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Food and nutrition security and role of smallholder farms: challenges and opportunities

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Abstract

How smallholders may contribute to food and nutrition security remains a key challenge in many developing countries. Despite being the main rural actors, smallholders are frequently the most food insecure, given an array of biophysical and socioeconomic challenges that were addressed during the workshop. These proceedings discuss the potential role of smallholders in food security and in poverty reduction. The opportunities and constraints are assessed, by analysing the availability, access and utilisation of production factors. The key message is that enhancing smallholders' production capacities and their economic and social resilience may have a positive impact on food security and nutrition at different levels. However, not all smallholders are the same, and assistance strategies need to differentiate between smallholders who should be 'moving up' into more productive systems and those who should be 'moving out' of farming. The choice should depend on the type of constraints smallholders face. The analysis considers, in addition to the role of small farmers as food suppliers, smallholders' role as consumers and their level of nutrition security. The link between agriculture and nutrition is analysed to understand how agriculture affects human health and dietary patterns. Given the importance of smallholder farms, strategies to increase productivity in agriculture are essential to improve food and nutrition security, as is food diversity. Finally, synergies and trade-offs between economic, environmental and social objectives and outcomes are analysed through an overview of the methods and tools used to assess food security on small farms at household level. Models at country level are usually focused on long-term conditions, but short-term analyses would also be welcome. Developing global models to assess food security is also relevant, to include trade issues in the analysis. Models at farm household level in developing countries have a valuable role to play in the analysis of the impact of any policy on small farmers.

Contents

List of abbreviations and definitions

2SLS	Two-stage least squares
ACRE	Agriculture and Climate Risk Enterprise Ltd
AM	Agricultural management
CAADP	Comprehensive Africa Agriculture Development Programme
CGIAR	Consultative Group for International Agricultural Research
DAC	Development Assistance Committee
DIIVA	Diffusion and Impact of Improved Varieties in Africa
DSSAT	Decision support system for agrotechnology transfer
DT	Drought Tolerant
EC	European Commission
EU	European Union
FAO	Food and Agriculture Organisation
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FARSIM	Farm simulator
FD	Functional diversity
FDI	Foreign Direct Investment
FI	Financial intermediaries
FINDEX	Global Financial Inclusion Database
FISP	Farm input subsidy program
FNS	Food and nutrition security
FRA	Food Reserve Agency
FSSIM-Dev	Farming System Simulator for developing countries
FVS	Food variety score
GCM	General Circulation models
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GLOBIOM	Global Biosphere Management Model
GM	Genetically modified
GPS	General positioning system
HDDS	Household dietary diversity score
HFIAS	Household food insecurity access scale
HHDDS	Household dietary diversity score
HIV/AIDS	Human immunodeficiency virus infection and acquired immune deficiency syndrome
IFPRI	International Food Policy Research Institute
IIASA	International Institute for Applied Systems Analysis
IMPACT	International model for policy analysis of agricultural commodities and trade
IES	Institute of Environment and Sustainability
ISP	Input subsidy program
IPTS	Institute for Prospective Technological Studies
JRC	Joint Research Centre
K	Potassium
LAC	Latin American countries
LES	Linear Expenditure System
LM	Local maize
LSMS-ISA	Living Standards Measurement Study - Integrated Surveys on Agriculture
MDG	Millennium Development Goal
MFAD	Modified Functional Attribute Diversity
MIHFP	Months of inadequate household food provisioning
MP	Mathematical programming
N	Nitrogen
NGO	Non-governmental organisation
NUANCES	Nutrient use in animal and cropping systems – efficiencies and scales
OECD	Organisation for Economic Co-operation and Development
OIMP	Other improved maize variety
OLS	Ordinary least squares
OPV	Open pollinated varieties

P	Phosphorous
P4P	Purchase for Progress
R&D	Research and Development
ReSAKSS	Regional Strategic Analysis and Knowledge Support System for Southern Africa
RIMISP	Latin America Centre for Rural Development
RW	Rural worlds
SDG	Sustainable Development Goals
SF	Small farm
SFM	Soil fertility management
SOAS	School of Oriental and African Studies
SOM	Soil organic matter
SSA	Sub-Saharan Africa
UN	United Nations
WFP	World Food Programme
WFS	World Food Summit
WS	Workshop

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Executive summary

This report constitutes a comprehensive compilation and synthesis of the principal issues and outcomes of the workshop on 'Local level food and nutrition security and the role of subsistence/smallholder farms' organised by the Joint Research Centre (JRC) of the European Commission (EC) in Seville on 9–10 September 2015. This was part of the programme of the Milan 99th Universal Exposition, under the theme 'Feeding the planet, energy for life'. Gathering a range of international experts and specialists in the field of food and nutrition security, the workshop aimed to share knowledge, experiences and approaches on the economic, institutional and social drivers of current and future global food and nutrition security in developing countries.

The main body of this report is organised in five chapters, one for each topic addressed in the workshop. Chapter 2, by Peter Hazell, reviews the role that smallholdings play and may play in improving food and nutrition security. Chapter 3, by Jacob Ricker-Gilbert, investigates the difficulties that small farmers face in gaining access to inputs and suggests some policy recommendations to make input subsidy programmes more cost-effective and sustainable. Chapter 4, by Steve Wiggins, analyses the challenges that smallholders face in access to financial services. Chapter 5, by David Sahn, addresses food security and the quality of people's diets, in terms of reducing micronutrient malnutrition and deficiencies. Finally, Chapter 6, by Ashok Mishra, emphasises the importance of models to assess the impacts of policies on food security at household level and summarises the debate around how to measure food security. The introduction, Chapter 1, presents the rationale and objectives of the workshop, and the concluding Chapter 7 summarises some of the lessons learned in the analysis of food and nutrition security at smallholder level. These two chapters were written by Laura Riesgo, Kamel Louhichi and Sergio Gomez y Paloma, who also acted as editors.

Chapter 2 (Peter Hazell) discusses whether or not smallholdings are still the key units to focus on in order to improve food and nutrition security in developing countries. It presents a perspective on the role of smallholders on the basis of three main issues: whether or not the farms are too small to provide viable livelihoods; whether or not being small is harming the competitiveness of farms; and the role of small farms in providing food security.

The chapter highlights a general increase in the number of small farms, a decrease in the average size of small farms, a reduction in the amount of farm produce that goes to market and an increase in smallholders' dependence on off-farm income. Even in these circumstances, it is important to consider that 80 % of the food supply in Asia and sub-Saharan Africa (SSA) is provided by smallholders. In this chapter, the author proposes to differentiate between small farms facing 'soft' constraints, such as access to markets, inputs, credit and technologies, and small farms facing 'hard' constraints, related to dense populations and location in remote and less favoured areas. Based on this classification, the author suggests that small farms facing 'hard' constraints should move out of farming and small farms facing 'soft' constraints should move up. Schemes for farm development should be promoted by using direct methods such as creating a rural investment climate, improving land markets, providing rural public goods, overcoming market failures and providing social protection to the poorest of the poor. In addition, non-agricultural issues should be taken into consideration to promote rural development, such as improving women's status in making household decisions, ensuring their access to land, credits, etc., providing safe water and sanitation, or education.

Chapter 3 (Jacob Ricker-Gilbert) discusses the challenges that smallholders in SSA are coping with in order to gain access to irrigation, improved seeds and inorganic fertilisers.

Using data from the World Bank, the chapter shows the small percentage of cultivated land under irrigation in SSA. Given these figures and the importance of irrigation to increase food security and reduce poverty, the potential to expand the irrigated area is significant. However, irrigation schemes may require large investments that most smallholders cannot afford.

The chapter also points out that, despite the importance of access to irrigation, other inputs, such as fertilisers and improved seeds, are needed. Improved seed results in higher yields as a result of increased resistance to drought or flood, greater tolerance to heat and pests, or lower requirements for inputs. However, the adoption of new seed varieties may lead to some serious issues, such as lower productivity in case of recycled seed, poorer performance in case of poor soil fertility or weeding problems, and greater susceptibility to insect pests during the post-harvest storage of the crop.

The chapter also analyses access to inorganic fertilisers by discussing different common perceptions of the low level of inorganic fertiliser use in SSA and how that may have changed recently. In addition, some reasons behind the low response rates to inorganic fertiliser are presented, such as the lack of access to irrigation, the poor quality of soils, late delivery and application of fertiliser, inappropriate management and lack of timely weeding.

Finally, the chapter draws up some policy recommendations to improve input subsidy programmes. It points out the need to clarify the goals and objectives of the programmes, compares them with other policy interventions (i.e. cash transfer and output price support programmes) and endorses long-run investments (e.g. investment in roads, education, agricultural research and development).

Chapter 4 (Steve Wiggins) investigates the challenges of finance for smallholders in sub-Saharan countries. Few households have accounts with banks and/or other formal financial intermediaries. The lack of formal finance may constitute a poverty trap, since small farmers cannot afford to buy improved seed, inorganic fertilisers and agrochemicals, or to access existing technology. This jeopardises yields and income.

Agriculture is a risky sector for suppliers of finance because farms are small and disconnected, smallholders lack credit histories, land tenure is collective in some areas and droughts happen. On the other hand, credit demand from smallholders is also weak since the timing of loans usually does not fit with agricultural cycles and farmers are risk averse to the loss of collateral assets pledged against loans.

The chapter also addresses the need to provide public support in both input and finance markets. Therefore, the use of 'smart subsidies', limited in time, may be a way to facilitate smallholders' access to finance.

Agricultural insurance schemes in SSA are reviewed, given the low willingness of rural households to adopt insurance alone. However, when bundled with other services such as providing inputs, insurance may become more attractive to farmers.

Some policy lessons are also provided to shed some light on the development of adequate financial instruments for smallholders. Making collateral flexible and appropriate for farmers, improving information on borrowers, considering agricultural seasonality and sharing risk between lenders and borrowers are key issues to improve the development of financial markets in developing countries.

