



Independent
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Council



WORKSHOP REPORT

GLOBAL AGRI-FOOD SYSTEMS TO 2050: THREATS AND OPPORTUNITIES

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In order to provide strategic guidance to the directions and priorities of the CGIAR - the world's largest public sector agricultural research system – the Independent Science and Partnership Council (ISPC) is engaging in a set of foresight activities tailored to the specificities of the CGIAR system. In April 2017 the ISPC co-hosted a workshop with the University of Naples on Global Agri-Food Systems to 2050: Threats and Opportunities. The objective of the workshop was to engage expertise outside the CGIAR System for perspectives on major trends and possible disruptions to the global food system to 2050. The workshop was organized around three thematic sessions: i) Analysis of emerging threats and challenges; ii) New opportunities and scientific discovery, and iii) Trends in the agricultural sector. The ISPC plans to follow up on this workshop by engaging people in the CGIAR system in a discussion about the implications for CGIAR future directions, including through the use of participatory scenario building.

This report summarizes the main ideas that emerged from the Naples workshop discussions.

Major findings from the workshop

We are facing a "perfect storm" of global threats and challenges that need agri-food R&D and policy solutions. These global threats are being felt contemporaneously and their combined effects are greater than the sum of their individual effects. The following are some of the dominant challenges faced by the global community:

- Rising urbanization, global migration patterns, and the changing demographic structure of rural populations and smallholder farming means that we will have very different profiles of agricultural workers and their activities in the future – and this varies considerably by region;
- Changing diets, food systems, and the rapid rise in over-nutrition and the epidemic of non-communicable diseases (NCDs) even as malnutrition rates remain high;
- Global environmental and sustainability challenges, including climate shocks and extreme events, environmental degradation and biodiversity loss;
- Trade integration and the declining competitiveness of developing country agriculture;
- Complexity and fragmentation of food systems, role of private industry vs. public investments in supporting the transformation of agri-food systems, and their connections with other sectors;
- Existence of a “missing middle” in African agri-business investments, and importance of the role of African SMEs in AFS and value chains.-
- Disruptive innovation in science and technology have much potential to increase productivity, but also displace rural workers – which could have serious implications for the poorest.

The workshop also identified the following gaps/omissions which were not addressed in the first set of papers: i) attention to the overall geopolitical context; ii) role and profiles of private sector across the food systems agenda (e.g., processing, logistics, role with regards to big data); iii) role of policies at national and regional levels; and iv) R4D providers and the comparative advantage of CGIAR.

The workshop provided a synthesis and in some cases validation of the findings of the numerous foresight exercises that have been conducted recently. What differentiates this initiative, and the forthcoming foresight activities of the ISPC, from the other exercises is the sharp focus on developing country agricultural systems and on the future prospects for the rural poor. The overarching question was identifying big trends – within and external to the agricultural sector - that would have a major effect on how food and agriculture research and policy should re-orient itself in order to remain effective. The workshop identified some initial drivers and key topics, summarized below, that need further elaboration and assessment in terms of their interaction with international research, technical innovation and policy action.

These papers will be finalized and collected in a book on “*Global Agri-Food Systems to 2050 – threats and opportunities*” to be published in 2018. As a next step in the ISPC foresight work, CGIAR scientists will be invited to further develop the key outcomes of the workshop, and provide inputs on the process to help guide future strategies and priority setting of CGIAR research. The workshop brainstorming session, agenda and list of participants are presented in Annex 1, 2 & 3.

Background

As part of its mandate to provide strategic guidance to the CGIAR System, the ISPC launched a foresight workstream in 2017. An independent foresight assessment was initiated with the aim of engaging a group of leading experts and strategic thinkers outside the CGIAR System on the main challenges, global trends, and likely disruptions to food and nutrition security that the world is facing and how these can be tackled in light of the SDGs and beyond. As part of the independent assessment, a series of chapters on various drivers of change and topics of relevance was commissioned. The foresight workstream was inaugurated with a workshop on “*Threats and Opportunities to Agri-Food Systems in 2050*” where initial outlines of the papers were discussed.

Session I - Setting the scene

The opening session provided background information to participants regarding the CGIAR, ISPC and the main objectives of the workshop.

Foresight is a fundamental pillar of the ISPC and an essential function to help understand the context in which the CGIAR operates by analyzing the global trends, anticipating change for better planning and constructing pathways from the present to the future; and, identifying future major challenges and priorities for Agricultural Research for Development (AR4D).

A first paper on **Global trends** presents an overview and synthesis of recent foresight on food and agriculture, and establishing a database on foresight studies for the analysis of key drivers and trends

with implications for food security, poverty and environmental sustainability. The paper describes fourteen global mega-trends based on the work done by the EC Foresight Group, and will analyse the possible implications of these trends on food and agriculture. The paper will also explore knowledge gaps and new potential avenues for R4D.

Session II - Emerging threats and challenges

This session consisted of six paper presentations on the following topics: climate change; demography and global migration; global trade; energy; environment and natural resources; and SDGs and global development challenges. The session was followed by a panel and general discussion on the emerging threats and challenges facing global agri-food systems.

The paper on **Climate Change Impacts** reviews how the projected shifts in mean climate and climate extremes are expected to impact agricultural systems, and describes the transdisciplinary integrated assessment frameworks used by the AgMIP network to assess the ramifications of these impacts. Important discussion points were raised on the differential climate impacts on staples versus coarse grains and millets, methodologies for aggregation of regional scenarios through to global scenarios, and the knowledge gaps related to importance of extreme events and shifts of agro-ecological zones.

