilized agricultural land including permanent meadows and pastures is 37 762 000 hectares, of which, 41.4 percent consist of areas of cereal and crop products.

Primary agriculture accounts for 6.7 percent of the country's GDP and employs 16 percent of its workforce.

According to the Food Security Index, Türkiye is a strong country with regard to proportional population under the global poverty line, sufficiency of supply, micronutrient availability, market access, agricultural financial services, food safety, protein quality and food safety net programmes.

Türkiye is self-sufficient in many crops, fruit and vegetables. We believe this is the result of the innovative and efficient actions taken under the National Rural Development Strategy, having as priority the following areas:

- protection and sustainable use of the environment and natural resources;
- transition to sustainable consumption and prevention of food loss and waste;
- food security;
- public health and food safety;
- inclusive sustainable food systems and poverty alleviation; and
- increasing the resilience of sustainable food systems against food crises.

Since the early 2000s, significant efforts have been made to build up national science, technology and innovation (STI) capacities, and to introduce new governance principles and support measures in STI.

Tax concessions and assistance through public–private partnerships have been provided to stimulate business research and development.

Agriculture and food are national STI priorities, and therefore benefit from special public funding schemes for priority areas.

Research and development outputs in the agrifood area have rapidly increased, and there has been active integration of national research into international research and development collaboration frameworks.

Some of the actions under this programme are the establishment of a digital value chain from seed to fork, the creation and implementation of an alternative support model with contracted production, the prevention of misinformation in food and increasing food literacy, the creation of the infrastructure for food loss and waste and the enactment of a water law, and establishment of a monitoring and evaluation system for their implementation.

Among the sectors benefiting from these programmes, ultimate importance is attached to agricultural production and, in particular, to high-quality seed, because we believe that when all the conditions are at optimum level for plant growing and agriculture, sufficient crop yield depends on the quality of seed used.

It is impossible to get higher yields from poor-quality seed. Production potential and other desired characteristics of seed limit plant production. Plant production inputs such as fertilizers, chemicals, etc. used in growing only help to realize the production potential of seed.

Seed is the most important input for the cultivation of plants. Farmer success depends on the seed quality of the plants they grow.

Even when other conditions are provided, it is impossible to get higher yields from varieties that are not well adapted to the environment.

In the light of these views, seed is the principal and the most significant input and technological element for increasing agricultural productivity and for reducing production cost. For this reason, we have a complete seed strategy to ensure the production of certified, healthy and high-quality seed, and that is economically efficient in input use for wheat and barley in particular, because wheat is a basic food and barley is an important input for the feed industry in Türkiye.

With its 37 enterprises all over the country, the General Directorate of Agricultural Enterprises (TIGEM), produces high-quality seed of wheat and barley. With its grain-seed production and processing facilities, with capacity for 287 tonnes per hour, TIGEM has the capacity to meet seed demand of Türkiye, between July and October each year.

On the other hand, it has the capacity to store seed in the same amount. This situation is also the same for alfalfa, other fodder crops and cotton. And here, let me express that we are looking to strengthen our collaboration with FAO and other international organizations to improve the seed sector.

In 2021, the Turkish government launched the Green Reconciliation Action Plan, which is a roadmap that is compatible with the transformation of policies taking place throughout world economies. This new strategy includes actions such as promoting organic farming, technological innovation, recycling and the implementation of renewable energy sources. The new Green Reconciliation Action Plan focuses on sustainability, because we believe that to stay competitive it is essential to create an efficient and highly productive agricultural sector that is environmentally and socially sustainable.

Therefore, it is important for our country to take actions towards sustainable agriculture, and studies are carried out to reduce the use of pesticides, antimicrobial and chemical fertilizers. This plan also details the need to make organic farming and biotechnical methods more popular among farmers since the demand for organic products is growing, and this creates opportunities for the development of sustainable and environmentally friendly organic farming production.

The plan also aims at creating the conditions for the reuse of waste and residues derived from farming activities while also raising consumer awareness about product cycles. While agriculture plays a pivotal role in the Turkish economy, significant efforts laid out in the plan are dedicated to the renewal of industrial areas, including new green districts for innovation and sustainability focusing on renewable energy strategies, especially geothermal energy.

Currently, a task force focused on maximizing the efforts is working to bring together researchers from public and private entities, universities, manufacturers and technology companies.

A specific national database is under development to gather data on raw materials, processes and emissions.

Those data will help to define the scope and the areas of intervention while also devising an environmental labelling system. It encourages green investments, contributes to the transformation of global value chains and thus supports value-added production.

Lastly, we look forward to expanding our cooperation and partnership with international organizations to strengthen our national strategies for better production, better nutrition, better environment and better life.

Thank you.

9.6 Closing, FAO Deputy Director-General, Beth Bechdol

Honourable Ministers, Excellencies,
Distinguished Guests and Participants,
Ladies and Gentlemen,

On behalf of the FAO Director-General and from all of us at FAO, let me thank the distinguished speakers at this high-level ministerial closing, both here in-person and online, and all of you who have been with us over the past two and a half days here in FAO headquarters, and the many of you who are online who contributed so actively to the discussion.

We had excellent interventions that have greatly enriched this conference.

I do want to thank again Martin Kropff for his leadership; the Steering Committee; the Technical Advisory Panel or Thematic Chairs, who led the discussions and served as moderators; to Dr Xia and the leadership of the Plant Production and Protection Division in the Secretariat; and to the interpreters who are doing such incredible work.

Let me close with a few points that I think capture some of what the Director-General wanted to share with all of you, and follows on so nicely from the comments by this panel and from Mr Kropff.

First, there is clearly a need for us to make sure that we focus continuously on farmers.

Farmers are agents of change for sustainable agriculture, and they will prepare and implement solutions – solutions that must be based on their needs and shaped own by their social, political, economic and environmental realities.

Second, we need to commit to more integrated approaches.

We know that one-sided, rigid solutions based on set rules or interventions will simply not work any longer.

Integrated approaches, that have a multidisciplinary, multistakeholder focus are critical.

Third, over the past days, we talked about technology.

New technologies have to be demand driven.

The private sector plays a critical role. We need to keep opening up opportunities for all actors to play a role in adopting, developing and contributing to the utilization of these new technologies.

These technologies must be environmentally compatible and climate-smart, but they also have to be economically viable and affordable, and inclusive of women, young people and other communities that have different practices, different ways of learning and different knowledge systems.

Fourth, we have to focus on policies.

We heard from this final panel about the importance of national strategies, commitments and political will that is bringing forth comprehensive policies, that more and more are underpinned by scientific advances in agricultural production.

These policies need to be in place for the transformation to more efficient, inclusive, resilient and sustainable agrifood systems.

And, **fifth**, the need for strategic partnerships.

Time and time again, you have heard us say that we must work together and that we all have a role to play.

As I close, let me convey to you the commitment of all of us at FAO to play our part.

We have to leverage the momentum generated by this conference and translate evidence and discussion into action.

From FAO, we commit to continue to:

- provide technical support at country, regional and global levels through our existing channels, but to also be in a position to work with all of you to explore new channels and working modalities;
- encourage, lead and convene more of these policy dialogues; and
- support countries and national governments in developing and implementing national policies, regulations and laws that support sustainable plant production.

It is for all these reasons that FAO commits to continue to provide a forum, like this one, where all voices can be heard on this important topic.