Chapter 5 (David Sahn) assesses the development of the nutritional status of the population in developing countries and its links to agriculture. Figures reveal real progress in reducing hunger but very uneven distribution of malnourished people around the world (65 % live in only six countries). In SSA, in particular, nutritional indicators have improved considerably since 1990. Part of this better performance is presumably explained by the increased availability and utilisation of health care services and public health measures, and not only by improvements in economic growth.

Since smallholders hold more than 50 % of agricultural land in every developing region in the world (except Latin America and the Caribbean), strategies to make agriculture work are essential to improve food and nutrition security. The implementation of any strategy would require both high-technology (e.g. bio-fortification and food fortification programmes) and low-technology (e.g. kitchen gardens and backyard livestock systems) mechanisms.

Smallholders' productivity should improve, but so should food diversity. Food diversity can be achieved by a diverse crop production system to complement those already in place. Nutritional functional diversity indicators are presented as a way to compare the contribution of farm production in three different countries representative of sub-Saharan cropping systems. Increasing similar food supply in the markets is important, but it is important to avoid jeopardising the diversity of local diets, because this local diversity plays an important role in risk management and in ecosystem and cultural services.

The chapter also debates the reverse influence of nutrition on agriculture. This causality is based on the idea that improvements in nutrition will have an effect on the ability to be productive in the labour market, on investment in both children and businesses and enterprises, and on the demographic dividend as the working age increases.

The question of whether or not economic and agricultural growth reduces the incidence of child nutrition is also discussed, as part of an ongoing debate. A recent investigation on this topic supports the view that overall growth in gross domestic product (GDP) may imply a reduction in stunting, even if the GDP growth is broken into different sectors.

Chapter 6 (Ashok Mishra) provides an overview of methods and modelling techniques used to assess food security among small farm households in developing countries. Some of the key issues on how to measure food security (quantitative and qualitative) are also discussed. Because food security is multidimensional, a combination of measures is usually used. Models at country level are usually focused on long-term conditions, but short-term analyses would be also welcome. The development of global models to assess food security is also useful as they enable trade issues to be included in the analysis.

This chapter also stresses the importance of land security for achieving food security and better nutrition. Although some studies suggest that economic efficiency is higher on rented land because of over-fertilisation, share-tenancy does not seem to be inefficient and may be a way to improve food security. Thus, better land governance is required in SSA in

order to respond to the recent increase in land demand and to increase the flexibility of agricultural systems and their adaptation to external and internal conditions.

Climate risks that smallholders have to face are also highlighted, especially in drought-prone areas of SSA. Markets may be developed to allow farmers access to new technologies, such as drought-tolerant seed varieties.

Finally, a farm household model used in the context of developing countries to gain knowledge on food security and rural poverty alleviation is presented (FSSIM-Dev). This model includes several particularities such as the dual role of farm households (consumers and suppliers), the transaction costs of market participation, heterogeneity of farm households, interaction among households to share factors use (i.e. labour, tools, etc.), and seasonality of cropping activities and resource use. Results from this model are shown, to analyse the impact of providing improved rice seeds to small farmers in Sierra Leone.

1. Introduction

Laura Riesgo, Kamel Louhichi, Sergio Gomez y Paloma

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Food and nutrition security has become one of the most important items on today's international political agenda and a serious issue for governments around the world. Guaranteeing a sustainable and equitable food supply in the context of climate change, price volatility and the global financial crisis is a challenging task. Even though food availability has grown significantly and consistently over time, both globally and in developing countries, access to food is still limited, particularly in many low-income economies. According to World Bank estimates (2015), 78 % of the world's extreme poor (i.e. with incomes of less than the equivalent of USD 1.25 per person per day) live in rural areas, and most of them are involved in farming. Although poverty continues to decline in many countries, major progress is yet to be made in rural parts of sub-Saharan Africa (SSA) and South Asia, areas where a large proportion of the population is extremely poor (i.e. 52 % of the rural population in SSA and 27 % of the rural population in South Asia) and dependent on smallholdings (FAO, 2015). In SSA, farm households persistently experience low levels of agricultural productivity and food insecurity.

Smallholders, as the main rural actors in SSA, are frequently the most food insecure because they face an array of challenges. Enhancing their production capacities and their economic and social resilience may improve food security and nutrition at different levels. According to the United Nations World Food Programme (WFP, 2012), growth in smallholder agriculture may have significant effects on the livelihood of the poor through increases in food availability and incomes. Empirical evidence shows that agricultural growth in SSA can be 11 times as effective in reducing extreme poverty as growth in other sectors.

Taking into consideration these issues and the increasing need for models/tools to measure food security, the Joint Research Centre (JRC) of the European Commission (EC) organised a workshop in Seville on 9–10 September 2015. The main aim of this workshop was to share knowledge about, experiences of and approaches to the economic, institutional and social drivers of current and future global food and nutrition security in developing countries. Special emphasis was devoted to the role and contribution of smallholdings in improving food and nutrition security at micro/local level. Agenda, List of Participants and Short biographies of participants can be found in the Annex I, II and III of this report.

This report constitutes a comprehensive synthesis of that workshop. It summarises the discussions on the role and contribution of smallholders in food security and reducing rural poverty in developing countries. This issue was addressed during the first session of presentations with the aim of answering the following questions: (i) Are smallholdings still the major engines for growth and poverty reduction in developing countries? (ii) Could smallholdings be more productive/competitive and contribute to local food and nutrition security? (iii) Can smallholdings generate the market surpluses needed to feed the growing population? (iv) To what extent could the promotion/extension of commercial/large farms contribute to reducing poverty in rural areas?

The opportunities and constraints that small households have to cope with were primarily addressed in the second session of the workshop, by analysing the availability of, access to and utilisation of production factors. Some key issues that were discussed related to (i) how smallholdings can improve their access to markets and how they may benefit from this access; (ii) what constraints smallholdings face on access to improved seeds, fertilisers and irrigation facilities; (iii) which policy incentives may be used to improve smallholders' access to agricultural inputs; (iv) to what extent irrigation adoption may improve smallholders' livelihoods; and (v) to what extent enhanced access to agricultural inputs may increase food security and rural development.

More accessible markets, not only for inputs but for financial instruments, may justify investments to improve smallholder sustainability and profitability. Following this idea, the third session of the workshop discussed the difficulties that smallholders face in obtaining access to credit. A number of issues were addressed, such as (i) to what extent access to formal credit contributes to the food security of the household, (ii) how financial instruments that are already available may be made more accessible to smallholders and (iii) the extent to which available financial services are relevant to smallholders' needs.

The opening and third sessions of the workshop, in addition to considering the role of small farmers as food suppliers,

discussed smallholders' role as consumers and their level of nutrition security. The link between agriculture and nutrition was analysed to understand the impact of agriculture on human health and dietary patterns. In this respect, some questions that were considered included (i) how growth may contribute to reducing child nutrition, (ii) what role small farms may play in reducing malnutrition and (iii) how agricultural policies may contribute to improving the nutrition of small farm households.

Finally, synergies and trade-offs between economic, environmental and social objectives and outcomes were analysed through an overview of the methods and tools used to assess food security at micro/local level. Thus, the workshop examined (i) how household models may inform policy makers on the potential effects of policy measures in improving food security of small farmers and (ii) what are the most suitable indicators for measuring the multidimensional aspects of food security over time.

2. The role of smallholder Farms in food security in developing countries

Peter Hazell

Independent consultant

The first session of the workshop discussed the role that smallholder farms play in food security in developing countries. The following four papers were presented and there was a concluding open discussion.

- 'Importance of smallholder farms as a relevant strategy to increase food security' by **Peter Hazell** (independent consultant);
- 'The contribution of subsistence farming to food security' by **Steve Wiggins** (Overseas Development Institute);
- 'Role of smallholder farms in a changing world' by **Shenggen Fan** (International Food Policy Research Institute);
- 'Dependence of African policies on smallholder farms' by **Donald Larson** (World Bank).

2.1 Importance of smallholdings as a strategy to increase food security

Development led by small farms has been the dominant agricultural development strategy since its remarkable success in driving Asia's green revolution. The paradigm is based on two major advantages claimed for small farms: (i) small farms are more efficient than large farms, as evidenced by an impressive body of empirical studies showing an inverse relationship between farm size and land productivity across Asia and Africa (Binswanger-Mkhize and McCalla, 2010; Eastwood *et al.*, 2010; Larson *et al.*, 2014); and (ii) in poor, labour-abundant economies, not only are small farms more efficient but, because they also account for large proportions of the rural poor, small farm development can be a 'win–win' proposition for growth and poverty reduction.

Is this paradigm still relevant today? That depends on the answers to three key questions about small farms today: (i) Are they becoming too small to provide viable livelihoods? (ii) Are they becoming too small to be competitive, given modern technologies and value chains? (iii) Can they contribute to food security?

2.1.1 Are small farms becoming too small to provide viable livelihoods?

There are more small farms than ever. At the last count, FAO estimated there are about 570 million farms in the world, of which about 475 million (about 84 %) are small (≤ 2 ha) (Lowder *et al.*, 2014). About 92 % of all farms are located in developing countries.

Given that the agricultural area is fixed in most countries, more small farms typically means that the average farm size also gets smaller, and this is exactly what is happening (Table 2.1).

Table 2.1. Census and survey based estimates of trends in average farm size

	1960s-1980s	2000s	Change (%)
Small farm developing countries			
SSA (N=14)	2.9	1.9	-32
Land abundant SSA (N=9)	3.0	2.9	-2.1
Land constrained SSA (N=5)	2.3	1.2	-46.9
India	2.7	1.2	-57
Other S. Asia (N=4)	2.5	1.1	-56
Indonesia	1.0	0.8	-20
China	0.7	0.6	-17
Other SE Asia (N=4)	1.6	4.2	158
Middle East & N. Africa (N=9)	7.6	5.4	-29
Commercialised agricultural economies			
South Africa	965.6	288.3	-70
Argentina	383.3	582.5	52
Brazil	70.7	68.2	-3.6
Other South America (N=7)	97.3	89.7	-8
Western Europe (N=16)	14.7	20.8	41
Canada	187.5	315.0	68
USA	157.6	169.3	7
Australia and New Zealand	1468.5	2070.3	41

Source: Headey (2015).