The paper on **Demography and Global Migration** presents an overview of the traditional pathways and emerging trends of rural versus urban demography and migration, in relation to agri-food systems and smallholder and subsistence farming. The paper will discuss the key drivers and trends of the increasing migratory pressures in the face of limited structural transformation and job creation. Discussion points included the importance of urbanization as natural growth and/or reclassifications (based on growing population clusters), the implications of rural migration for urban agriculture, diversification of livelihoods, and the effects of policy change and regional dynamics of structural transformation.

The paper on **Global Agri-Food Trade Futures** discusses the trends in openness to trade, documents the current extent of trade in farm products and the trade barriers in this area, summarizes projections of trade needs by 2050, and suggests ways to increase the openness of emerging economies to avoid going down the agricultural protection track taken by Japan, Korea and other high-income countries in the past. In the discussion, a concerns were raised about the global trends of food industry, relationships between trade and nutrition, trade and markets, transformation and possible concentration of power in agri-food systems. Scenarios on animal production and consumption (e.g. impacts of imports of maize, etc.) will also need to be considered. The paper seems to focus a lot more on productivity than on sustainability issues which will shape global markets.

The paper on **Future of Energy** examines the growing role of renewable energy in the global energy mix, bioenergy's share in that role, the conditions (including policy environment) which favor it, and the associated impacts and benefits. Discussants stressed the need to think more broadly about energy trends i.e., not just focus on renewable energy. Such an approach would consider for example, how agriculture links to petroleum and natural gas products (fertilizers) or the use of capital inputs – power for mechanization and/or irrigation. Discussion points also touched upon the effectiveness of using government subsidies to kick start the renewable energy sector; and the assumptions underlying the potential for bioenergy expansion – the efficient use of pasture land, rate of conversion to cropland, and the potential environmental impacts.

The paper on **Environment and Natural Resources** considers the environmental and resource management issues which may impact the sustainability of global agri-food systems in the future. The study identifies threats and opportunities through examination of the present state of natural resources, key drivers of change, and plausible future scenarios. The implications of these emerging threats and opportunities will be evaluated with respect to the specific environment and resource management related SDGs. In discussion, the need to include the costs and trend lines for water in the investment context was highlighted. There is also a question on the alternative scenarios presented (World Economic Forum scenarios), and to what extent these relate to business-as-usual. There is also a need to examine the likely implication on R4D and what it would mean for the CGIAR.

The paper on **SDGs and Global Development Challenges** explores the potential, actual and emerging uses of (strategic) foresight in the actualization of the SDGs at global, regional, national and sub-national level in the Global South, and by different actors, such as governments, private sector, civil society, and multilateral and bilateral development organizations, especially in relation (but not limited to) SDG 2 and SDG 12. The paper formulates a preliminary outline of how the SDGs foresight division of labor between international organizations, national governments, civil society organizations and private suppliers could look like. Discussion points touched upon the UNDP planning processes and work on SDGs, the need to analyze future trends and drivers of development to gain insights on future scenarios and plausible actions, as well as what the endpoint for foresight work is (whether UNDP focuses on the scenarios or the insights).

In the panel discussion general feedback was provided as well as recommendations for the papers presented in the session:

- Foresight should be an ongoing process to improve strategy and make institutions pro-active and agile. It implies accepting diversity of pathways and interdependency between drivers.
- The Green Revolution provided food availability, but the future questions will be around access to food and nutrition. This implies the need for a paradigm shift and to address tensions related to availability and resource efficiency and to pay attention to providing jobs to the growing population, especially in Africa.
- For the CGIAR, we need to identify new research questions and priorities, keeping in mind that the System is very small, compared to the research capacity of the private sector which has been growing recently, especially in middle-income countries. The growing role of the private sector raises questions of intellectual property rights, access to genetic resources, and use of local genetic resources, which makes the role of the CGIAR very important.
- Many chapters focus on on-going trends, but do not stress enough the weak signals, i.e., indications of a potentially important new event or an emerging phenomenon that could become a new trend, and potential breaks. In the chapters, the authors should identify the controversies related to the topic, and show interactions with other chapters/drivers (cf. Meadows' leverage points).
- Little has been said about the governance of food systems and possible changes. The actors of the food systems are changing: The role of the Nation-State is often declining and large agri-food companies are major influencers of the food systems. Donors and civil society are also playing important roles.

- Climate change: IPCC scenarios have to be adapted to agriculture because they were not initially developed with agriculture in mind. There is potential for disruptions to occur with regard to climate change. For instance, a proactive political approach and a strong commitment of the civil society towards stabilizing climate change; development of new sources of electricity in the next 10-20 years; and efficiency of instruments for emissions reduction. There is a need to look at the role of climate in rising sea water, and how that may become a major driver of migration.
- Demography and migration: There is potential for changes with the growing importance of seasonal migration and gender issues, i.e., women in charge of agriculture but lacking land tenure. In SSA, there is a sense that youth wish to move away from agriculture, even if there are few immediate opportunities in other sectors of the economy.
- Trade: Many countries are increasingly dependent on food trade either as importers or as exporters, and the products traded have changed as has the center of gravity of trade. Even in the context of increasingly liberalized economies, there are new barriers created by norms and standards (and there could be an increase in regulations). It is also important to note the strong increase in trade of oil crops, ultra-processed products, and alcoholic beverages, and the decrease in the trade of cereals. Agri-food and trading companies are emerging in Asia and traditional trading companies are diversifying their activities.
- Energy: There is a need to stress the effect of energy transition, and make the link between climate change and energy transition; importance of energy for agriculture (fertilizers and mechanization), but also carbon sequestration.
- The role of history and culture in foresight: ‘Globalization’ is not a new concept and trade of food has occurred (and been disrupted) throughout time. In thinking about ‘what –if’ scenarios, it is important to consider alternative views: what if we continue with the free trading system? What if we don’t? And what would that mean? It is fundamental to anticipate disruptions in innovative ways (for instance, food system disruptions on the health system via food safety issues). Another challenge is in casting a wide net initially, and then focusing within a sector/topic.