Thank you again to all of you for being here.

With this, we can close the first ever FAO Global Conference on Sustainable Plant Production.

Thank you.

Chapter 10. Conference recommendations

Recommendations from the Global Conference on Sustainable Plant Production FAO headquarters, 2 to 4 November 2022

The Food and Agriculture Organization of the United Nations (FAO) hosted the first ever Global Conference on Sustainable Plant Production with the theme "Innovation, Efficiency and Resilience" at the FAO headquarters in hybrid format from 2 to 4 November 2022. The conference attracted over 4 500 participants from FAO Members, stakeholders and partners.

The objective of the conference was to provide a neutral forum for FAO Members, farmers, scientists, development agencies, policymakers, extension agents, civil society, opinion leaders and the private sector to engage in dialogues on **innovation** that creates **efficient** plant production systems with **resilience** to biotic and abiotic stresses, and climate change. Strategically, the event was intended, through the implementation of the FAO Strategic Framework 2022–2031, to **support the 2030 Agenda** for the transformation to MORE efficient, inclusive, resilient and sustainable agrifood systems for *better production, better nutrition, a better environment* and *a better life*, leaving no one behind, to contribute to achieving the SDGs, especially SDG 1, SDG 2, SDG 8 and SDG 12.

The opening speech by the Director-General of FAO, Dr QU Dongyu, preceded eight keynote addresses. The closing plenary session included a report on the conference recommendations and a high-level ministerial segment. In between these plenaries, there were twelve subsessions, two for each of the six themes: Seed Systems, Field Cropping Systems, Protected Cropping Systems, Natural Resource Management, Integrated Pest Management, Mechanization and Digitalization. The seventh theme, Farmers and Enabling Environment, was held as a plenary session.

To maintain momentum, consensus was reached on strategic priorities and action-oriented recommendations to develop and implement sustainable plant production systems towards 2031, to be adapted to local contexts. Based on submissions before, during and after discussions at the conference, the Steering Committee of the conference validated the following 20 recommendations:

Thematic areas

Farmers and enabling environment

1. *Adopt* policies and investment mechanisms to implement recommendations formulated by the global conference on sustainable plant production, to transition to systems that are culturally appropriate, beneficial to local societies, economies and environments, leaving no one behind.
2. *Enhance* capacities of farmers to transition towards sustainable plant production, by increasing access for all to knowledge, technologies, inputs, and public and private services, with particular focus on participatory extension benefitting small-scale farmers, women and young people.

Seed systems

3. *Support* governments, the private sector and civil society organizations to conserve and characterise genetic diversity and to develop productive and locally adapted plant varieties that can meet future demands for high-quality and plentiful food despite increased occurrence of pests and diseases, limited natural resources and unpredictable changes in weather and climates.
4. *Ensure* farmer access to high-quality and disease-free seed and planting materials for all types of farming systems, through the development of regulatory frameworks, public–private partnerships, stronger farmer and market representation, and effective assurance mechanisms.

Field cropping systems

5. *Innovate* cropping systems, based on traditional and new knowledge, use of adapted varieties of local and global crop species, to increase food production and better protect natural resources, biodiversity and the environment, while creating decent jobs both on- and off-farm.
6. *Develop* solutions to enhance cropping-system resilience to stresses caused by pests, diseases, climate fluctuations and socioeconomic factors by engaging appropriate partnerships and markets to improve farmer livelihoods and incentivize protection of biodiversity and natural resources.

Protected cropping systems

7. *Develop* applicable business cases and *facilitate* local market development, to optimize protected cropping systems and ensure farmer access to inputs, services and technologies that increase yields and climate resilience, while reducing demands for natural resources.
8. *Support* the transition to profitable and productive urban and peri-urban horticultural systems based on durable access to land and inputs, and efficient use and recycling of resources, to optimize the provision of safe, fresh and nutritious foods.

Natural resource management

9. *Optimize* resource-use efficiency by adopting integrated and collaborative approaches that leverage both local knowledge and scientific methods, to ensure soil health and sustainable management of water and nutrients.
10. *Develop* and promote sustainable cropping systems that harness (agro-) ecological processes and interactions, integrate local sociocultural values, promote economic inclusion and environmental adaptation, to strengthen farmer livelihoods, community resilience and ecosystem preservation.

Integrated pest management

11. *Reduce* risks from biotic threats by improving surveillance, diagnostics and modelling for better understanding of the effects of climate change and for more efficient tracking and predicting of the movements of transboundary pests and pathogens; developing guidance on strategies for management, risk reduction and plant protection.
12. *Develop*, scale up and promote biological and ecology-based methods, technology packages and digital tools to control critical pests and diseases while minimizing pollution risks.

Mechanization and digitalization

13. *Develop and promote* innovative business models that give access to sustainable agricultural mechanization and power sources, and that

provide multiple services and commercial benefits to small-scale farmers, while offering climate-resilient solutions and empowering women and young people.

14. *Create* an equitable digital ecosystem that leverages big data and digital solutions to give farmers, regardless of their knowledge, skills, location and resources, access to a range of tools that respond to their needs and support them in achieving financial independence, environmental sustainability, and social inclusion.

Cross-cutting themes, applicable to all recommendations.

15. *Empower* farmers, women and young people to be co-**innovators** with academic institutions, research organizations and the private sector, of technologies, practices, policies and business models facilitating the science- and evidence-based transition to more beneficial, productive, sustainable, healthy, resilient and socially inclusive agrifood systems.
16. *Address* climate change by enhancing **resilience** of plant-based agriculture systems by improving adaptive capacity, reducing vulnerability and greenhouse gas emissions, avoiding deforestation and increasing carbon sequestration.
17. *Improve* the **efficiency** of plant production and agrifood systems, produce more and better plant-based nutritious food, with a smaller environmental footprint.

Call to action

18. *Design*, refine and bring to scale integrated and inclusive development approaches by brokering partnerships involving farmers, markets, and the public and private sectors to build capacity through participatory learning and strong governance.
19. *Establish* synergistic technical networks that involve diverse actors with multidisciplinary approaches to leverage their unique strengths, and support the transition to sustainable plant production.
20. *Facilitate* coordination among key stakeholders to collaboratively establish priorities, mobilize resources to test, adapt and scale up innovative approaches.

Governments, development partners and all stakeholders are encouraged to implement the strategic actions outlined above to support sustainable plant production. FAO encourages wide publication of these recommendations through appropriate electronic and print media, and their incorporation into advocacy materials. FAO also requests feedback from stakeholders on the successes and failures of implementing these strategic actions.

Annex 1. Conference organizational bodies

Organization

The Global Conference on Sustainable Plant Production (GPC) was organized by FAO with the support of a Steering Committee, a Technical Advisory Panel and a Secretariat.

Steering Committee

The specific role of the Steering Committee is to: provide advice on all aspects of the conference, including its structure; provide advice to the Technical Advisory Panel regarding the draft programme, upon their request; provide advice to the Secretariat, when requested; provide advice on resource mobilization, when requested; act as the event's ambassador among the respective organizations/networks/countries of the Steering Committee members; encourage people to attend the conference; and provide advice on potential follow-up to the conference.