But are small farms also getting smaller? The evidence is mixed. In some countries (e.g. India, north-east China, Kenya) the distribution of land is shifting in favour of small farms, and their average size (especially in per capita terms) is not necessarily diminishing (Huang and Ding, 2015; Hazell, 2015). In other countries (e.g. Rwanda, Zambia, Ghana) the land distribution is shifting in favour of medium-sized and large farms, and small farms are becoming smaller on average (Jayne *et al.*, 2015).

Farm households are coping with smallness by diversifying into high-value farming, wage employment, migration and non-farm activity. Diversification opportunities are much better in fast-growing countries (e.g. China and India) than in slower-growing countries, and better in urban hinterlands than in lagging regions. In India, diversification has helped prevent increases in income gaps between rural and urban households. In parts of Africa and lagging regions in Asia, diversification can be more a desperate coping strategy that helps prevent or slow the descent into deeper poverty.

In China, non-farm income as a proportion of total household income increased, on average, from 33.7 % in 1985 to 70.9 % in 2010 (Huang *et al.*, 2012). This is an extreme case, but non-farm income has reached 40 % or more in many other Asian and African countries (Haggblade *et al.*, 2007), and is typically higher for small farms. Diversification is enabling large numbers of small-farm households to achieve viable livelihoods on their farms, better, it would seem, than the alternative of leaving the farm altogether.

2.1.2 Are small farms becoming too small to be competitive, given modern technologies and value chains?

There is a large body of evidence, spanning several decades, showing that land productivity declines with farm size, and that small farms are more productive (Binswanger-Mkhize and McCalla, 2010; Eastwood *et al.*, 2010; Larson *et al.*, 2014). There is mixed evidence on whether or not this is changing, with some suggestion that the relation is now more of an inverted U curve, with the smallest farms being less productive than middle-sized farms (e.g. in China and Ghana), but perhaps still more productive than large farms (Huang and Ding, 2015; Jayne *et al.*, 2015).

In some countries small farms face growing competition from corporate-sized farms that can exploit entirely new types of farming technologies — such as GPS-controlled

precision farming, minimum tillage, genetically modified (GM) seed and agrochemical packages — and back this with investments and political connections that give them privileged access to markets, modern inputs, insurance and credit, all of which may result in yields and cost structures that small farms simply may not be able to beat. A good example is the development model of Brazil's Cerrado region, which is being transplanted by private investors to parts of Africa.

This threat, which drove some of the 'land grabbing' of recent years, seems less compelling now that world agricultural prices have fallen, but we still have very little evidence about the cost structure of these large farms and how they compare with the costs incurred by small farms. On the other hand, there is evidence from some countries (e.g. Ghana, Kenya, Zambia, China) that middle-sized family farms are obtaining technological and marketing advantages over small farms and this is leading to greater land consolidation (Huang and Ding, 2015; Jayne *et al.*, 2015). However, this is the normal farm size transition that one expects as countries develop.

Small farms have several options for raising land productivity, including switching into higher-value, labour-intensive crops and livestock, making land-improving investments and adopting more input-intensive technologies. However, access to markets, credit and modern inputs remains an important constraint for many small farmers, and especially women farmers.

2.1.3 Can small farms contribute to food security?

During the green revolution in Asia, small farmers produced most of the food that led to national surpluses and fed the cities. Today, small farms still provide for the food security of huge numbers of rural poor, but many have become net buyers of food and contribute little towards feeding urban populations. As a result, the proportion of food staples supplied to markets by small farms is falling in many countries.

Urban population shares are projected to grow strongly across the developing world, and feeding these populations will require even more rapid growth in marketed food supplies. While some small farms, particularly those in urban hinterlands and well-connected areas, will supply urban areas with many high-value perishable products, the supplies of most other foods will need to come either from farms that are large enough to generate net surpluses or from imports.

It follows that a food security agenda for food staples needs two pillars. One pillar is to provide support to the many smallholders who farm largely to meet their own subsistence needs. The other pillar is to invest in larger farms that can produce marketed surpluses for the cities.

2.1.4 What can we conclude about small farms?

The general pattern is one in which there are more small farms than ever, and these are becoming smaller, produce smaller (if any) amounts of food surpluses and have become more dependent on non-farm sources of income for their livelihoods. However, there is considerable country and regional variation around this broad narrative. Small farms are not becoming smaller everywhere, and in some countries land is beginning to be consolidated into larger holdings. Some small farms are successfully marketing high-value perishable products such as fruits, vegetables and milk, but many more are not. Some are still net sellers of foods, whereas others are net buyers. Non-farm income diversification is proving a successful livelihood strategy for small farms in fast-growing countries and regions where more opportunities abound, but for many others it is little more than a coping strategy that prevents or slows the descent into deeper poverty.

Two key conclusions can be drawn. First, earlier assumptions that small-farm growth is a win–win proposition for growth, poverty alleviation and food security can no longer be taken for granted. These goals may now be less complementary. For example, the farms that can best feed the cities with food staples may not be the ones that it is best to target to reduce rural poverty and food insecurity. Where middle-sized or large farms are becoming more efficient, small farms may not be the best ones to target for agricultural growth. It may now be necessary to target different types of farms to achieve different goals.

Second, small-farm assistance programmes need to be cognisant of the diversity of small farm situations today, and to build strategies appropriate to each. This targeting requires the development and use of small-farm classification schemes or typologies. These may need to distinguish between subsistence-oriented and market-oriented small farms and small farms that are at various stages of transition out of farming through non-farm income diversification. It may also be necessary to differentiate between small farms in dynamic versus lagging regions because of the different opportunities and constraints they face.

2.2 The contribution of subsistence farming to food security

There are about 500 million small farms, and they are very diverse in their livelihood and farming options. To better understand them and the options for development assistance, it is useful to have a typology of small farms. Several have been proposed, including the following:

- The Organisation for Economic Co-operation and Development Development Assistance Committee (OECD/DAC) proposes five rural worlds (RWs): large-scale

commercial farms (RW1); commercially-oriented family farms that may hire labour (RW2); subsistence-oriented farms that put food first (RW3); landless rural workers (RW4); and the chronically poor (RW5) (OECD, 2006).

- The School of Oriental and African Studies and Wye College (SOAS/Wye) (Dorward *et al.*, 2009) identifies three types of farms: those that are 'stepping up' into higher productivity and market-oriented states; those that are 'stepping out' by diversifying into non-farm activity; and those that are 'hanging in' to subsistence-oriented farming.

- The Latin America Centre for Rural Development (RIMISP) identifies three groups of family farms based on regional context and household assets (Berdegué and Escobar, 2002). The first category (class A) comprises family farms with good assets (land, labour and/or access to capital) and locations in places with good agricultural potential and access to markets. These farmers are usually fully integrated in a market economy and make a substantial contribution to the production of food for domestic and international markets. The second category (class B) comprises family farms that have reasonable assets and agricultural potential but are constrained by being located in slow-moving regional economies with limited market access. The third category (class C) comprises resource-poor farmers located in places where conditions are adverse not only for agriculture but often for non-farm activities. The majority of smallholders in this group are poor and subsistence oriented, and may be diversified into low-productivity non-farm sources of income. During the workshop, Steve Wiggins presented pooled data from 12 Latin American countries showing that 12 % of farmers were of class A (3 % large-scale commercial farms and 9 % family farms); 20 % were of class B; 43 % were of class C; and 25 % of farmers were rural landless. These data, along with similar results for many African and Asian countries, show that the vast majority of small farms are either subsistence oriented or located in areas with poor market access or relatively unfavourable growing conditions. This poses difficult challenges for small-farm development.

Small-scale farming contributes to food and nutrition security (FNS) in three ways: as a direct source of food; as a source of income; and by lowering food prices. However, these pathways are not assured, since they are also affected by household spending behaviour, women's status in household decisions and how young children are cared for (Gillespie *et al.*, 2012). The implication is that it will take more holistic strategies than agriculture alone to ensure FNS.

How can small farms contribute more to FNS?

First, this can be done by promoting small-farm development to capitalise on the direct pathways to FNS. This requires (i) the creation of a more enabling rural investment climate, not necessarily perfect, but meeting certain minimal standards (Rodrik *et al.*, 2004); (ii) investment in rural public goods (roads, power, irrigation, education, health, water, research and development (R&D), etc.); (iii) overcoming failures in rural product and input markets, especially for small farms, and overcoming credit constraints; and (iv) social protection for the chronically poor — the 'hanging in' group.

Second, small farms can increase their contribution to FNS by giving more attention to non-agricultural pathways to FNS, such as household spending behaviour, women's status in household decisions and how young children are cared for. Women play key roles in these pathways, so an FNS agenda has to be very pro-woman. Some important areas for intervention are (i) home gardens and more diverse farming (including neglected crops and animals); (ii) ensuring women farmers have equal access to land, technologies, inputs, credit and markets to that of male farmers; (iii) freeing up women's time; (iv) bio-fortification; (v) safe water and sanitation; and (vi) education, especially for women.

2.3 Role of smallholder farms in a changing world

The current global situation is that, while 10.9 % of the world's population (23.2 % in Africa) is undernourished, many others are overnourished: in the developing world, 8.6 % of children under five years of age are overweight or obese, as are 14.1 % in the developed world. The global demand for food is rising rapidly, mainly in the developing world, and is projected to increase by 60 % by 2050. At the same time, climate change is an increasing threat to global food production.

Smallholders are still key to global food security and nutrition. They provide up to 80 % of the food supply in Asia and sub-Saharan Africa (SSA), yet make up the majority of the poor and hungry. However, not all smallholders are the same, and assistance strategies need to differentiate between smallholders who should be 'moving up' into more productive systems and those who should be 'moving out' of farming. The choice should depend on the type of constraints smallholders face. If the main constraints are access to markets, inputs, credit and technologies, then these can be fixed to help farmers move up. If the main constraints are that they live in densely populated, agriculturally relatively unfavourable and remote areas, then these cannot be fixed and many should be encouraged to move out of farming.