The discussion was framed around five crosscutting themes:

- Interactions between technologies, institutions and policies; in the CGIAR, how CRPs are breaking down ‘silos’.
- Interaction across sectors, and connections agri-food systems with other sectors. This has implications for the kind of partnerships CGIAR should be considering.
- Interactions across space and time. This also has implications for partnership strategy.
- Need for system models and the interactions between modelling efforts and stakeholder engagement (participatory work as a necessary complement to systems modelling); this could be an area where the CGIAR could leverage its social capital.
- The role of data and information management. It is not clear if data is readily and easily accessible for such foresight exercises, and this has implications. The role of information and communication technology – and the coming wave over big food. There is a need for links between ICT and food production to cope with disruptions.

Session III - New opportunities and scientific discovery

This session consisted of six paper presentations followed by a panel and general discussion.

The paper on **Food systems** states that for a food systems approach to be useful in addressing food and nutrition security, it is important to consider all the system activities (i.e. not just agricultural production). While primary production is often the focus of food security considerations, “post-farm gate” activities (processing, packaging, transporting, marketing, consuming, and disposing of food and food-related items) are important for food security and enterprise issues, and they also impinge on environmental issues. The food systems approach allows food chain activities to be linked to their social, economic and environmental context. The paper will also examine how food systems “thinking” can help in CGIAR strategic planning; to help identify and address root causes of malnutrition in all its forms; identify points of intervention across the whole food system which can help alleviate malnutrition; and identify and analyze the synergies and trade-offs of interventions (between food and nutrition security, environment and other societal goals). In addition, thinking across all different aspects of the food systems can help to identify connections with other systems (e.g. energy, infrastructure, information) that might be either enabling or constraining options for food system change.

The paper on **Breeding and Biotechnology** focuses on innovations in crop breeding, after describing the challenge of accelerating rates of genetic gain in “breeders’ equation” and the importance of adaptation of new varieties and integration with agronomic practices. The paper will describe the technologies and factors which can lead to an acceleration in the rate of genetic gain, including the efficient use of genetic resources, generating novel variation through mutagenesis, gene editing, and genetic engineering, accessing genomic regions, and exploiting heterosis through hybrids and apomixes. The paper also demonstrates the importance of population size, trait heritability and intensity of selection, and duration of the breeding cycle. It also describes cross-cutting technologies, for data management, mechanization, and phenotyping. Finally the paper analyses the factors involved in successful technology adoption acceptance by farmers, consumers and governments.

The paper on **Precision Agriculture** provides a definition of PA, its historical evolution and recent developments in technology including applications in GIS, GNSS and remote sensing. The paper shows examples of current applications of precision agriculture in Europe, America, Australia, Japan and other developed countries, as well in China and other developing countries. Technological progress in PA is described including optimized algorithms, massive (big) data, and high-performance computing power. Finally the paper will describe the technology trends and future evolution of PA and mobile technologies over the coming decades, both in terms of technologies and at system level. In discussion, questions were raised about the scale (farm size) and production costs for precision agriculture applications, in addition to the possibilities of future use of big data and remote sensing in smallholder agriculture.

The paper on **Bioeconomy** describes the evolution of the concept of bioeconomy, which is defined as “*the knowledge-based production and utilization of biological resources, innovative biological processes and principles to sustainably provide goods and services across all economic sectors*”. The paper then highlights the change from a resource-based view of bioeconomy (focusing on replacing fossil-based resources by bio-based resources) towards a broader concept, which emphasizes the opportunities offered by the application of advances in biological sciences. An important section is to be devoted to analyzing the driving forces and future scenarios of the bioeconomy policies, strategies and governance and to deriving the implications for agricultural research, with a focus on international agricultural research carried out by the CGIAR. The last section addresses the following topics: reducing trade-offs

between use of biomass for the bioeconomy and food security, consumers and citizens in bioeconomy, global governance, and implications for the organization of agricultural research. The discussion focused on the principles of governance for bioeconomy, issue of scale and links to circular economy, and aspects of sustainability. There is also a question around land grabbing and links with the systems of land tenure.

The paper on **Investor Perspectives** provides an insight into investor perspectives on the agri-food sector in Africa, and uses this framework to identify the gaps and opportunities in agricultural development over the coming decades. It highlights emerging technologies with commercial prospect and the potential to be transformative in terms of scale of impact. The paper provides an overview of the major macro-trends that are influencing private sector appetite for investing in agri-food businesses in Africa including demand-side factors such as: increasing domestic demand; opportunities for import substitution; and increasing demand for high value food products; increasing global prices. Supply-side factors such as: low level of current productivity and profitability; scope for expansion of area under production versus the challenge of declining farm size; low labour costs; and opportunities for expansion of exports. The paper will look at the current capital flows to African agriculture, discussing the nature of major sources, and the so-called 'missing middle' of investment in African agribusiness. The paper will identify the near-term trends of the sector and the likely misalignments that will become increasingly important in the longer-term. Finally, the paper will evaluate emerging technology areas that promise to have a transformative effect on target agribusiness sectors. Discussion centered on the emerging applications of sensor technologies and electronic biosensors; distribution of investor profiles; criteria for responsible investment in agriculture and investor standards for risk mitigation; and the role of African SMEs in AFS and value chains.