COMPOSITION

Chairperson:

- **Beth Bechdol**, Deputy Director-General, Food and Agriculture Organization of the United Nations (FAO)

Co-chairperson:

- **Martin Kropff**, Global Director, Resilient Agrifood Systems Science Area (RAFS), CGIAR

Vice-chairpersons:

- **Alzbeta Klein**, CEO/Director-General, International Fertilizer Association (IFA), France and United Kingdom of Great Britain and Northern Ireland
- **Josse de Baerdemaeker**, Em. Professor, KU Leuven, Belgium
- **Michael Keller**, Secretary General, International Seed Federation (ISF)
- **Sunday Ekesi**, Head, Integrated Sciences and Capacity Building, International, Centre of Insect Physiology and Ecology (icipe), Nairobi, Kenya
- **Xiangzhao Gao**, Professor and Chief Scientist, National Agro-Technical Extension and Service Center (NATESC), Ministry of Agriculture and Rural Affairs, China
- **Marcela Quintero**, Associate Director-General, Research Strategy and Innovation. Alliance of Bioversity International and CIAT, Colombia; Leader, CGIAR Agroecology Initiative
- **Ana María Loboguerrero Rodríguez**, Research Director of Climate Action, Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT), CGIAR

Members:

- **Niels Louwaars**, Managing Director, Plantum, Kingdom of the Netherlands
- **Jon Hellin**, Platform Leader, Sustainable Impact through Rice-Based Systems, International Rice Research Institute (IRRI), CGIAR
- **Yüksel Tüzel**, Professor, Ege University, Faculty of Agriculture, Department. of Horticulture, Bornova-Izmir, Türkiye; former ISHS President 2018–2022
- **Graciela Metternicht**, Professor, University of New South Wales, Sydney (UNSW)
- **Robert Bertram**, Chief Scientist, Bureau for Resilience and Food Security, United States Agency for International Development (USAID)
- **Geoffrey Mrema**, Professor, Agricultural Engineering, Sokoine University of Agriculture, United Republic of Tanzania
- **Channing Arndt**, Director, Environment and Production Technology, International Food Policy Research Institute (IFPRI), CGIAR

- **Elizabeth Nsimadala**, Director, Women Affairs, Pan Africa Farmers Organization (PAFO). Ex-President, PAFO; President, Eastern Africa Farmers Federation (EAFF)
- **Robert Delve**, Lead Global Technical Advisor – Agronomy, Sustainable Production, Markets and Institutions Division, International Fund for Agricultural Development (IFAD)
- **William R. Sutton**, Global Lead Climate-Smart Agriculture (CSA) and Lead Agricultural Economist, World Bank
- **Jerome Bandry**, Secretary General, European Agricultural Machinery Association (CEMA)
- **Sayed Azam Ali**, CEO, Crops for the Future (CFF)
- **Lifeng Li**, Director, Land and Water Division (NSL), Food and Agriculture Organization of the United Nations (FAO)
- **Marcela Villarreal**, Director, Partnerships and UN Collaboration Division (PSU), Food and Agriculture Organization of the United Nations (FAO)
- **Qu Liang**, Director, Joint FAO/IAEA Centre (Nuclear Techniques in Food and Agriculture) (CJN), Food and Agriculture Organization of the United Nations (FAO)
- **Zitouni Ould Dada**, Deputy Director, Office of Climate Change, Biodiversity and Environment (OCB), Food and Agriculture Organization of the United Nations (FAO)

Executive Secretary:

- **Jingyuan Xia**, Director, Plant Production and Protection Division (NSP), Food and Agriculture Organization of the United Nations (FAO).

Technical Advisory Panel

The Technical Advisory Panel for the conference has the specific role to develop an innovative and inspiring programme covering the main conference topics, with proposals for the names of potential keynote speakers, presenters, panellists, chairs and rapporteurs for the different sessions. In developing the programme, the TAP follows guidance from the FAO Secretariat to ensure the list of speakers/chairs/panellists is balanced with respect to gender, different geographic areas and to different stakeholder groups, and seeks internal consensus also based on inputs from professional colleagues on the final programme that will be proposed for final endorsement to the Steering Committee.

COMPOSITION

Chairperson:

- **Martin Kropff**, Managing Director, Resilient Agrifood Systems Science Area (RAFS), CGIAR

Co-chairperson:

Ismahane Elouafi, Chief Scientist, Food and Agriculture Organization of the United Nations (FAO)

Vice-chairpersons:

- **Niels Louwaars**, Managing Director, Plantum, Kingdom of the Netherlands
- **Jon Hellin**, Platform Leader, Sustainable Impact through Rice-Based Systems, International Rice Research Institute (IRRI), CGIAR
- **Yüksel Tüzel**, Professor, Ege University, Faculty of Agriculture, Department of Horticulture, Bornova-Izmir, Türkiye; former ISHS President 2018–2022
- **Graciela Metternicht**, Professor, University of New South Wales, Sydney (UNSW)
- **Robert Bertram**, Chief Scientist, Bureau for Resilience and Food Security, United States Agency for International Development (USAID)
- **Geoffrey Mrema**, Professor, Agricultural Engineering, Sokoine University of Agriculture, United Republic of Tanzania
- **Channing Arndt**, Director, Environment and Production Technology, International Food Policy Research Institute (IFPRI), CGIAR

Members:

- **Emmanuel Okogbenin**, Director, Programme Development and Commercialization, African Agricultural Technology Foundation (AATF), Kenya
- **Tammi Jonas**, President, Australian Food Sovereignty Alliance (AFSA)
- **Juliana Jaramillo**, Lead, Regenerative Agriculture Advocacy and Theme, RAINFOREST ALLIANCE
- **Bernard Vanlauwe**, Deputy Director-General, Research for Development, International Institute of Tropical Agriculture (IITA), Kenya
- **Weijie Jiang**, Professor, Institute of Vegetables and Flowers, Chinese Academy of Agricultural Sciences (IVF/CAAS), China
- **Pietro Tonini**, Doctoral Researcher, Institute of Environmental Science and Technology, Autonomous University of Barcelona (ICTA-UAB)
- **Shamie Zingore**, Director, African Plant Nutrition Institute (APNI)
- **Felix Reinders**, Chair, Steering Committee, the Global Framework on Water Scarcity in Agriculture (WASAG)
- **Roma Gwynn**, Vice President, International Biocontrol Manufacturers Association (IBMA)
- Ibrahim Al-Jboory, President, Arab Society for Plant Protection
- **Saidi Mkomwa**, Executive Secretary, African Conservation Tillage Network (ACT)
- **Salah Sukkarieh**, Professor, Robotics and Intelligent Systems, University of Sydney, Australia
- **Rasheed Sulaiman**, Director, Centre for Research on Innovation and Science Policy (CRISP)
- **Elizabeth Nsimadala**, Director, Women Affairs, Pan Africa Farmers Organization (PAFO); Ex-President, PAFO. President, Eastern Africa Farmers Federation (EAFF)
- **Fenton Beed**, Senior Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Maher Salman**, Senior Land and Water Officer, Land and Water Division (NSL), FAO
- **Guilherme Brady**, Partnerships Officer, Partnerships and United Nations Collaboration Division (PSU), FAO
- **Anne-Katrin Bogdanski**, Technical Officer, Joint FAO/IAEA Centre (Nuclear Techniques in Food and Agriculture) (CJN), FAO
- **Preetmoninder Lidder**, Technical Adviser, Office of Chief Scientist (DDCC), FAO
- **Sheila Willis**, Director, International Programmes, Pesticide Action Network (PAN)
- **Bruno Gérard**, Professor, AgroBioScience Lead, Mohammed VI University, Morocco
- **Frederic Castell**, Senior Natural Resources Officer, Office of Climate Change, Biodiversity and Environment (OCB), FAO

Secretariat

The Secretariat is in charge of the organization of the conference, including its programme, logistics and communication.