Policies to support smallholders should also reflect the stage of economic development of a country. In agrarian countries, raising the productivity of smallholders should be the lynchpin of an agricultural strategy, but, as countries transform and get richer, farms need to consolidate to provide adequate incomes, and remaining smallholders need to move into high-value agriculture.

Smallholders face a range of challenges. These include:

- Limited farm size. The amount of arable land available per person today is about half of what it was in 1950. Farms are becoming smaller and in many African countries 20 % of the farms are less than 2 ha.

- Limited access to finance and capital. There is an estimated financial gap of about USD 100 billion needed for investment in developing-country agriculture, excluding infrastructure. Microfinance is not able to fill the gap, and foreign direct investment (FDI) has uncertain impacts on small farmers.

- Inadequate access to modern markets.

- Food price increases and volatility. Price volatility can have harmful effects on the poor but, in the long run, higher food prices can increase smallholder income and stimulate poverty reduction.

- Rising agriculture-related health risks. Human health is increasingly affected by intensive food production methods, and this is affecting the ability of many smallholders to adopt more productive and innovative systems.

Key interventions to help smallholders 'move up' include:

- Promote land rights and efficient land markets. Land rights need to be secure, and this often requires formal certification of ownership or lease rights, and land sale and rental markets should be allowed to operate freely without size constraints.

- Invest in agricultural R&D to produce more with less. Expand smallholder-friendly agricultural R&D for breeding high-nutrient crop and livestock varieties; increasing resource-use efficiency, e.g. water, energy; and promoting climate-smart practices, e.g. 'triple win' strategies for adaptation/mitigation and productivity.

- Support efficient and inclusive food value chains. Promote smallholder-friendly innovations such as mobile-phone-based payment services for finance, the World Food Programme's Purchase for Progress (P4P) and weather index insurance. Improve post-harvest handling, enhance food safety and quality standards, and invest in rural infrastructure. Operation Flood in India is a good example of what can be done to link smallholders to a high-value market chain.

- Close gender gaps. Research shows that gender equality in agriculture leads to higher agricultural output, productivity gains, reduced hunger and malnutrition, especially for the next generation, and improved rural livelihoods.

- Develop young farmers by investing in infrastructure and their land, capital and skills, to create new opportunities in farming.

- Scale up productive cross-sector social safety nets. Promote better-targeted and more productive social protection policies, and design cross-sector social protection to reach the poor more effectively (e.g. Ethiopia's Productive Safety Net Programme and Bangladesh's Vulnerable Group Development Programme).

Collaboration among relevant national and international agencies for smallholder development is crucial. There is scope to exploit large knowledge and resource bases between developing countries, such as the Regional Strategic Analysis and Knowledge Support System for Southern Africa (ReSAKSS) and the South–South Experience Exchange Facility. There is also opportunity to engage in broader and more innovative partnerships, such as multi-disciplinary and multi-stakeholder research partnerships, and national and global research institutions, e.g. the Consultative Group for International Agricultural Research (CGIAR) and Compact2025.

2.4 Dependence of African policies on smallholder farms

Most farms in Africa are small. The average size is 1.6 ha, which is about the same as in Asia. Farms are also becoming smaller in many African countries. The value added per agricultural worker is less than that per non-agricultural worker, so there ought to be a much faster transition of workers out of agriculture in Africa. However, most African economies are not creating enough non-agricultural jobs to keep up with a growing labour force, let alone to bring down the absolute number of workers in agriculture. Many Asian countries are facing a similar problem, but their rural populations are peaking in size and beginning to decline, while in Africa rural population growth is projected to grow for a few more decades.

Given this reality, Africa badly needs a green revolution of its own led by small farms: one that will raise the productivity and incomes of small farms, reduce rural poverty, make Africa more self-sufficient in food, lower food prices, which would benefit the urban poor, and stimulate growth-inducing investments in human and physical capital in rural areas. As shown by estimates that smaller farms are significantly more productive than larger ones (negative area elasticities), there is no immediate reason why they should be displaced by large farms. Moreover, there is nowhere else for small farm households to go.

African countries, through the Comprehensive Africa Agriculture Development Programme (CAADP), and several leading development agencies are supporting a small-farm-led green revolution agenda. The challenges are greater than the ones Asian countries faced at the time of their green revolution. Most African agriculture is rainfed rather than irrigated, and both diets and production systems are highly diversified. This requires many mini-revolutions for different crops in diverse growing environments, whereas, in Asia,

standard technology packages for irrigated rice and wheat were able to spread quickly to millions of hectares.

Progress to date has been patchy. Some rice-growing areas have achieved Asian-like gains, progress with cassava and sweet potatoes has been good but is under-researched, and advances in raising the productivity of maize and other cereals are disappointing. Poor market access and risk appear to be major constraints.

Moving the green revolution agenda forward requires both long- and short-term strategies.

Strategies for the long term are (i) support for policies that ease out-migration constraints, such as rural education and health systems, and infrastructure; (ii) support that improves land markets; and (iii) support for connecting farmers to markets.

For this generation of rural poor, it is necessary to (i) provide safety nets; (ii) support new technologies and dissemination with a focus on small farms; and (iii) give a broad portfolio that offers risk-reducing technologies as well as high-yielding technologies.

2.5 Open discussion

There was a common set of messages in the four presentations: small farms still dominate agricultural production in much of Africa and Asia and are incredibly important for the food security and livelihoods of vast numbers of rural poor, but they may be less important today for supplying the cities with food staples. Smallholders face difficult challenges today: they have become much smaller, and many are being squeezed out of modern value chains in terms of their access to inputs, credit and product markets. They also face more risk from volatile food markets and climate change. The majority of small farms are now subsistence oriented (often net buyers of food), and most have diversified into non-farm sources of livelihood.

While assistance strategies can help more smallholders succeed in farming as a business, many more smallholders need assistance in growing and diversifying their own diets, and many need some form of social protection. Since different types of interventions are proposed for different types of smallholders, they must be targeted, and this requires a typology of small farms. Several typologies were proposed, most sharing some features. One shared feature is that they differentiate farms by the type of region in which they are located (especially its agricultural potential and access to markets); another is that they also attempt to differentiate the farm households themselves by their individual characteristics (e.g. by their assets, business orientation and acumen, and degree of diversification into off-farm sources of income).

Agricultural development is a necessary but not sufficient condition for improving FNS. Also required is the appropriate development of some non-agricultural pathways to better FNS, such as better household spending behaviour, improved status of women in household decisions, and better care for young children. Women play key roles along these pathways, and need to be at the centre of development efforts for FSN.

Noting that there was a high degree of convergence among the four presentations, the chair suggested that the discussion focus on possible areas of divergence. Two major topics were identified and discussed.

2.5.1 Yield gaps in Africa

Proponents of a green revolution for Africa argue that there are big yield gaps for farmers to exploit. These arguments are mostly on the basis of comparing crop yields with those in Asia or showing that yield has grown little over recent decades. On the other hand, evidence of low fertiliser response was presented, suggesting that there are few easy yield gains given current farm gate prices for fertilisers and crop products. It was proposed that a better way to evaluate the potential productivity gaps in Africa is profit per hectare, as this would reflect the realities farmers face in trying to raise yields. It was also noted that fertiliser by itself may not be sufficient to raise yields in a profitable way, and farmers need to apply a technology package that includes improved seeds, fertiliser, and better soil and water management practices. This is difficult for many smallholders, but, just as Asia's green revolution was built on a package approach (seeds, fertiliser, pesticides and water), so Africa's green revolution may also have to be built around a package, albeit one more suitable to their farming systems.

2.5.2 The role of subsidies

One way to close Africa's yield gap quickly is through use of fertiliser subsidies, as evidenced by the recent experience of Malawi. While few question the ability of subsidies to raise yields quickly (which can be extremely important to the food security of many small farms), the cost of a subsidy grows with fertiliser use and, as shown in several countries, can soon crowd out funding for longer-term public investments in infrastructure, fertiliser distribution systems and agricultural R&D, which have the potential to transform agricultural productivity on an unsubsidised basis. The problem with the latter approach is that it takes time, often years, while hungry people and governments facing food crises need more immediate solutions.

On the assumption that subsidies are not going to go away, resolution of the debate requires careful analysis of the circumstances under which subsides can be justified (for social as well as economic reasons), and the design of efficient mechanisms for delivering a subsidy to achieve its defined end. There is much interest today in 'smart subsidies' that can be targeted in ways that benefit the poor, encourage the development of commercial fertiliser distribution and

sales, have a low total cost, and can be phased out once they have achieved their primary purposes. With these objectives, fertiliser vouchers are showing considerable promise, and have now been adopted in a number of African countries.

A deeper discussion on input subsidy programmes can be found in Chapter 3.

2.5.3 Other issues

A number of other issues were discussed but not fully resolved.

Although the concept of smallholder typologies was accepted, none of the presentations addressed the question of how different types of smallholders could be identified on the ground for implementation of development assistance programmes. Much recent work used geographical information systems (GISs) and spatial analysis methods to identify target areas for rural development purposes. Most of this work focuses on mapping different regions in terms of their agro-ecology, market access and rural population density, but, so far, there has been limited work on disaggregating further according to differences in farmer resource endowments, market orientation and gender.

While many appropriate interventions were proposed for different types of small farms, little guidance was given on how to integrate various types of interventions to ensure that they made sense from the perspective of a household's farm or livelihood. For example, if farmers need packages of technologies, inputs, credit and market links to succeed, then how will assistance programmes solve the complementarity problem and ensure that all elements of the package are available and not just parts of it? This is particularly challenging when private-sector marketing and distribution systems are poorly developed, and the solution may require an orchestrated value chain approach. There is also the challenge of integrating safety net programmes with agricultural assistance programmes, especially in managing the risks that farmers face.