The paper on **Disruptive Innovation** builds on several foresight studies on disruptive technologies (EU foresight) to provide a structured list of agriculture technologies and of technologies that are closely related to agriculture, and using future scenarios attempts to put these technologies in a broader context. The list of technologies considered includes: 3D and 4D printing, smart materials, robotics and autonomous microrobots, sensor technology, IT infrastructures, bioinformatics, smart farming, sustainable energy/ renewables, bio-refinery and biofuels, gene technology, synthetic biology, protein transition, food design, aquaculture, vertical agriculture, conservation technology, transport technology, weather modification. The authors will also connect new technologies with societal developments, to explore possible factors that might hinder or promote the development of technologies, and specify conditions under which certain technologies can become breakthrough technologies or in a different way add value to society in general and to the agriculture industry in particular. In discussion, the authors were encouraged to go beyond hard technologies, and consider disruptions in know-how and software that could change the face of agriculture.

In panel discussion general feedback and recommendations were provided on the papers presented during the session. It is critical to highlight the assumptions underlying the analyses in various chapters (for instance, many papers seem to assume that land tenure issues will be resolved – this may not be the case in parts of Africa and Asia), as is contextualizing discussions to capacity of institutions. It is also important to understand the formal and informal ways in which decisions are made; issues around acceptance of technologies – for example, the pushback against GM with a growing anti-science movement; the question of new social models – for example, how farming will occur in the future; political economy aspects and control of technology; where does indigenous knowledge fit in and

feature in all this – how will it be built on; the importance of time lags in crop breeding and innovation; the need to focus on post-harvest technologies for agribusiness and food value chain, particularly in the context of the rhetoric around getting youth involved in agriculture; and finally, the importance of political conflicts and how it may affect other drivers of change.

Other comments were made on the following topics: i) the complexity of messaging: the need to pick out a set of narratives on the basis of which to make recommendations for future investments. The narrative should center only around technology, but include political science aspects, software/soft inputs, etc.; and, ii) the need to have a sense of the role of private sector and other players to help define the comparative advantage of public systems not just in science, but also investments. There are many examples: DARPA is investing in food innovations – meals that are ready-to-eat and extending shelf life for the military, and this may feed back into the commercial sector; innovation in food substitutes (insect protein) is already a focus of the private sector; there exists a US\$ 30 billion pet food market – 1 billion ton of the 2.5 billion ton of grain produced is for feed, and most of that feed is for poultry (which then goes into pet food); and, the role of pharmaceutical sector in producing vitamins and minerals, which implies a need to understand the nutrient cycle more broadly.

The general discussion focused on the following points:

- Trends of concentrations or mergers in the food industry, and the power relations that are evolving over time. Second, long-term technology deployment; e.g., take-up of DT GM crops – until recently, it has not looked viable.
- The need to consider the effects of technology use on labour and employment.
- Disruption technology – the need to categorize what occurs because of disruptions; we may find that the list of disruptions becomes more manageable.
- For analyzing each driver, there is a need alternative hypotheses for drawing up scenarios.
- The need to consider conflict and political dimensions in the foresight exercise.
- Discussion of scenarios will be in the second stage of the foresight activity.

Session IV - Trends in the agricultural sector

This session consisted in the presentation of five papers followed by a panel and general discussion.

The paper on **Urbanization, Agriculture and Smallholder Farming** describes the basic trends in urbanization. Continuing population growth and urbanization are projected to add 2.5 billion people to the world's urban population by 2050, with nearly 90 per cent of the increase concentrated in Asia and Africa. By 2050, 82.4% of the world's urban population will be based in less-developed regions. Urbanization is leading to more diversified national diets with increased per capita demands for livestock and horticultural products and processed and pre-cooked foods, and reduced per capita demands for traditional food staples. The paper predicts that what we may see in the future is a growing gap between large numbers of small, part-time farms and a modest but growing number of medium to large-scale commercial farms; between commercially-oriented small farms that are well linked to value chains, and a much larger number of subsistence or non-farm oriented farms; and between small farms in favorable areas with good market connectivity, and those in poorly connected and often marginal areas. The paper proposes four classes of farms for strategy purposes, and analyses the implications for the CGIAR and the kinds of interventions that may be relevant for each of the three groups of small farms.

The paper on **Food, Agriculture and Nutrition policy** starts with an analysis of the drivers of future policy, by discussing how demand and supply side factors are changing the scope within which policy will have to operate in order to ensure availability of a balanced food system in the future. The paper describes the tenets of a new integrated policy approach; which lies at the intersection between food, agriculture, and climate and health policy. The main goals for an inclusive policy would encompass: i) moving agriculture away from subsistence to commercial and profitable production systems, ii) integrating the domains of food and health by designing a cost effective nutritious food system is key to improving both variety and quality of diets and will have direct impact on managing future health concerns, iii) sustainable intensification of crop and livestock production systems, iv) further integration of global agricultural markets through the reduction of trade barriers, removal of inefficient subsidies and integration of domestic and international value chains will allow small farmers to specialize in the areas of their competitive advantage, v) concerted investments in human capital development in urban and rural areas to support the ‘depopulation’ of rural areas and for income generation are needed to ensure equitable distribution. Subsequently, the paper will discuss the specific policy implications for South Asia and Africa. Using a few cases, paper will highlight how global and local priorities currently influence national policy. Given that countries in Asia and Africa will face the largest population pressures and have the most potential for sustainable intensification of agriculture, an inclusive multi sector design for food, agriculture and nutrition policy is essential for these countries. The paper will discuss the readiness of policy makers in these contexts for ensuring a balanced diet with the current policy paradigm and propose how policy in these regions should be re-envisioned within the new framework to ensure both regional and global nutrition security by 2050.