COMPOSITION

Executive Secretary:

- **Jingyuan Xia**, Director, Plant Production and Protection Division (NSP), FAO

Coordinator:

- **Fenton Beed**, Senior Agricultural Officer, Plant Production and Protection Division (NSP), FAO

Assistant Coordinator:

- **Makiko Taguchi**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO

Focal points of thematic session:

- **Wilson Hugo**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Emma Siliprandi**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Makiko Taguchi**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Fenton Beed**, Senior Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Ivan Landers**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Buyung Hadi**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Maged Elkahky**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Josef Kienzle**, Agricultural Engineer, Plant Production and Protection Division (NSP), FAO
- **Karim Houmy**, Sustainable Agriculture, Mechanization Consultant, Plant Production and Protection Division (NSP), FAO
- **Anne Sophie Poisot**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Joseph Mpagalile**, Agricultural Engineer, Plant Production and Protection Division (NSP), FAO
- **Shawn Mcguire**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Antonio Mele**, Ecosystem Services Consultant, Plant Production and Protection Division (NSP), FAO
- **Soren Moller**, Agroecology and Food Systems Consultant, Plant Production and Protection Division (NSP), FAO

Core members for operations and support:

- **Nadia Sozzi**, Office Assistant, Plant Production and Protection Division (NSP), FAO
- **Alessia Laurenza**, Office Assistant, Plant Production and Protection Division (NSP), FAO
- **Bruno Telemans**, Consultant Sustainable Crop Production, Plant Production and Protection Division (NSP), FAO
- **Nadine Aschauer**, Intern, Plant Production and Protection Division (NSP), FAO
- **Haekoo Kim**, Technical Adviser, Plant Production and Protection Division (NSP), FAO
- **Shangchuan Jiang**, Agriculture Specialist, Plant Production and Protection Division (NSP), FAO
- **Mirko Montuori**, Communication Officer, Plant Production and Protection Division (NSP), FAO
- **Isabella Trapani**, Crop and Food System Specialist, Plant Production and Protection Division (NSP), FAO
- **Paul Howard**, Office Assistant, Plant Production and Protection Division (NSP), FAO

Working groups:

- **Programme**: Fenton Beed, Haekoo Kim, thematic session focal points, Bruno Telemans, Nadine Aschauer
- **Communication**: Mirko Montuori, Shangchuan Jiang, NSP communication group members (Ginevra Virgili, Micah Goldsmith, Maria Soledad Fernandez Gonzalez, Isabella Trapani, Linda Perella, Francisco Martinez, Riccardo Mazzucchelli, Matteo Casling)
- **Resource Mobilization**: Fenton Beed, Wilson Hugo
- **Logistics**: Makiko Taguchi, Nadia Sozzi, Alessia Laurenza, Bruno Telemans

Observers:

- **Hafiz Muminjanov**, Technical Advisor, Plant Production and Protection Division (NSP), FAO
- **Ariella Glinni**, Senior Technical Officer, Plant Production and Protection Division (NSP), FAO
- **Dina Rahman**, Senior Coordinator, Office of the Director-General (ODG), FAO
- **Svetlana Velmeskina**, Office Assistant, Plant Production and Protection Division (NSP), FAO

Annex 2. Conference programme

WEDNESDAY, 2 NOVEMBER 2022

Plenary Session 1: Opening *09.30–09.50*

Moderator: *Beth Bechdol, FAO Deputy Director-General*

Opening Remarks

QU Dongyu, FAO Director-General

Plenary Session 2: Keynote Addresses *09.50–12.30*

Moderators: *Beth Bechdol, FAO Deputy Director-General, and Martin Kropff, Managing Director, Resilient Agri-Food Systems (RAFS), CGIAR*

Keynote Address Section A *(four presentations, each 15 minutes)*

1. Sustainable plant production is at the heart of agrifood systems transformation for resilience (**Martin Kropff**)
2. Transforming food, land and water systems under climate change (**Ana Maria Loboguerrero Rodriguez**)
3. Collaborating towards achieving progress on SDG 1, SDG 2 and SDG 12 (**Michael Keller**)
4. Plant nutrition – Key connector between food and energy (**Alzbeta Klein**)

Discussion (20 minutes)

Keynote Address Section B *(four presentations, each 15 minutes)*

1. Agroecology: More than practices. A holistic approach to make a sustainable transition to sustainable food systems (**Marcela Quintero**)
2. Crop yield increase and green agricultural development in China (**Xiangzhao Gao**)
3. Confronting the global burden of pests and pathogens in a changing climate: Challenges and opportunities (**Sunday Ekesi**)
4. Digital opportunities and appropriate agricultural mechanization (**Josse de Baerdemaeker**)

Discussion (20 minutes)

Lunch Break 12.30–14.00

Thematic Sessions 1.1 and 2.1 *14.00–15.30*

Moderator: *Session Chair*

Thematic Session 1: Seed Systems

Session 1.1: ***Adapted varieties***

Thematic Session 2: Field Cropping Systems

Session 2.1: ***Efficient cropping systems***

Break 15.30–16.00

Thematic Sessions 1.2 and 2.2 *16.00–17.30*

Moderator: *Session Chair*

Thematic Session 1: Seed Systems

Session 1.2: ***Quality seeds***

Thematic Session 2: Field Cropping Systems

Session 2.2: ***Resilient cropping systems***

Reception at FAO headquarters 18.00–20.00

THURSDAY, 3 NOVEMBER 2022

Thematic Sessions 3.1 and 4.1 *09.30–10.30*

Moderator: *Session Chairs*

Thematic Session 3: Protected Cropping Systems

Session 3.1: ***Optimizing production efficiencies***

Thematic Session 4: Field Cropping Systems

Session 4.1: ***Maximizing resource-use efficiency***

Break 10.30–11.00

Thematic Sessions 3.2 and 4.2 *11.00–12.30*

Moderator: *Session Chairs*

Thematic Session 3: Seed Systems

Session 3.2: ***Transforming urban horticulture***

Thematic Session 4: Field Cropping Systems

Session 4.2: ***Ecosystems approaches to resilience***

Lunch Break 12.30–14.00
FAO launch event on implementation of OCOP country projects 12.30–14.00

Thematic Sessions 5.1 and 6.1 *14.00–15.30*

Moderator: *Session Chairs*

Thematic Session 5: Integrated Pest Management

Session 5.1: ***Challenges in plant pests and diseases***

Thematic Session 6: Mechanization and Digitalization

Session 6.1: ***Smart Mechanization***

Break 10.30–11.00

Thematic Sessions 5.2 and 6.2 *11.00–12.30*

Moderator: *Session Chairs*

Thematic Session 5: Integrated Pest Management

Session 5.2: ***Solutions for plant pest and disease management***

Thematic Session 6: Mechanization and Digitalization

Session 6.2: ***Digital Agriculture***

FRIDAY, 4 NOVEMBER 2022

Thematic Session 7 *09.30–10.30*

Moderator: *Elizabeth Nsimadala*

Thematic Session 7: Farmers and Enabling Environment

Break 10.30–11.00

Plenary Session 3 *11.00–12.30*

Moderators: *Martin Kropff, Managing Director, Resilient Agri-Food Systems (RAFS), CGIAR, and Jingyuan Xia, NSP Director, FAO*