The session did not adequately resolve the question of how rapidly growing urban populations are to be fed in the future. In 2011, the urban population was estimated to have reached 40 % of the total population in Africa and 45 % in Asia. The UN projects that urbanisation will increase faster than total population in both continents, and by 2050 the urban population is expected to reach 58 % of the total population in Africa and 64 % in Asia. If many small farmers are becoming net buyers of food, and are too small to make a decent living from growing food staples (rather than high-value products) for the market, then the cities will have to be fed either by larger farms that can profitably grow food staples at scale or from imports. This is a topic that warrants further research, as it has important implications for national policies about the desired land distribution (portfolio of farm sizes) and the willingness to depend on food imports at a time of uncertain prices. Another key question is: how big would productivity increases of food staples have to be among small farms to change these dynamics?

The whole question of how to accelerate worker exits from farming in Asia and Africa was not adequately resolved. Exits of farm workers in Asia seem too slow to prevent widening of rural–urban income gaps, despite relatively rapid growth in manufacturing employment (China may be an exception). And this is with relatively slow population growth. In Africa, urbanisation has proceeded equally rapidly, but has not been matched by growth in agricultural productivity or manufacturing. Most non-agricultural jobs have been created in the services sector, and driven in part by booming commodity exports, development assistance spending, rapid rural population growth and a stagnant agricultural sector. This is not the normal pattern of economic transformation observed in the past, and there are serious questions about its sustainability, especially now that commodity prices have fallen. Without a clearer pathway for Africa's economic transformation, it is difficult to foresee the best strategies for small farms.

Risk management was identified as a major issue for African smallholders, but we do not yet have viable policies for managing it. Market-mediated insurance such as weather index insurance looks promising, but has yet to make serious inroads. Price volatility seems to have increased, but remains unaddressed since governments pulled out of their price stabilisation programmes. The challenge of risk management will only increase as climate change adds to the uncertainties farmers face in the future.

3. Smallholders' access to financial instruments in sub-Saharan Africa: a review of the evidence on irrigation, seeds and fertiliser

Jacob Ricker-Gilbert

Purdue University

The second session discussed the current state of knowledge on access to irrigation, modern seeds and inorganic fertiliser among smallholder households in sub-Saharan Africa (SSA). The following two papers were presented and there was a concluding open discussion.

'Irrigation of smallholder agriculture in sub-Saharan Africa' by **Munir A. Hanjra** ([1]), Jennie Barron, Robyn Johnston and Tim Williams;

'Access of smallholder farms to seeds and fertilizer in sub-Saharan Africa' by **Jacob Ricker-Gilbert**.

3.1 Introduction

This chapter is based on a recent study by Sheahan and Barrett (2014) that analyses and summarises current levels of irrigation, modern seed, and inorganic fertiliser use among smallholder farm households in SSA. The data used by Sheahan and Barrett come from new nationally representative smallholder household data in six countries in SSA, collected by the World Bank's Living Standards Measurement Study —Integrated Surveys on Agriculture (LSMS-ISA) project. Other studies on the potential impacts of using modern inputs were also reviewed. A substantial portion of the report is then devoted to the returns to inorganic fertiliser and the benefits, costs and challenges associated with input subsidy programmes (ISPs) to encourage inorganic fertiliser use among smallholders. ISPs are currently being promoted by numerous governments in SSA to the tune of USD 1.05 billion per year in 2011, equivalent to 28.6 % of public spending on agriculture (Jayne and Rashid, 2013). Some policy briefs were also drawn on the basis of the study that Ricker-Gilbert *et al.* (2014) carried out for the World Bank and the government of Malawi, along with other recent studies, to identify and discuss challenges for the success of ISPs. Finally, some ways that ISPs can become more cost-effective and sustainable were also suggested.

3.2 Smallholder access to irrigation

Water management is a key factor that affects crop productivity and, through it, improved income and food security. Smallholder farmers in many parts of SSA are completely dependent on rainfed agriculture, which leaves them susceptible to droughts during the main season and with no options for obtaining a second harvest during the dry season. Access to irrigation offers a way to control water more effectively, and it can help smallholders maintain higher yields during years of drought and potentially obtain a second (or in some places third) harvest during the dry season. Although the possible benefits of irrigation on household income and food security are large, in reality access to and use of irrigation among smallholders in SSA is negligible. Table 3.1 is borrowed from Sheahan and Barrett (2014), who summarise the descriptive statistics on smallholder irrigation access in SSA from the recent World Bank LSMS-ISA datasets. The table indicates that an extremely small percentage of all land cultivated by smallholders is under irrigation. Interestingly, a slightly higher percentage of households has at least some irrigation access on farms. This could be pieces of land near a stream or buckets that can be used to water small home gardens or other pieces of land.

1 Presenter of the paper.

Table 3.1. Irrigation Access by Smallholder Farm Households

Country	Total ha of cultivated land under irrigation by smallholders	Percent of all cultivated land under irrigation by smallholders	Percent of households with at least some irrigation on farm	Most common water source for irrigating households
Ethiopia	163,087	1.3	8.7	River
Malawi	4,090	0.2	0.4	Bucket
Niger	136,383	1.4	6.9	Well
Nigeria	274,681	2.5	4.1	Divert stream
Tanzania	239,493	1.8	3.6	Flooding
Uganda	174,972	3.5	3.9	-
Average	165,451	1.8	4.6	-

Source: Sheahan and Barrett (2014), from World Bank LSMS-ISA data.

Although access to irrigation is clearly limited for most smallholders in SSA, evidence suggests that the potential to expand irrigated areas in SSA is tremendous (You *et al.*, 2011; Pavelic *et al.*, 2013). However, Rosegrant *et al.* (2009) state that irrigation is generally profitable only for cash crops and other high-value crops. Regardless, when irrigation schemes exist, the impacts can be large. According to Hussain and Hanjra (2003) and the United Nations Development Programme (UNDP, 2006), irrigation has the potential to enhance food security and reduce poverty. This can be achieved through (i) increasing production, (ii) increasing income and consumption, (iii) increasing employment, (iv) increasing food security and (v) environmental improvements. That being said, it seems clear that irrigation may be a necessary condition for improving smallholder well-being, but it is not a sufficient condition. Other inputs are needed, such as fertiliser, improved seed, better infrastructure and increased market linkages (Hanjra, 2015).

Since irrigation schemes may require relatively large fixed-cost investments, community irrigation schemes may be one way to achieve economies of scale in irrigation and also help more households reap the benefits of such investments. Svendsen *et al.* (2009) find that most of the irrigated land in SSA is under large-scale irrigation projects. However, these community schemes depend on the readiness and initiatives of the communities. This entails that communities have a business model in place that includes financing, market linkages and value addition.

3.3 Smallholder access to improved seeds

Improved cultivars of cereals (maize, wheat, sorghum, millet, rice) are essential elements for raising smallholder productivity and improving food security in SSA. Improved seed varieties may have desirable properties that smallholders demand, such as higher yields (more grain produced per plant) as a result of increased drought or flood resistance, heat tolerance or pest resistance or improved responsiveness to other inputs such as inorganic fertiliser and water. Maize is the major staple in most of SSA, particularly in eastern and southern Africa, and improved varieties are either hybrids or open pollinated varieties (OPVs). Hybrid varieties are generally higher yielding than OPVs, but yields are reduced if the seeds are recycled and used for more than one season; in contrast, OPV maize seeds yields can be maintained for several seasons before the seeds need to be replenished. Farmers may like local varieties because they can be recycled, whereas private companies prefer to develop hybrid varieties because the seeds have to be purchased again every year. This tension is part of the challenge in developing a sustainable seed supply chain in many parts of SSA.

There is evidence that smallholder uptake of improved varieties of cereals and other grains has been increasing over time. Table 3.2 is borrowed from Sheahan and Barrett (2014), and it compiles information on improved seed adoption across Africa between 1998 and 2009, which was originally available in the Consultative Group for International Agricultural Research (CGIAR) project Diffusion and Impact of Improved Varieties in Africa (DIIVA). Table 3.2 clearly shows a significant increase in both total area under improved varieties and percentage of land under improved varieties between 1998 and 2009, which is an encouraging sign.

Table 3.2. Adoption of improved crop varieties over time in SSA

	1998		2009	
	Total hectares under crop	Percent of land under improved varieties	Total hectares under crop	Percent of land under improved varieties
Ethiopia				
Barley	897,360	11.0	913,863	33.8
Maize	1,881,000	8.5	1,768,120	27.9
Durum wheat	797,998	80.0	1,163,056	77.8
Malawi				
Maize	1,243,000	13.8	1,609,000	43.0
Groundnuts	170,517	10.0	266,946	58.0
Niger				
Millet	-	-	6,513,140	11.5
Sorghum	-	-	2,544,740	15.1
Cowpea	-	-	5,203,530	17.0
Groundnuts	-	-	588,651	11.9
Nigeria				
Maize	4,255,000	40.0	3,708,000	95.0
Cowpea	-	-	3,768,193	39.0
Sorghum	-	-	4,736,730	20.0
Millet	-	-	3,749,600	35.0
Tanzania				
Maize	1,646,000	4.2	2,961,330	35.4
Rice	-	-	627,600	13.0
Sorghum	622,400	2.0	874,219	37.7
Groundnut	-	-	535,000	32.1
Uganda				
Maize	574,000	8.9	887,000	54.0
Banana	-	-	915,877	6.2
Groundnut	196,000	10.0	253,000	55.0

Source: Sheahan and Barrett (2014) from CGIAR's DIIVA project http://www.asti.cgiar.org/diiva

It should be noted that, especially in the case of maize, traditional or local varieties remain popular and in cultivation by many smallholder households for a variety of reasons. Although they are generally lower yielding than improved varieties, they can be recycled just like OPVs and may have many other desirable traits that farmers prefer. For example, since many households in SSA grow maize for their own consumption, they continue to grow local varieties because they prefer the taste (Smale *et al.*, 1995; Lunduka *et al.*, 2012). Lunduka *et al.* (2012) found that households in Malawi prefer local varieties of maize because of its taste, ease of pounding and suitability for storage. Furthermore, it is common knowledge that local maize varieties are less susceptible to insect pests after harvest than traditional varieties, thanks to their softer husks. Accordingly, Ricker-Gilbert and Jones (2015) find that households that use storage chemicals to reduce insect pests in the post-harvest

season are more likely to plant improved maize varieties the following year.