The paper on **Nutrition, Diets and Health** states that most countries in Asia are rapidly moving through the nutrition transition, with increasing rates of adult overweight and obesity even as child undernutrition, despite improvements, remains a large public health problem. Many of these changes have occurred rapidly over the last decade or so, suggesting that this will soon reach epidemic proportions in rural Asia. Non-communicable diseases associated with over-nutrition are also on the increase, with little capacity in public health systems as yet to deal with them. This chapter will focus on the several structural changes in the rural environment, which pose both challenges to and opportunities for the design of food and nutrition policies in Asia. These include: a systematic decline in labour force participation rates for women all over Asia; a paradigm shift in the policy environment; a lack of improvement in adult anemia; increasing scarcity of fresh water; food safety is poor and post-harvest losses are high. Often neglected in the policy discussion, these factors will play an increasing role in influencing both under and over-nutrition. The discussion focused on the importance of zoonotic diseases, links between women’s education and nutrition, and the relationship between women’s income and family care and malnutrition in Africa.

The paper on Nutrition, Diets and Health was received positively and in response, a brief summary of the foresight report on “*Diets and Nutrition: Challenges of the 21st century*” recently published by the Global Panel on Agriculture and Food Systems for Nutrition (see www.Glopan.org/foresight) was provided. The report concludes that most global burden of disease risk factors are linked to diet. Recommendations of the Global Panel include the need to focus system-wide policies on diet quality; ensure that food-based dietary guidelines inform policy decisions to reshape food systems (not only consumer-focus); make fruits, vegetables, pulses, nuts and seeds, fish more available, affordable and safe; policy support for animal source foods should be pragmatically evidence-based rather than driven by ideology.

The paper on **Ecological Intensification** takes stock of on-going, evidence-based research and development initiatives to promote the ecological intensification (EI) of agricultural systems, with emphasis on smallholder family agriculture, considering different scales and social-ecological environments. The paper will also examine opportunities and future challenges for EI from the perspectives of technological and organizational innovations. The examples discussed include ecological replacement, landscapes approaches, soil restoration, and the use of novel technologies. The paper also discusses the organizational innovations and enabling environments. Discussion focused on the opportunity cost in comparing agroecological systems to other approaches, due to initial lock-in or transition periods; the importance for change at the institutional, markets and policy levels; and the need to separate out organic farming from ecological intensification, and science-based approaches, including biotechnologies and gene editing.

The paper on **Agricultural Transformation Pathways** is based on two workstreams: i) Agriculture transformation pathways initiative (*Dobermann, Treyer and Schwoob*), and ii) Structural transformation (*Timmer and Andersson*). The paper includes a follow up to the SDSN report on food security and sustainable food systems in the framework of SDGs. It describes long-term and country-specific transformation pathways to reach the SDGs and discusses transition pathways (technical, economic and sociopolitical processes), based on three pilot case studies (China, Uruguay, UK) and other ongoing studies (France, Netherlands, Tunisia, New Zealand). The paper shows that rural transformation processes are going to be country-specific and may look very different from historical patterns, depending on non-agricultural growth and related capital intensity. Difficult pathways like (re)diversification might prove to be more sustainable but the question is how to make them possible. In discussions, a point was made that diversification and specialization might not be mutually exclusive. Additional discussion points included the question of basins of production and how the specific country case studies may relate to global scenarios.

In the panel discussion feedback and recommendations for the papers presented in the session included:

- Many papers did not really address who is going to be farming in the future, where, and how.
- Trends in urbanization and migration are not constant or static – weak signals from some parts of the world that reverse trends do occur – for example, the possibility of youth moving back into agriculture and value chain interventions.
- Structural transformation: there is a question of how best to reconcile transformation driven by processed food industries (recognizing there is need for such economic transformations) with the need for better nutrition and health outcomes.
- The need to look at market institutions, and the nature / dynamics of competitive markets. Input markets are concentrating as are agri-food value chains – this may have implications for how farmers are integrated, and whether they get fair value from marketplace interactions.

Conclusions: major findings from the workshop

We are facing a "perfect storm" of global threats and challenges that need agri-food R&D and policy solutions. These global threats are being felt contemporaneously and their combined effects are greater than the sum of their individual effects. The following are some of the dominant challenges faced by the global community:

- Rising urbanization, global migration, and the “depopulation” of rural areas as well as the changing demographic structure of rural populations and smallholder farming;
- Changing diets, food systems, and the rapid rise in over-nutrition and the epidemic of non-communicable diseases (NCDs) even as malnutrition rates remain high;
- Global environmental and sustainability challenges, including climate shocks and extreme events, environmental degradation and biodiversity loss;
- Trade integration and the declining competitiveness of developing country agriculture;
- Complexity and fragmentation of food systems, role of private industry vs. public investments in supporting the transformation of agri-food systems, and their connections with other sectors;
- Disruptive innovation in science and technology and game changers across sectors and disciplines.

The workshop also identified the following gaps/omissions which were not addressed in the first set of papers: i) attention to the overall geopolitical context; ii) role and profiles of private sector across the food systems agenda (e.g., processing, logistics, role with regards to big data); iii) role of policies at national and regional levels; and iv) R4D providers and the comparative advantage of CGIAR.