Reports on Thematic Sessions and conference recommendations

- **Introduction** (5 minutes)
- **Highlights of each thematic session by Chair or Vice-Chair from seven Thematic Sessions** (5 minutes each)
- **Presentation on conference recommendations by Chair or Vice-Chair of Thematic Session 7** (10 minutes)
- **Discussion and conclusion** (40 minutes)

Lunch Break 12.30–14.00

Plenary Session 4 - High-level Ministerial Segment and Closing *14.00–15.30*

Moderator: *Beth Bechdol*

High-Level Ministerial Segment

- **5 Ministers** from 5 FAO Regions (10 minutes each): Nigeria (Africa), Thailand (Asia and the Pacific), Türkiye (Europe and Central Asia), Mexico (Latin America and the Caribbean) and United States of America (North America)
- **Discussion** (20 minutes)
- **Closing** (10 minutes)
- Beth Bechdol, FAO Deputy Director-General

Detailed Programme

Wednesday, 2 November 2022

09.30–09.50, PLENARY SESSION 1: OPENING

Moderator: ***Beth Bechdol****,*
FAO Deputy Director-General

Opening remarks
QU Dongyu, *FAO Director-General*

09.50–12.30, PLENARY SESSION 2: KEYNOTE ADDRESSES

Moderators: Beth Bechdol, FAO Deputy Director-General, and Martin Kropff, Managing Director, Resilient Agrifood Systems Science Area (RAFS), CGIAR

Section A:

- *A.1 Sustainable plant production is at the heart of agrifood systems transformation for resilience* (15 minutes), **Martin Kropff**, Managing Director, Resilient Agrifood Systems Science Area (RAFS), CGIAR
- *A.2. Transforming food, land and water systems under climate change* (15 minutes), **Ana María Loboguerrero Rodríguez**, Research Director of Climate Action at the Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT) – CGIAR
- *A.3. Collaborating towards achieving progress on SDG 1, SDG 2 and SDG 12* (15 minutes), **Michael Keller**, Secretary General, International Seed Federation (ISF)
- *A.4. Plant Nutrition – Key connector between food and energy* (15 minutes), **Alzbeta Klein**, Director-General, International Fertilizer Association (IFA)
- Discussion (20 minutes)

Section B:

- *B.1 Agroecology: More than practices. A holistic approach to make sustainable transition to sustainable food systems* (15 minutes), **Marcela Quintero**, Associate Director Multifunctional Landscapes, General, Research Strategy and Innovation. Alliance of Bioversity International and CIAT/ CGIAR
- *B.2. Crop yield increase and green agricultural development in China* (15 minutes), **Xiangzhao Gao**, Professor and Chief Scientist, National Agro-Technical Extension and Service Center (NATESC), Ministry of Agriculture and Rural Affairs, China
- *B.3. Confronting the global burden of pests and pathogens in a changing climate: Challenges and opportunities* (15 minutes), **Sunday Ekesi**, Head, Integrated Sciences and Capacity Building, International, Centre of Insect Physiology and Ecology (icipe), Nairobi, Kenya
- *B.4. Digital opportunities and appropriate agricultural mechanization* (15 minutes), **Josse de Baerdemaeker**, Em. Professor, KU Leuven, Belgium
- Discussion (20 minutes)

14.00–17.30, PARALLEL THEMATIC SESSIONS: THEMES 1 AND 2

THEME 1: SEED SYSTEMS

13.30–15.30, Session 1.1: Adapted varieties

Chair:

- **Niels Louwaars**, Managing Director, Plantum, Kingdom of the Netherlands

Co-chairs:

- **Emmanuel Okogbenin**, Director, Programme Development and Commercialization, African Agricultural Technology Foundation (AATF)
- **Tammi Jonas**, President, Australian Food Sovereignty Alliance (AFSA)

Rapporteurs:

- **Wilson Hugo**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Shawn Mcguire**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Needs of Indigenous farmers in a changing world* (10 minutes), **Gisela Illescas Palma**, NGO Movimento Agroecologico de Latino America y Caribe (Mexico)
- *Breeding with farmers* (10 minutes), **Rene Salazar**, NGO, Philippines
- *Responding to diversity of farmers' needs* (10 minutes), **Ian Barker**, Senior Director, Strategy, Delivery and Scaling, One CGIAR, United Kingdom of Great Britain and Northern Ireland
- *Research progress on super-hybrid rice in China* (10 minutes), **Wenbang Tang**, Director-General, China National Research Center of Hybrid Rice, China, and **Yaosong Yang**, China National Hybrid Rice Research & Development Center / Hunan Hybrid Rice Research Center, China
- *Gene bank contributions to seed systems* (10 minutes), **Nora Castañeda-Álvarez**, Project manager, Global Crop Diversity Trust, Germany
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

16.00–17.30, Session 1.2: Quality seeds

Chair:

- **Niels Louwaars**, Managing Director, Plantum, Kingdom of the Netherlands

Co-chairs:

- **Emmanuel Okogbenin**, Director, Programme Development and Commercialization, African Agricultural Technology Foundation (AATF)
- **Tammi Jonas**, President, Australian Food Sovereignty Alliance (AFSA)

Rapporteurs:

- **Wilson Hugo**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Shawn Mcguire**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Community knowledge and technological innovations* (10 minutes), **Andrew Mushita**, Executive Director, Community Technology Development Organisation, Zimbabwe
- *Emergency seed assistance: updates on what to do and what not to do* (10 minutes), **Louise Sperling**, Research Director, SeedSystem, United Stated of America
- *Perspectives on the sustainability of seed business and African small-scale seed supply* (10 minutes), **Monica Kansiime**, Deputy Director, Development and outreach Africa CAB International, Kenya
- *Seed technology to upgrade crop sustainably* (10 minutes), **Marcia Werner**, Research and Technology Director, Incotec, Brazil
- *International seed trade – an essential component of resilient seed systems* (10 minutes), **Niels Louwaars**, Managing Director, Plantum, Kingdom of the Netherlands

- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

THEME 2: FIELD CROPPING SYSTEMS

13.30–15.30, Session 2.1: Efficient cropping systems

Chair:

- **Jon Hellin**, Platform Leader, Sustainable Impact through Rice-Based Systems, International Rice Research Institute (IRRI), CGIAR

Co-chairs:

- **Juliana Jaramillo**, Lead, Regenerative Agriculture Advocacy and Theme, RAINFOREST ALLIANCE
- **Bernard Vanlauwe**, Deputy Director-General, Research for Development, International Institute of Tropical Agriculture (IITA), Kenya

Rapporteurs:

- **Makiko Taguchi**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Ivan Landers**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Transitioning to sustainable and resilient smallholder farming in sub-Saharan Africa – Taking farmer perspectives into account* (10 minutes), **Katrien Descheemaeker**, Professor, Plant Production Systems, Wageningen University, Kingdom of the Netherlands
- *Research and development of mechanized rice ratooning technology in China* (10 minutes), **Shaobing Peng**, Professor, Huazhong Agricultural University, China
- *Practical precision agronomy in perennial systems to reduce cash, carbon and biodiversity costs* (10 minutes), **Piet van Asten**, Vice President, Head Sustainable Production Systems, Olam Food Ingredients
- *Improving dryland production* (10 minutes), **Arvind Kumar**, Deputy Director-General – Research, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India
- *Climate change and variability: farm-level vulnerability, coping and adaptation opportunities* (10 minutes), **Mercy Kamau**, Senior Research Fellow, Tegemeo Institute of Agricultural Policy and Development, Egerton University, Kenya
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

16.00–17.30, Session 2.2: Resilient cropping systems

Chair:

- **Jon Hellin**, Platform Leader, Sustainable Impact through Rice-Based Systems, International Rice Research Institute (IRRI), CGIAR

Co-chairs:

- **Juliana Jaramillo**, Lead, Regenerative Agriculture Advocacy and Theme, RAINFOREST ALLIANCE
- **Bernard Vanlauwe**, Deputy Director-General, Research for Development, International Institute of Tropical Agriculture (IITA), Kenya

Rapporteurs:

- **Makiko Taguchi**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Ivan Landers**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Integrated transformations to deliver climate-smart agriculture* (10 minutes), **Rachael McDonnell**, Deputy Director-General, Research for Development, International Water Management Institute, Rome, Italy

- *Fertilizer and soil health – two sides of the same coin?* (10 minutes), **Bernard Vanlauwe**, Deputy Director-General, Research for Development, International Institute of Tropical Agriculture (IITA), CGIAR, Kenya
- *Climate-adaptive production systems* (10 minutes), **Caroline Mwongera**, Thematic Leader, Climate-Smart Agriculture Practices and Technologies, Alliance for Bioversity International and CIAT, Kenya
- *Agroforestry and regenerative agriculture in coffee-growing areas with climate change* (10 minutes), **Elias de Melo**, Agroforestry Specialist (Research, Postgraduate and Technical Cooperation), Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica
- *Indigenous Peoples' food systems as game changers, feeding the world in a sustainable manner* (10 minutes), **Tania Eulalia Martínez-Cruz**, Associate Researcher, Free University Brussels.
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

Thursday, 3 November 2022

09.00–12.30, PARALLEL THEMATIC SESSIONS: THEMES 3 AND 4

THEME 3: PROTECTED CROPPING SYSTEMS

09.00–10.30, Session 3.1: Optimizing production efficiencies

Chair:

Yüksel Tüzel, Professor, Ege University, Faculty of Agriculture, Department of Horticulture, Bornova-Izmir, Türkiye; former ISHS President 2018–2022

Co-chairs:

- **Weijie Jiang**, Professor, Institute of Vegetables and Flowers, Chinese Academy of Agricultural Sciences (IVF/CAAS)
- **Pietro Tonini**, Doctoral Researcher, Institute of Environmental Science and Technology, Autonomous University of Barcelona (ICTA-UAB)

Rapporteurs:

- **Fenton Beed**, Senior Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Ivan Landers**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Improving resource use efficiency* (10 minutes), **Yüksel Tüzel**, Professor, Ege University, Faculty of Agriculture, Department of Horticulture, Bornova-Izmir, Türkiye; former ISHS President 2018–2022
- *The evolution of Jamaica's protected agriculture value chain: a possible route for others* (10 minutes), **Jervis Rowe**, President, Jamaica Greenhouse Growers Association, Jamaica
- *Adapting protected cultivation systems for small-scale farmers* (10 minutes), **Lusike Wasilwa**, Kenya Agricultural and Livestock Research Organization, Kenya
- *A biocircular approach to soilless culture in China* (10 minutes), **Weijie Jiang**, Professor, Institute of vegetables & Flowers, Chinese Academy of Agricultural Sciences (IVF/CAAS) and **Dong Ruifang**, General Manager, Beijing Easy Agriculture Science and Technology Pvt., Ltd., China
- *Evaluating greenhouse production systems based on United Nations Sustainable Development Goals* (10 minutes), **Leo Marcelis**, Professor Horticulture and Product Physiology
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

11.00–12.30, Session 3.2: Transforming urban horticulture

Chair:

Pietro Tonini, Doctoral Researcher, Institute of Environmental Science and Technology, Autonomous University of Barcelona (ICTA-UAB)

Co-chairs:

- **Weijie Jiang**, Professor, Institute of Vegetables and Flowers, Chinese Academy of Agricultural Sciences (IVF/CAAS)

Rapporteurs:

- **Fenton Beed**, Senior Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Ivan Landers**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Protected horticulture: a way forward to sustainable agriculture in arid regions* (10 minutes), **Muhammad Tahir Akram**, Assistant Professor, Department of Horticulture, PMAS-Arid Agriculture University, Rawalpindi, Pakistan
- *Plant factory innovations towards inclusive and sustainable societies* (10 minutes), **Eri Hayashi**, Vice-President, Japan Plant Factory Association, Japan
- *Urban farming and water conservation* (10 minutes), **Redouane Choukr-Allah**, Senior Professor University Mohamed VI Polytechnic, Benguerir, Morocco
- *Life cycle environmental impact of urban horticulture* (10 minutes), **Martí Rufí-Salís**, Postdoctoral Researcher, Universitat Autònoma de Barcelona, Spain
- *Ecosystem services in urban agriculture in Quito, Ecuador* (10 minutes), **Alexandra Rodríguez Dueñas**, Coordinator Proyecto de Agricultura Urbana Participativa AGRUPAR, Corporación de Promoción Económica CONQUITO, Quito, Ecuador
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

THEME 4: NATURAL RESOURCE MANAGEMENT

09.00–10.30, Session 4.1: Maximizing resource-use efficiency

Chair:

- **Shamie Zingore**, Director of Research & Development, African Plant Nutrition Institute (APNI)

Co-chair:

Felix Reinders, Chair, Steering Committee, Global Framework on Water Scarcity in Agriculture (WASAG)

Rapporteurs:

- **Antonio Mele**, Ecosystem Services Consultant, Plant Production and Protection Division (NSP), FAO
- **Soren Moller**, Agroecology and Food Systems Consultant, Plant Production and Protection Division (NSP), FAO
- **Emma Siliprandi**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Towards a circular bionutrient economy linking sanitation and agriculture* (10 minutes), **Rebecca Nelson**, Professor, Cornell University, United States of America
- *Optimizing water use: Lessons from around the globe* (10 minutes), **Marco Arcieri**, Vice President, ICID – International Commission on Irrigation and Drainage, Italy
- *Improving nutrient management to increase crop productivity and sustainability* (10 minutes),

Fusuo Zhang, Dean, National Academy of Agricultural Green Development, China Agricultural University, China
- *How making food from forgotten desert trees can strengthen both food security and biodiversity* (10 minutes), **Josef Garvi**, Executive Director, Sahara Sahel Foods, Niger
- *Cocreation of knowledge between farmers and researchers* (10 minutes), **Chukki Nanjundaswamy**, International Planning Committee for Food Sovereignty (IPC)
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

11.00–12.30, Session 4.2: Ecosystem approaches to resilience

Chair:

- **Felix Reinders**, Chair, Steering Committee, the Global Framework on Water Scarcity in Agriculture (WASAG)