Another issue surrounding adoption of improved seed is that the improved varieties may perform better than local varieties on experiment stations or in researcher-managed on-farm trials. However, when the seeds are adopted by farmers and experience real-world conditions, such as being planted on land with poor soil fertility, on plots where little to no inorganic fertiliser is applied, and where weeding schedules are less than optimal, improved varieties may perform poorly. This point is demonstrated in a recent study by Bulte *et al.* (2014), in which smallholders in Tanzania were part of a double-blind experiment that attempted to separate out the effort effect (i.e. re-allocation of labour) associated with adopting an improved cowpea seed from the genetic effect that the improved seed had on yields. The authors found that the entire yield increase attributable the improved seed could be explained by the labour re-allocation and increased effort on the part of those who received the improved seed, rather than the yield-improving genetics of the seed itself. This finding highlights the need for crop breeders to test their new varieties thoroughly under real-world farm conditions if they expect smallholders to adopt the new varieties consistently over time.

3.4 Smallholder access to inorganic fertiliser

Nutrients such as nitrogen, phosphorus and potassium are key inputs into the production of cereals. The most effective mechanism to deliver these nutrients to crops is through the application of inorganic fertiliser. However, there is a common perception that farmers in SSA use significantly less fertiliser than is economically optimal. This belief has spurred significant research into the constraints that inhibit and limit smallholders from using fertiliser. Reasons commonly given include supply-side problems such as poor infrastructure, late delivery of fertiliser, few input suppliers, inappropriate fertiliser blending and application rate recommendations that do not conform to local soil qualities (Gregory and Bumb, 2006). A number of studies of demand-side constraints identify lack of credit at planting as a major inhibitor to using fertiliser (Coady, 1995; Dorward *et al.*, 2004; Duflo *et al.*, 2011). Other studies point to unfavourable fertiliser/maize price ratios (Croppendstedt *et al.*, 2003; Duflo *et al.*, 2008) and poor soil quality leading to low response rates of maize to fertiliser (Marenya and Barrett, 2009) as reasons for low uptake of fertiliser.

The following subsections discuss the common perceptions underlying low levels of inorganic fertiliser use in SSA and how these may have changed in recent years. Subsequently, I discuss the problem of low response rates of maize to fertiliser, and factors that explain them. From there, I detail how this problem creates a major challenge for the cost-effectiveness and sustainability of ISPs.

3.4.1 Background: common perception of low inorganic fertiliser use in sub-Saharan Africa

There remains a common perception that inorganic fertiliser use among smallholder households in SSA is extremely low. Aggregate, national-level data from FAOSTAT suggest that, on average, farmers across the region use only 13 kg of fertiliser nutrients per hectare of arable land, which is far below the developing-country average of 94 kg/ha (Minot and Benson, 2009). Low fertiliser use, low yields and persistent poverty, along with several food price spikes over the past 10 years, have increased awareness of the need to increase smallholder staple crop production in SSA.

As a result, numerous African policy makers met in Abuja, Nigeria, in 2006 at the Africa Fertilizer Summit, where they vowed to help smallholders access inorganic fertiliser as the primary mechanism for increasing agricultural productivity. The main policy mechanism advocated was through targeted ISPs. In targeted subsidy programmes a subsample of farm households that meet certain criteria are able to acquire a limited quantity of inorganic fertiliser at a price below the market price (subsidy). These targeted programmes in theory are supposed to overcome the problems with universal fertiliser subsidies that were common across SSA in the 1970s and 1980s. Under universal subsidy programmes, the government controls the price of fertiliser and makes it available to all farmers below the market rate. Evidence suggests that most of the benefits from universal subsidies go to wealthier households, which are better able to access the fertiliser, and to input suppliers who do not fully pass the cost savings back to farmers (Brooks *et al.*, 2008). In addition, because of their high costs, universal subsidy programmes became financially untenable in many countries and were phased out in the late 1980s and 1990s under structural adjustment.

The World Bank collected nationally representative household-level panel survey data from six countries in SSA in the years after input subsidies were scaled up in many countries. This recent evidence indicates that inorganic fertiliser use may not be as low as commonly perceived. Table 3.3, from Sheahan and Barret (2014), shows that the average rate of inorganic fertiliser nutrients is 26 kg/ha, double the 13 kg/ha indicated by FAOSTAT data. In addition, several countries have nutrient use rates for inorganic fertiliser that are significantly higher than 26 kg/ha. It is also not surprising that the countries with the highest rates of inorganic fertiliser use — Malawi, Nigeria and Ethiopia — have all funded large fertiliser subsidy programmes in recent years. Malawi and Nigeria administer a targeted ISP, while Ethiopia uses a universal subsidy programme whereby the government imports fertiliser and distributes it at below the market price to farmers across the country through its network of cooperative unions.

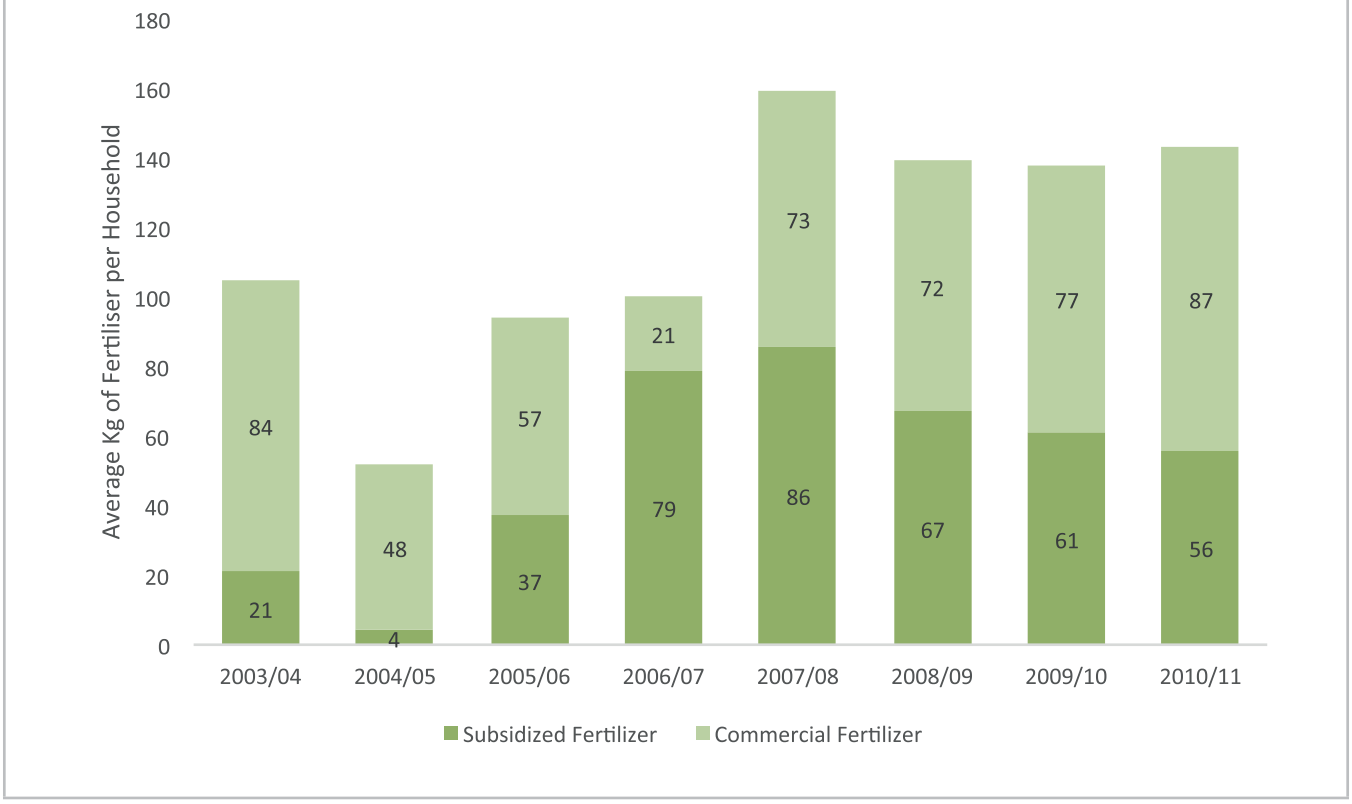
Table 3.3. Average Household-level Organic and Inorganic Fertiliser Use Trends

Country	% of cultivating households using inorganic fertiliser	Use (kg/ha) of inorganic fertiliser across all households (includes zeros)	
		Mean total	Mean nutrients
Ethiopia	55.5	45.0	25.2
Malawi	77.3	146.0	56.3
Niger	17.0	4.5	1.7
Nigeria	41.4	128.2	64.3
Tanzania	16.9	16.2	7.7
Uganda	3.2	1.2	0.7
Average	35.2	56.9	26.0

Source: Sheahan and Barrett (2014).

Ricker-Gilbert and Jayne (2015) also find that fertiliser use in Malawi is higher than commonly perceived. The study follows 462 Malawian smallholder households over eight years. Fertiliser use patterns for these households are presented in Figure 3.1 below. The figure demonstrates that the ISP in Malawi has contributed to raising fertiliser use since it was first scaled up during the 2005/2006 season. Average fertiliser use per household stood at slightly more than 100 kg in 2003/2004, but increased to nearly 150 kg in 2010/2011. The figure also shows that commercial fertiliser use declined during the first years when the subsidy was scaled up, but has since rebounded to its pre-subsidy level.

Figure 3.1. Average Kilograms of Fertiliser Used by Households in Malawi, by Year and Source



N=462 Households in each year

Source: Ricker-Gilbert and Jayne (2015).

3.4.2 Challenge of low response rates of maize to fertiliser

Although the evidence suggests that input subsidies have contributed to increasing fertiliser use among smallholders in SSA in recent years, fertiliser acquisition and use are just one component for raising yields and productivity. The first major challenge facing ISPs is making sure that recipients are using fertiliser efficiently so that the marginal benefits of using fertiliser are greater than the marginal costs of doing so.