The workshop provided a synthesis of the findings of the numerous foresight exercises that have been conducted recently. What differentiates this initiative, and the forthcoming foresight activities of the ISPC, from the other exercises is the sharp focus on developing country agricultural systems and on the future prospects for the rural poor. The overarching question is *how food and agriculture research and policy should re-orient itself to address the above challenges?* The workshop identified some initial drivers and key topics, summarized below, that need further elaboration and assessment in terms of their interaction with international research, technical innovation and policy action.

Rural Prosperity in the 21st Century

By 2050, more than 80% of the world’s urban population will be based in low and middle income regions of the world. Economic growth, structural transformation and rapid urbanization could lead to new growth opportunities for the rural poor. Agricultural systems are increasingly focused on meeting the needs of these urban centers and with that there is a shift from agriculture as a “way of life” to “agriculture as a business”. Smallholder farmers can benefit from the new growth opportunities by better integration with agri-business value chains that provision urban areas. There is also a risk that farmers who are unable to integrate with value chains will be left behind - may be forced to move to marginal land, or become unemployed and food insecure. Significant research is needed on enhancing the competitiveness of smallholder agriculture systems through modern technologies and evidence-based policies. Innovations in biotechnology, ICT, labor-saving and mobile technologies, smart and precision farming technologies as well as technologies for enhancing food quality and safety and reducing waste would fall into this category. Increased global trade integration and the openness of emerging economies add to the need for enhancing the competitiveness of domestic agriculture systems. Effective aggregation models for linking small farms to agri-business value chains will continue to be a major area of applied research.

Food Systems for Better Health

The global R&D and policy community is faced with the unprecedented challenge of responding to the escalating nutrition and dietary dilemmas in the developing world. While malnutrition continues to be an important priority, the rise of obesity and NCDs in the developing world needs urgent and concurrent attention. Moving away from the current, almost predominant, focus on the big three staple grains –

rice, wheat and maize, and towards promoting a nutrition-sensitive food system can help address both ends of the nutrition problem. Advances in genomics and molecular biology targeted towards enhancing the nutritive value of crops, particularly the less commonly researched crops such as millets as well as innovations in agronomy, food processing, and the use of modern communication technologies for enhancing consumer demand are some of the options that ought to be examined. Food systems “thinking” can help in CGIAR strategic planning to identify points of intervention across the whole food system which can help alleviate malnutrition; and better understand the synergies and trade-offs between food, nutrition, and the environment strategic goals. International R&D could also draw on advances in food technology being developed by advanced country public and private systems. For instance, innovations around enhancing the shelf life of food for “Mars Missions” or for armed forces, could have significant spin-off benefits for the target population in developing countries. Also, advances made by the agri-food industry and the pharmaceutical industry in nutrient-rich food targeted to the commercial food sector could have similar spin-off benefits.

Climate Resilient Food and Agriculture Systems

While there has been significant modelling work on the implications of the projected shifts in mean climate and climate extremes on agricultural systems, it has again concentrated on the big three staples (rice, wheat and maize). Very little is known of the adverse impacts of climate change on the crops and resources that are important to the poor such as millets, roots and tubers and crops of emerging significance, such as fruit and vegetables, livestock and fish. Understanding climate implications, especially the impact of extreme events on developing country food systems and food security is a crucial priority. A holistic strategy is needed for a long-term research portfolio and a development strategy for dealing with climate shocks and for building a climate resilient food system that takes into account the complexity of the food-water-energy nexus. This would include an understanding of the disruptive effect of shifts in agro-ecological zones and production systems due to climate change on livelihoods of the rural poor. Impacts of mean climate change and extreme climate events (such as droughts, floods, etc.) on the nutritional status of the poor would also be an important area for further investigation.

Sustainable Intensification of Smallholder Systems

Modern science and technology with “big data” tools such as GIS, remote sensing, and precision agriculture has the potential to contribute significantly to sustainable intensification (including maximization of the use of inputs) in smallholder farming systems. Improved understanding of hydrological and biogeochemical cycles, such as N and P cycles could help to improve soil nutrient balance and water and nutrient use efficiency. Advances in renewable sources, such as solar and biofuels, could contribute to efficiency of energy use and sustainability of the resource base. However, the challenge with use of transformative innovations and modern tools is that they are often not designed for smallholder use. Adaptation to smaller scales is a major challenge for research and technology design targeted for developing country agriculture.

Evolving Organization of the R&D System

The role of the international agricultural research system has evolved significantly over the last few decades and will change substantially over the next few decades. In contrast to the 1960s and 1970s, many NARES have become able AR4D partners for the CGIAR enabling the System to adapt its own profile to take best advantage of (and further cultivate) this emerging capacity in the target regions, and to sharpen its focus on International Public Goods (IPGs). Multinational bioscience companies have

displaced advanced country public research systems as the major source of scientific research and technology development. This trend is likely to continue into the future, and this holds true for disruptive innovations with potential applications to developing countries as well. The international agriculture research system may need to increasingly focus on its comparative advantage in areas of “market failure”, where private sector investments are limited. The continued amalgamation of the bioscience companies and the food industry can transform power relations in ways that could hamper access to technology for the poor. It is important to understand the conditions under which the CGIAR could play an essential role as a conduit for technology access, adaptation and delivery to poor, smallholder agricultural systems.