Co-chairs:

- **Shamie Zingore**, Director, African Plant Nutrition Institute (APNI)

Rapporteurs:

- **Antonio Mele**, Ecosystem Services Consultant, Plant Production and Protection Division (NSP), FAO
- **Soren Moller**, Agroecology and Food Systems Consultant, Plant Production and Protection Division (NSP), FAO
- **Emma Siliprandi**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Multifunctional landscapes* (10 minutes,) **Lucas Garibaldi**, Director, IRNAD; Professor, UNRN; Senior Researcher, CONICET, Argentina
- *Efficient production for resilience in small-scale systems* (10 minutes), **Arjumand Nizami**, Country Director, Helvetas Swiss Intercooperation, Pakistan
- *Australian perspectives on farmer-led regeneration of agricultural ecosystems health* (10 minutes), **Walter Jehne**, Climate Scientist, Microbiologist and Founder of Healthy Soils Australia, and **Ben Fox**, Public advocate of creativity
- *Building resilience through agroecological innovation in arid and semi-arid lands* (10 minutes), **Paulo Petersen**, Executive Coordinator, AS-PTA – Family Farming and Agroecology, Brazil
- *Regenerating the world's grasslands through holistic management* (10 minutes), **Nicholas Sharpe**, Director, Global Projects, Savory Institute, Spain
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

THEME 5: INTEGRATED PEST MANAGEMENT

13.30–15.00, Session 5.1: Challenges in plant pests and diseases

Chair:

- **Ibrahim Al-Jboory**, President, Arab Society for Plant Protection

Co-chairs:

- **Roma Gwynn**, Vice President, International Biocontrol Manufacturers Association (IBMA)

Rapporteurs:

- **Buyung Hadi**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Maged Elkahky**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- Opening remarks: *challenges, threats and opportunities in plant health management* (5 minutes), **Ibrahim Al-Jboory**, President of the Arab Society for Plant Protection (ASPP)

- *Climate change, plant pests and pathogens* (10 minutes), **Daniel Bebber**, Associate Professor of Ecology, University of Exeter, United Kingdom of Great Britain and Northern Ireland
- *Pesticide Pollution – an underrepresented environmental problem* (10 minutes), **Fiona H.M. Tang**, Lecturer, School of Environmental and Rural Science, University of New England, Armidale, Australia
- *Biological invasions and their economic costs on agriculture* (10 minutes), **Franck Courchamp**, CNRS Director of Research, University Paris Saclay, France
- *Area-wide IPM in locust control: Current Knowledge and Challenges* (10 minutes), **Arianne Cease**, Associate Professor and Director, Global Locust Initiative, Arizona State University, United States of America
- *Prevention of transboundary spread of pests and pathogens is enhanced with farmer support* (10 minutes), **Safaa G. Kumari**, Head of Seed Health Lab/Plant Virologist, International Center for Agricultural Research in the Dry Areas (ICARDA), Terbol Station, Beqaa Valley, Zahle, Lebanon
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

15.30–17.00, Session 5.2: Solutions for plant pest and disease management

Chair:

- **Roma Gwynn**, Vice President, International Biocontrol Manufacturers Association (IBMA)

Co-chairs:

- **Ibrahim Al-Jboory**, President, Arab Society for Plant Protection

Rapporteurs:

- **Buyung Hadi**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Maged Elkahky**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- *Opening remarks: pathways to the future in health management* (5 minutes), **Roma Gwynn**, Vice President, International Biocontrol Manufacturers Association
- *Coordination of digital tools for locally adapted decision support in IPM* (10 minutes), *Berit Nordskog*, Research Scientist, Norwegian Institute of Bioeconomy Research (NIBIO), Norway
- *Changes in farmer's perception and adoption of biological control* (10 minutes), **Italo Delalibera**, Professor, Frugivory and seed dispersal, Biocontrol, and Food web ecology, University of São Paulo
- *Application of precision agricultural aviation technology in an ecological unmanned farm* (10 minutes), **Yubin Lan**, Director and Chief Scientist of the National Center for International Collaboration Research on Precision Agricultural Aviation Pesticides Spraying Technology (NPAAC), South China Agricultural University / Shandong University of Technology, China
- *Participatory innovation platform for plant health management* (10 minutes), **Rica Joy Flor**, Scientist II – Innovation Systems, International Rice Research Institute (IRRI), Cambodia
- *Farmer-oriented and science-driven plant health management for West Africa* (10 minutes), **Manuele Tamò**, Principal Scientist – Entomologist, International Institute of Tropical Agriculture IITA, Cotonou, Benin
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

THEME 6: MECHANIZATION AND DIGITALIZATION

13.30–15.00, Session 6.1: Smart Mechanization

Chair:

- **Geoffrey Mrema**, Professor, Agricultural Engineering, Sokoine University of Agriculture, United Republic of Tanzania

Co-chairs:

- **Saidi Mkomwa**, Executive Secretary, African Conservation Tillage Network (ACT)
- **Salah Sukkarieh**, Professor, Robotics and Intelligent Systems, University of Sydney, Australia

Rapporteurs:

- **Josef Kienzle**, Agricultural Engineer, Plant Production and Protection Division (NSP), FAO
- **Joseph Mpagalile**, Agricultural Engineer, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Agricultural mechanization: where are we and where are we going* (10 minutes), **Gajendra Singh**, Chair, Science Committee, Appropriate Scale Mechanization Consortium of University of Illinois, Michigan State University, Kansas State University and NC A&T State University
- *Digital innovations and precision agriculture – an opportunity for small-scale farming systems in sub-Saharan Africa* (10 minutes), **Cecilia M. Onyango**, Department of Plant Science and Crop Protection, University of Nairobi, Kenya
- *Mechanization solutions for enhanced climate resilience, productivity and reduced environmental footprints in drylands of the Global South* (10 minutes), **Mangi Lal Jat**, Global Research Program Director, Resilient Farm and Food Systems, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
- *Business models and economics perspectives of agricultural mechanization development* (10 minutes), **Hiroyuki Takeshima**, Senior Research Fellow, International Food Policy Research Institute (IFPRI), USA
- *The Africa we want: Agenda 2063: The sustainable agricultural mechanization framework – towards commercial, environmental and socioeconomic sustainability* (10 minutes), **Pascal Kaumbutho**, Founder and Managing Director, Agrimech Africa Ltd. Kenya
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

15.30–17.00, Session 6.2: Digital Agriculture

Chair:

- **Salah Sukkarieh**, Professor, Robotics and Intelligent Systems, University of Sydney, Australia

Co-chairs:

- **Saidi Mkomwa**, Executive Secretary, African Conservation Tillage Network (ACT)
- **Geoffrey Mrema**, Professor, Agricultural Engineering, Sokoine University of Agriculture, United Republic of Tanzania

Rapporteurs:

- **Josef Kienzle**, Agricultural Engineer, Plant Production and Protection Division (NSP), FAO
- **Karim Houmy**, Sustainable Agriculture, Mechanization Consultant, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Digitalization in the agricultural system of southern Africa (newly released case study for the SADC region)* (10 minutes), **Majola L. Mabuza**, Programme Coordinator, Agricultural Productivity Programme for Southern Africa (APPSA) at the Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA)
- *Research and practice of digital agriculture in China* (10 minutes), **Zhao Chunjiang**, Professor, Chief Scientist, National Engineering Research Center for Information Technology in Agriculture (NERCITA), member of the Chinese Academy of Engineering, China
- *Agricultural automation for small-scale producers with applied cases on weed control in vegetables and vineyards* (10 minutes), **Ingrid Sarlandie**,