The marginal product of fertiliser (kilogram of maize produced per kilogram of nitrogen) is a key factor determining whether or not the benefit/cost ratios for ISPs are greater than 1.0 and thus break even or do better than that. Jayne and Rashid (2013) review the literature on ISPs in SSA and compile a table of studies across the region that estimate the marginal product of maize to nitrogen, and benefit/cost ratios. Results from these studies are presented in Table 3.4 below. The main conclusion that can be drawn from this table is that the marginal product of fertiliser is quite low and thus the benefit/cost ratios are around 1 or are below 1 in many contexts. This consistent finding raises questions about whether or not subsidies for fertiliser can be a cost-effective strategy by themselves for raising smallholder agricultural productivity.

Table 3.4. Recent Estimates of Maize Response to Nitrogen Applications in SSA

Study	Country	Agronomic response rate (kg maize per kg N)	Benefit/Cost Ratio
Minten *et al.* (2013)	Ethiopia	10-14	1.0 – 1.4
Sheahan *et al.* (2013)	Kenya	14-21	1.3 - 3.7
Marenya and Barrett (2009)	Kenya	17.6	1.76
Matsumoto and Yamano (2011)	Uganda	8.0	0.75 – 1.05
Burke (2012)	Zambia	9.6	0.3 – 1.2
Ricker-Gilbert *et al.* (2013)	Malawi	8.1	0.6 – 1.6
Holden and Lunduka (2011)	Malawi	11.3	-
Pan and Christiaensen (2012)	Tanzania	11.7	-

Source: Adapted from Jayne and Rashid (2013) and Burke et al. (2015).

3.4.3 Reasons for low response rates of maize to fertiliser

The next logical question to ask is: why are response rates to fertiliser so low and what can be done to improve them so that inorganic fertiliser is more profitable for smallholders in SSA to use as an input? The first potential challenge is, as mentioned earlier, that many farmers in SSA are dependent on rainfed agriculture and lack access to water control through irrigation. Water control is crucial for plant growth, and for the economic returns on using fertiliser. Dependence on rainfall raises the risk associated with purchasing inorganic fertiliser, as climate trends suggest that most of SSA has been receiving less and more sporadic rainfall, and will continue to do so in the future under most climate change scenarios (Niang *et al.*, 2014). Access to irrigation affords more reliable water control and more stable yield response to fertiliser than does rainfed cultivation. Unfortunately, only 4 % of arable land is under irrigation in SSA, compared with 45 % in South Asia (Jayne and Rashid, 2013). This difference helps explain why fertiliser application rates and maize to fertiliser response rates are much lower in SSA than in South Asia.

The second reason that explains low response rates of maize to fertiliser in SSA is poor and degrading soil quality. Rapid population growth in many parts of SSA leads to smaller and smaller farms that continuously cultivate cereals year after year with little nutrient replenishment, leading to worsening soil quality, which in turn leads to lower yields. Marenya and Barrett (2009) demonstrate that, in western Kenya, soil organic matter is an important indicator of soil degradation that has a strong effect on response rates of maize to fertiliser. The authors conclude that, given low levels of soil organic matter, it is not profitable for many smallholders to purchase inorganic fertiliser.

Intercropping maize with legumes is one relatively low-cost way for soil fertility to be maintained or perhaps restored. Legumes have the ability to fix nitrogen at a higher rate than cereals do, so their presence in a cropping system can help build nitrogen and organic matter over time (Snapp *et al.*, 1998). Unfortunately, the percentage of maize fields intercropped with legume is not as high as it could be and there is some evidence that the rate of intercropping may be declining over time. For example, Snapp *et al.* (2014) found that, in Malawi, 50.1 % of maize plots were intercropped with legumes in 2002/2003, but this percentage declined to 46.1 % in 2006/2007, 45.4 % in 2008/2009 and 37.9 % in 2009/2010, a worrying trend.

The third reason for low response rates is late delivery and application of fertiliser. Proper timing of fertiliser application is important to prevent nutrient loss, increase nutrient use efficiency and prevent damage to the environment through nutrient run-off (Jones and Jacobson, 2003; Snapp *et al.*, 2014). Xu *et al.* (2009) find that timely application of fertiliser is one of the major factors that have a positive impact on maize response to fertiliser in Zambia. However, it is unfortunately not the case that farmers always acquire and apply fertiliser at the appropriate time. Snapp *et al.* (2014) found that more than half of all smallholders in Malawi apply their first dosage of fertiliser more than three weeks after planting, which is generally later than optimal for yield maximisation. There could be various explanations for late application of fertiliser, such as late delivery to fertiliser retailers, smallholders lacking sufficient labour to apply the fertiliser, and not having the management ability and knowledge to apply it appropriately.

The fourth reason for low response rates is lack of appropriate management and timely weeding. Weeding is essential to improve the ability of plants to access and use nitrogen and phosphorus effectively. Multiple weedings of maize during a growing season are essential to maximise yields, and farmers who weed their maize only once during the growing season can experience a 26–34 % decline in yields due to the build-up of weeds (FAO, 2000). Pests such as the parasitic weed *Striga* are a major challenge for many smallholders in SSA, which can cause major yield losses if not removed through weeding or herbicide application. Snapp *et al.* (2014) find that in Malawi only 65–70 % of plots are weeded twice, as recommended, and between 25 % and 27 % of maize plots are weeded only once or not at all. Furthermore, the authors report that 13.7–17.3 % of households say that they have experienced yield reductions due to crop diseases or pest over the past two to three years.

3.5 Implications for input subsidy policy

Dependence on rainfed agriculture, poor and worsening soil quality, late delivery and application of fertiliser, and insufficient weeding all help explain the low response rates of maize to fertiliser observed in the studies presented in Table 3.4. Low response rates are a major challenge for input subsidies and undermine their cost-effectiveness and long-term sustainability. The issues highlighted above demonstrate that inorganic fertiliser is just one input into the production of cereals, which also depends on land, seed, water, labour, soil fertility and management ability. Therefore, there is a need for countries in SSA to move from a development strategy, whereby substantial shares of national agricultural budgets are devoted to subsidising nitrogen and phosphorus, to a more holistic agricultural development strategy that focuses on soil fertility as a complement to inorganic fertiliser.

Unfortunately, in the past, a focus on soil fertility has sometimes been viewed as 'low-input' or 'alternative' agriculture. However, research in the agronomy and soil science literature increasingly indicates that holistic soil fertility management will be required to enable smallholders to use inorganic fertiliser more intensively and profitably. In this light, soil fertility management and inorganic fertiliser can be viewed as complements that are necessary for one another rather than substitutes that should take the place of each other. Elements of a holistic strategy would include

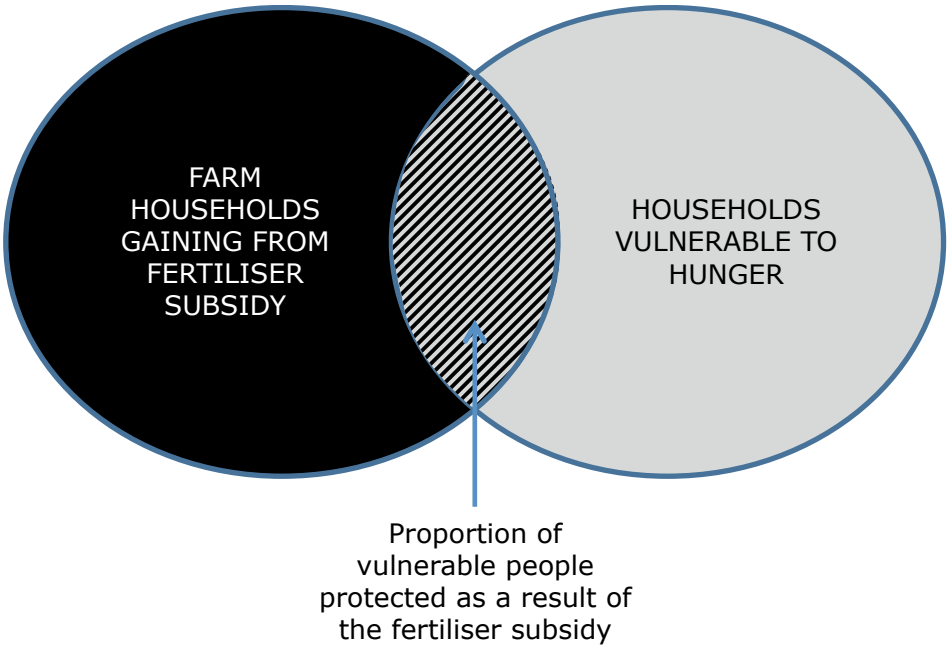
(i) developing improved seeds that have the characteristics that farmers desire, which would require more support to national agricultural research systems; (ii) increasing funding and support for extension programmes to help farmers with limited resources improve response rates of maize to fertiliser. This could occur through better training on weeding and improved fertiliser management along with programmes to restore soil fertility (Snapp *et al.*, 2014).

3.5.1 Need to clarify input subsidy programme goals and objectives

As mentioned previously, the need for complementary investments to raise maize to fertiliser response rates is the first challenge for making ISPs cost-effective and sustainable. The second is the ambiguity of the goal and expectations for these programmes. Take for example the goals of Malawi's Farm Input Subsidy Programme (FISP), which are to increase productivity and reduce poverty by targeting the 'productive poor', who are broadly defined as full-time smallholders who can contribute to increasing national-level production, but cannot afford to purchase one or two 50-kg bags of fertiliser at commercial prices (Dorward *et al.*, 2008). This definition can be compared with the official targeting criteria for selecting beneficiaries under the FISP as of 2007/2008: (i) households headed by a Malawian who owns and currently cultivates land; (ii) vulnerable households, including guardians of physically challenged persons, and households headed by females, orphans or children. There is clear inconsistency between targeting the 'productive poor' and targeting vulnerable households, because vulnerable households often do not have the land, labour and skills necessary to use inputs effectively. This inconsistency complicates the evaluation of both how well ISPs target the intended beneficiaries, and how effectively the FISP meets its stated objectives of increasing maize productivity, promoting household food security and reducing poverty.