The way forward

A series of chapters are being commissioned on various drivers of change and topics of relevance to the assessment. The papers of the independent assessment will be edited for publication in a Book on *“Global Agri-Food Systems to 2050 – threats and opportunities”*, to be published in 2018. The ISPC plans to hold a follow-up meeting with CGIAR experts and partners to validate and add to the findings of the independent experts group. This workshop will be followed by formal foresight scenarios exercise with the aim of identifying specific entry points to the CGIAR strategy and research priorities.

Annex 1. Brainstorming & Emerging Key Messages

The session consisted in a facilitated group and plenary brainstorming around the following four questions:

Q1 – What is the most surprising/interesting thing you have heard over the course of the workshop?

The important aspects highlighted by the audience can be clustered in five groups:

- i) The role of smallholder farming, which is surprisingly still increasing, more fragmented and diversified, possibly as consequence of reverse migration fluxes from cities to rural environments (megacities are un-prepared to absorb people: no jobs, urban poverty). However, small/medium farms can feed the cities. New opportunities to scale up smallholder farming from subsistence to business farming;
- ii) Sustainable intensification has to be seen as implementation of new technologies that may help preserving the environment while guaranteeing adequate yield and revenues for small and big farms. Associating sustainable intensification to organic farming is misleading and counterproductive. In contrast, biotechnologies, precision farming and other new technologies may help achieving sustainable intensification. The social dimension of sustainability should not be overlooked;
- iii) Nutrition should be more central in agri-food systems. Economic transformation is linked to changes in food nutrients uptake. Over-nutrition is becoming an issue in emerging countries with cheap food/junk food causing problems of obesity;
- iv) Food systems are many and fragmented. Private and public investments can/should support a sustainable transformation of food systems;
- v) CGIAR should look at trends and strengthen preparedness and flexibility to respond to changing scenario.

Q2 – What are the omissions/gaps?

- i) Lack of attention to the overall geopolitical context: are we moving towards more/less conflict or increased/reduced cooperation?
- ii) Role and profile of private sector across target agenda - as key actors in food system; role of private industry especially with regards to big data;
- iii) CGIAR comparative advantage in future agri-food ecosystems;
- iv) Food processing/logistics;
- v) Nutrition – impact of agricultural development policies;
- vi) Role of national policies;
- vii) Placing sustainable intensification in the context of global agri-food systems.

Q3 – Are there any important factors or drivers of food systems that have not been presented or discussed in the papers?

- i) Land tenure and use; need to protect farmers throughout transitions;
- ii) Food waste (post-harvest, retailers, house level);
- iii) Role of technologies in agribusiness;
- iv) Informal production/consumption systems and their role in global food security;
- v) Political issues, including geopolitics, trade, conflicts.

Q4 – Final message or suggestion on the way forward?

The input from participants is summarized below:

- Need to think through the food systems lens;
- Importance of nutrition and diets – changes are accelerating and unpredictable (GLOPAN Report); diet-related diseases and link to agriculture – is it realistic to assume that CGIAR can help diversify diets?;
- Smallholder farmers (definition and typology) – do they feed the world or themselves? Where is the saleable surplus coming from? Link to job market;
- Alternative non-agricultural strategies should be defined (too small to survive/diversification of income). Need to ensure smooth and well controlled transition;
- Managing demand is different from meeting demand, which is changing and linked to consumer preferences. Farmers producing for customers or consumers? Power balance between producers and marketers. Tension between demand of basic/bulk foodstuffs and high value products;
- Increased risk of climate shocks and extreme events as a threat to food systems (climate change and early warning signs);
- Green revolution paradigm is outdated yet it still seems to drive thinking. Potential for surprises in multiple dimensions, impacting the resilience of the system [thresholds and tipping points]. Need for a shift in thinking and a new narrative – (if not, there will be conflict). Need to deal with complexity of the agriculture and food systems problems, with interconnections with health/climate/geopolitics/employment etc.;
- Traditional approach to food security is environmentally wasteful – need to focus on the undernourished and over-nourished (different approaches/quality of diet);
- Food and agriculture – need to think about energy and water nexus as well. Demands to produce biomass for other uses than agriculture;
- Importance of food waste, and role and questions for research;
- Data – capture, use and ownership issues;
- Ecological intensification – paradigm shift – great potential. What are the practical approaches?
- What resources does the farmer need? Quinoa: what are the next ‘quinoas’ and how will the CGIAR respond?;
- Food safety in context of drought, pests, and diseases;
- Tipping points, including biodegradation.