Former Chief Operating Officer (COO), Naïo Technologies, France and **Gaëtan Séverac**, Naïo Technologies, France
- *Opportunities and challenges in digital agriculture: global patterns and policy issues on the way towards sustainable agriculture* (10 minutes), **Sarah Hackfort**, Agricultural and Food Policy Group, Humboldt University Berlin, Germany
- *Commercialization and scaling innovations from digital agriculture start-ups through national policies* (10 minutes), **Kamal Yakub**, Co-Founder, Chief Visionary Officer, TROTRO Tractor Ltd, Ghana, Togo, Benin, Nigeria, Zimbabwe and Zambia
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

Friday, 4 November 2022

09.00–10.30, THEMATIC SESSION: THEME 7

THEME 7: FARMERS AND ENABLING ENVIRONMENT

09.00–10.30, Session: Farmers and Enabling Environment

Chair:

- **Elizabeth Nsimadala**, Director, Women Affairs, Pan Africa Farmers Organization (PAFO); Ex-President, PAFO. President, Eastern Africa Farmers Federation (EAFF)

Co-chairs:

- **Rasheed Sulaiman**, Director, Centre for Research on Innovation and Science Policy (CRISP)

Rapporteurs:

- **Anne Sophie Poisot**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- **Ivan Landers**, Agricultural Officer, Plant Production and Protection Division (NSP), FAO
- Opening Remarks (5 minutes)
- *Accelerating digital innovation and making big data work for small-scale farmers* (10 minutes), **Owen Barder**, CEO, Precision Development (PxD)
- *Biovillages – landscape-level management and governance of agroecosystems* (10 minutes), **G.V. Ramanjaneyulu**, Scientific Director, Centre for Sustainable Agriculture, India
- *Promoting access and adoption of sustainable inputs and technologies* (10 minutes), **Elizabeth Nsimadala**, Director, Women Affairs, Pan Africa Farmers Organization (PAFO); Ex-President, PAFO. President, Eastern Africa Farmers Federation (EAFF)
- *Overcoming extension gaps: increasing access to extension and advisory services* (10 minutes), **Kristin Davis**, Senior Research Fellow, International Food Policy Research Institute (IFPRI), United States of America
- *Agroecological transition in Mexico: promote the agroecological transition and face the challenges of farmers* (10 minutes), **Víctor Suárez Carrera**, Undersecretary of Food Self-sufficiency, Secretariat of Agriculture and Rural Development of the Government of Mexico and **Hector Robles** Berlanga, Director-General de Organización para la Productividad
- Q&A session and discussion (30 minutes)
- Concluding remarks (5 minutes)

11.00–12.30, PLENARY SESSION 3: REPORTS ON THEMATIC SESSIONS AND CONFERENCE RECOMMENDATIONS

Moderators: ***Martin Kropff****, Managing Director, Resilient Agrifood Systems Science Area (RAFS), CGIAR, and* ***Jingyuan Xia****, Director, Plant Production and Protection Division (NSP), FAO*

REPORTS ON THEMATIC SESSIONS

- *Theme 1: Seed Systems* (5 minutes)
  Niels Louwaars, Managing Director, Plantum, Kingdom of the Netherlands
- *Theme 2: Field Cropping Systems* (5 minutes)
  Juliana Jaramillo, Lead, Regenerative Agriculture Advocacy and Theme, RAINFOREST ALLIANCE
- *Theme 3: Protected Cropping Systems* (5 minutes)
  Yüksel Tüzel, Professor, Ege University, Faculty of Agriculture, Department of Horticulture, Bornova-Izmir, Türkiye; former ISHS President 2018–2022
- *Theme 4: Natural Resource Management* (5 minutes)
  Graciela Metternicht, Professor, University of New South Wales, Sydney (UNSW)
- *Theme 5: Integrated Pest Management* (5 minutes)
  Roma Gwynn, Vice President, International Biocontrol Manufacturers Association (IBMA)
- *Theme 6: Mechanization and Digitalization* (5 minutes)
  Saidi Mkomwa, Executive Secretary, African Conservation Tillage Network (ACT)
  Salah Sukkarieh, Professor, Robotics and Intelligent Systems, University of Sydney, Australia
- *Theme 7: Farmers and Enabling Environment (5 minutes)*
  Rasheed Sulaiman, Director, Centre for Research on Innovation and Science Policy (CRISP)

REPORT ON CONFERENCE RECOMMENDATIONS

- Recommendations (10 minutes)
  Elizabeth Nsimadala, Director, Women Affairs, Pan Africa Farmers Organization (PAFO); Ex-President, PAFO. President, Eastern Africa Farmers Federation (EAFF)
- Discussions and conclusion (40 minutes)

16.00–17.30, PLENARY SESSION 4: HIGH-LEVEL MINISTERIAL SEGMENT AND CLOSING

Moderator: ***Beth Bechdol****,*
FAO Deputy Director-General

- H.E. **Chalermchai Sri-on**, Minister of Agriculture and Cooperatives, Thailand
- H.E. **Víctor Manuel Villalobos Arámbula**, Secretario de Agricultura y Desarollo Rural, Mexico
- H.E. **Mohammad M. Abubakar**, Minister for Agriculture and Rural Development, Nigeria
- H.E. **Chavonda Jacobs-Young**, United States Department of Agriculture, Under Secretary for Research, Education, and Economics, United States of America
- Mr **Ayhan Baran**, Alternate Permanent Representative, United Nations Agencies in Rome, Türkiye
- Discussion (20 Minutes)

CLOSING

Beth Bechdol, FAO Deputy Director-General (10 minutes)

CONTACTS

For more information visit:
https://www.fao.org/events/detail/global-conference-on-sustainable-plant-production/en
or contact us at:

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The Proceedings of the Global Conference on Sustainable Plant Production (GPC) summarizes key components of the FAO convened event held from 2 to 4 November 2022.

FAO organized the GPC to provide a neutral forum for its Members, farmers, scientists, development agencies, policy makers, civil society, private sector representatives and other stakeholders to discuss **innovation** that creates **efficient** plant production systems with **resilience** to biotic and abiotic stresses, climate change, natural hazards, and geopolitical disruptions.

Results from focused dialogues are included, on how to produce more food, with less environmental impact while strengthening local and diversified agrifood systems, to generate incomes, create social equity and decent jobs.

The proceedings provide a record of the main highlights, including the opening and keynote addresses, a high-level ministerial segment and thematic sessions covering: seed systems, field cropping systems, protected cropping systems,

natural resource management, integrated pest management, mechanization and digitalization, farmers and enabling environment.

The conference was timely, informative, inclusive and inspiring and developed 20 actionable recommendations that prioritize the way forward for collective action to develop and deliver solutions.

Sustainable plant production systems must be farmer-centric, placing the farmer's needs, knowledge and constraints at the core of the solution and acknowledging the need for a multiplicity of options to be available to respond to complex and heterogeneous production environments that promote greater resilience to climate change and protect biodiversity through integrated approaches.

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