Annex 2. Workshop Agenda

FRIDAY 7 April 2017	
<i>Department of Agricultural Sciences, Portici - Chinese Room</i>	
OPENING SESSION - INTRODUCTION, RATIONALE & OBJECTIVES <i>Chair: Leslie Lipper (ISPC Secretariat)</i>	
09:00-09:05	Welcome address Matteo Lorito
09:05-09:15	Setting the scene Prabhu Pingali (<i>ISPC & Cornell University</i>)
09:15-09:45	Global trends: A synthesis based on recent key foresight exercises Fabiana Scapolo (<i>European Commission</i>)
SESSION 2 - EMERGING THREATS & CHALLENGES OF FUTURE AGRI-FOOD SYSTEMS <i>Chair: Patrick Webb (Tufts University)</i>	
09:45-10:15	Climate change impact Alex Ruane (<i>NASA</i>)
10:15-10:45	Demography and global migration David Suttie (<i>IFAD</i>)
10:45-11:15	Futures of global trade Kym Anderson (<i>University of Adelaide</i>) – <i>presented by P.Pingali</i>
11:15-11:30	<i>Coffee Break</i>
11:30-12:00	The futures of energy Jeff Skeer (<i>IRENA, Germany</i>)
12:00-12:30	Environment and natural resources Dan Godfrey & Kristel van der Elst (<i>Global Foresight Group, Switzerland</i>)
12:30-13:00	SDGs and global development challenges Peter van de Pol (<i>GCPSE-UNDP, Singapore</i>)
13:00-14:00	<i>Lunch</i>
14:00-14:30	Discussion Panel: Marie Gasquet-Delattre (<i>CIRAD, France</i>) & Tom Tomich (<i>ISPC & UC Davis</i>)
SESSION 3 - NEW OPPORTUNITIES & SCIENTIFIC DISCOVERY <i>Chair: Jennifer Thomson (Univ. Cape Town)</i>	
14:30-15:00	Futures of Agri-food systems John Ingram (<i>Oxford Univ., UK</i>)
15:00-15:30	Innovation in breeding and biotechnology Peter Langridge (<i>Adelaide University</i>)
15:30-16:00	Precision agriculture, mobile data and emerging technologies Yanbo Huang (<i>USDA, MS.</i>) and Molly Brown – <i>Via WebEx</i>
16:00-16:30	<i>Coffee Break</i>
16:30-17:00	Bioeconomy Regina Birner (<i>Hohenheim Univ.</i>)
17:00-17:30	Agribusiness and agri-food value chain systems Jonathan Crouch (<i>Agrinovis, UK</i>)
17:30-18:00	Disruptive innovation – Horizon scan 2050 Silke de Wilde & Patrick van der Duin (<i>STT, Netherlands</i>) – <i>Via WebEx</i>
18:00-18:30	Discussion

	<i>Panel: Arthur Muliro (SID) & Patrick Webb (ISPC & Tufts Univ.)</i>
19:00-20:00	<i>Dinner</i>
Saturday 8 April Hotel Punta Quattroventi – Conference room	
SESSION 4 - TRENDS IN AGRICULTURE SECTOR <i>Chair: Jonathan Wadsworth (World bank)</i>	
8:30-09:00	Global trends in agriculture and smallholder farming <i>Peter Hazell (IC London, UK)</i>
09:00-09:30	Food, agriculture & nutrition policy <i>Prabhu Pingali (Cornell Univ.)</i>
09:30-10:00	Nutrition, food systems, diets and health <i>J.V. Meenakshi (Delhi, India) – Via WebEx & Patrick Webb (Tufts Univ.)</i>
10:00-10:30	<i>Coffee Break</i>
10:30-11:00	Ecological intensification <i>Pablo Tittonell (INTA, Argentina)</i>
11:00-11:30	Agricultural transformation pathways <i>Sebastien Treyer (IDDRI, France)</i>
11:30-12:00	Discussion <i>Panel: Lorenzo G Bellu (FAO) & Oluwabunmi Ajilore (GFAR)</i>
12:00-13:00	<i>Lunch</i>
SESSION 5 – SYNTHESIS AND WAY FORWARD: STRUCTURING THE FORESIGHT <i>Chair: Prabhu Pingali - Facilitator: Shirin Elahi</i>	
13:00-13:30	Synthesis of key messages
13:30-15:00	Structuring the foresight process – Key drivers & high level scenarios – Potential redundancies, contradictions and knowledge gaps – Major challenges and implications for R4D
15:00-15:30	<i>Coffee Break</i>
15:30-16:30	Conclusions Next steps – foresight process and finalizing the papers
16:30	<i>Departure ***</i>

Annex 3. List of participants

1. Bunmi Ajilore (GFAR Secretariat, Rome, Italy)
2. Kym Anderson (Univ. Adelaide, Australia) *Via WebEx*
3. LorenzoGiovanni Bellu (FAO, Rome, Italy)
4. Regina Birner (Hohenheim Univ., Germany)
5. Jonathan Crouch (Agrinovis, UK)
6. Marie de Lattre-Gasquet (CIRAD, Paris, France)
7. Silke de Wilde (STT, Netherlands) *Via WebEx*
8. Shirin Elahi (Normann Partners, London, UK)
9. Dan Godfrey (Global Foresight Group, Switzerland)
10. Peter Hazell (IC London, UK)
11. Yanbo Huang (USDA Stoneville MS, USA) *Via WebEx*
12. John Ingram (Oxford Univ., UK)
13. Lakshmi Krishnan (ISPC Secretariat, Rome Italy)
14. Peter Langridge (Univ. Adelaide, Australia)
15. Leslie Lipper (ISPC Secretariat, Rome Italy)
16. Matteo Lorito (Univ. Naples, Italy)
17. Albino Maggio (University of Naples, Italy)
18. J.V. Meenakshi (Delhi School of Economics, India) *Via WebEx*
19. Arthur Muliro (Society of International Development SID, Rome, Italy)
20. Prabhu Pingali (Cornell Univ., USA)
21. Alex Ruane (NASA, USA)
22. Fabiana Scapolo (European Commission, Belgium)
23. Rachid Serraj (ISPC Secretariat, Rome, Italy)
24. Jeff Skeer (IRENA, Bonn Germany)
25. David Suttie (IFAD, Rome, Italy)
26. Pablo Titonnell (INTA, Argentina)
27. Jennifer Thomson (Univ. Cape Town, South Africa)
28. Tom Tomich (UC Davis, USA)
29. Sebastien Treyer (IDDRI, France)
30. Peter van de Pol (UNDP-GCPSE, Singapore)
31. Jonathan Wadsworth (World Bank, Washington DC)
32. Patrick Webb (Tufts Univ., USA)