As mentioned, subsidies for fertiliser and seed require complementary inputs such as land, labour and management practices, so it makes sense for their goals to focus on helping smallholders boost food production. However, owing in part to their high cost and substantial share of the budget, many people expect that ISPs should be able to both increase food production and reduce household vulnerability to poverty and hunger. There may be some overlap between households that can increase maize production through input subsidies and households that have their vulnerability reduced through input subsidies. This relationship is shown in Figure 3.2, which is borrowed from Ellis and Maliro (2013). If the two circles overlap completely then the ISP could be considered an adequate programme to increase maize production and reduce vulnerability. However, doing so would require enough households to have the complementary land, labour and management inputs to use fertiliser and seed effectively. The actual size of this overlap in most actual ISPs is not entirely clear. Nevertheless, given the uncertainty around the impact that these programmes have on poverty reduction, there is a need to recognise that input subsidies cannot reduce rural poverty by themselves, and complementary programmes that directly reduce household vulnerability are required.

Figure 3.2. The Intersection of Input Subsidies and Vulnerability

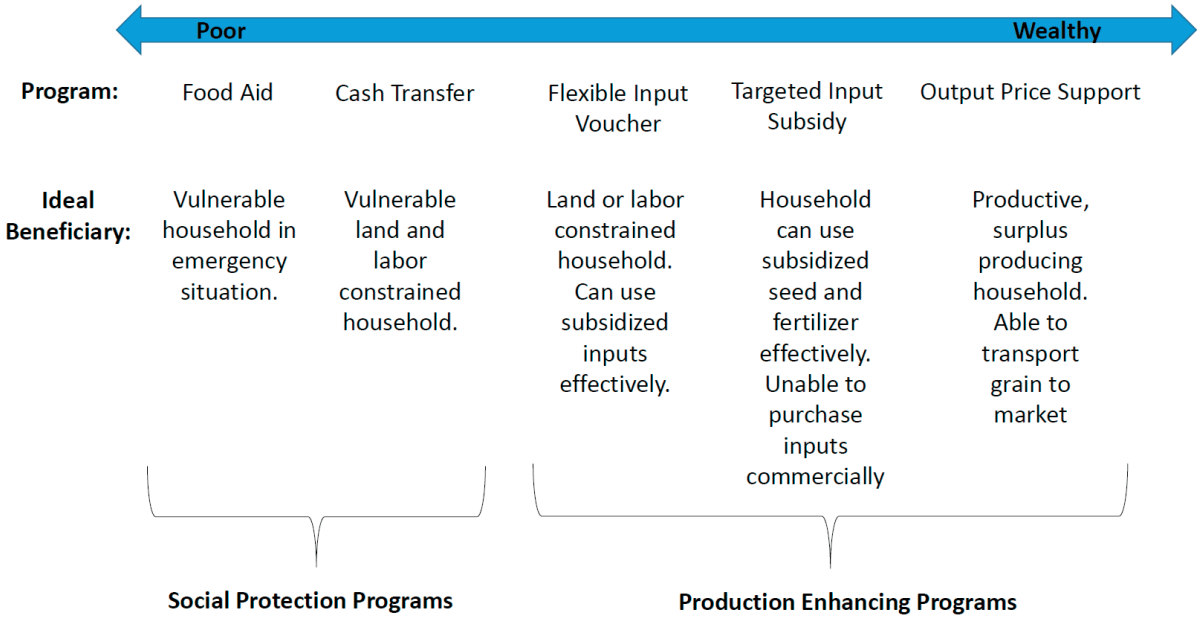


Source: Ellis and Maliro (2013)

3.5.2 Input subsidy programmes compared with other policy interventions

Figure 3.3, originally presented by Ricker-Gilbert *et al.* (2014), compares ISPs with other policy interventions, where the interventions are shown on a continuum of wealth status by intended beneficiaries. Each intervention may be the best option for a specific situation, and a specific group of households, but they all potentially compete for the same scarce public funds. Input subsidy programmes, along with flexible input vouchers and output price support programmes, fall into the category of policies that should help people boost food production. In contrast to input subsidies, which require sufficient complementary inputs, social protection programmes such as food aid or cash transfer schemes provide money and/or food directly to recipients. These programmes can help people survive shocks and smooth out their income and consumption. For example, cash for public work programmes can create productive assets in communities, and can generate income and assets for households, particularly those with too little land to make farming a viable livelihood.

Figure 3.3. Continuum of Policy Interventions, by Wealth Status of Intended Beneficiary



a) Input subsidy programmes versus cash transfer programmes

Cash transfer programmes can be defined as social protection programmes that provide money to beneficiaries directly. Unlike ISP, cash transfers do not require beneficiaries to have complementary land and labour input to make use of them. In terms of effectiveness, targeted cash transfers suffer from many of the same problems as targeted ISPs, including greater participation by individuals who have connections to local leaders and households 'gaming the system' to appear more needy than they actually are (Ellis and Maliro, 2013). However, one would expect that the administrative burden of distributing a cash transfer would be lower than the burden for distributing subsidised inputs. Cash transfer programmes would probably be a more effective mechanism than ISPs for directly reaching beneficiaries with limited resources to provide them with direct resources to reduce their vulnerability to hunger and poverty.

b) Input subsidy programmes versus output price support programmes

Output price support programmes are production-enhancing programmes, just like ISPs. They require complementary inputs of land and labour, just like ISPs. However, output price support programmes also require households to produce a surplus for sale and have market access in order to benefit from them. An example of the impacts of an output price support programme can be seen in Zambia, where the government has scaled up maize purchases by its Food Reserve Agency (FRA). The Zambian FRA purchases maize from farmers at a pan-territorial price that is consistently above the market price paid by private traders (Mason *et al*., 2014). The objective of the FRA purchase programme is to provide farmers with an outlet to sell maize, and to procure maize for the country's strategic grain reserve. Evidence of the programme's impacts suggest that FRA's increased prices induce farmers to increase maize production, but this increase comes from increasing the area under cultivation and reducing fallow land (Mason *et al*., 2014). Furthermore, Mason *et al*. find that the increased prices resulting from the FRA programme have regressive impacts. Most of the benefits from higher maize prices go to relatively well-off farmers who have enough land to expand the area under production, and have the ability to transport maize to the FRA depots for sale. In addition, poorer farmers with less land who do not produce enough maize to meet their needs for the year are harmed by these higher prices when they have to purchase maize at market. Given these results, it seems that the impacts of output price support programmes are more regressive and less pro-poor than ISPs.

3.5.3 Input subsidy programmes compared with other long-term investments

To my knowledge, the clearest example that compares the benefits and costs of input subsidies with other types of investments is from India for the period 1960–2000. Table 3.5 is borrowed from Fan *et al*. (2008). It illustrates the rupees produced per rupee spent on different policies and investments over 40 years, broken down by decade. Table 3.5 suggests that, during the initial decades, returns on subsidised fertiliser in India were relatively high. For example, INR 1 spent on fertiliser subsidies returned INR 2.41 in the 1960s and INR 3.03 in the 1970s. Unfortunately these returns fell substantially over time to the point where the return from INR 1 spent on subsidising fertiliser was less than INR 1 in the 1980s and 1990s. The changes in returns over time from fertiliser subsidies and other investments show that payoffs to different interventions are not constant. Therefore, policy makers should be willing to change policies as development occurs and the needs of the country change.

The other important message from Table 3.5 is that subsidies for fertiliser, irrigation and power almost always provided lower returns than subsidies for credit or investments in roads, education and agricultural research and development. The returns to agricultural research and development actually increased over time in India, possibly as a result of multiplier effects generated once a critical mass of scientists were trained and technologies were developed. Although the economic and policy contexts of present-day SSA and India between 1960 and 2000 are very different, the general conclusions from Table 3.5 are important to keep in mind when African governments decide how to allocate scarce budget resources among competing uses.

Table 3.5. Returns in Agricultural Growth to Investments and Subsidies in India, 1960-2000

Returns to Agricultural GDP	1960's		1970's		1980's		1990's	
Rupee produced /Rupee spent	Return	rank	Return	rank	Return	rank	Return	rank
Road investment	8.79	1	3.80	3	3.03	5	3.17	5
Education investment	5.97	2	7.88	1	3.88	3	1.53	3
Irrigation investment	2.65	5	2.10	5	3.61	4	1.41	4
Irrigation subsidies	2.24	7	1.22	7	2.28	6	NA	6
Fertiliser subsidies	2.41	6	3.03	4	0.88	8	0.53	8
Power subsidies	1.18	8	0.95	8	1.66	7	0.58	7
Credit subsidies	3.86	3	1.68	6	5.20	2	0.89	2
Agriculture R&D	3.12	4	5.90	2	6.95	1	6.93	1

Source: Fan et al., 2008.

3.6 Conclusions

This chapter reviews the literature on African smallholders' access to irrigation, modern varieties of seeds and inorganic fertiliser. In addition, the effectiveness of ISPs is discussed such a policy mechanism that is often used to increase input use among smallholders.

The main conclusion about smallholders' access to irrigation and water control is that, while there is tremendous potential for impact and expansion, the irrigated area remains very limited. Evidence suggests that most smallholders who have access to irrigation are involved with large-scale commercial irrigation projects that produce cash crops or other high-value crops. For irrigation potential to expand, other inputs such as credit, improved seeds, inorganic fertiliser, infrastructure, market access and value addition are needed. Community irrigation schemes are one method for achieving economies of scale in irrigation investment, but the communities themselves need to be organised and motivated to make such investments.

The main conclusion about smallholders' access to improved seed is that, while there is evidence that adoption of improved varieties of cereals and other grains has been increasing over time, there is still a challenge in developing a sustainable supply chain for seed in SSA. In the case of maize, many farmers may prefer OPVs that can be recycled, whereas private seed companies prefer to develop hybrid varieties that have higher yields than OPVs but cannot be recycled and whose seeds must be purchased anew every season. At the same time, local varieties have desirable consumption and storability characteristics that make them appealing to smallholder households that are both producers and consumers of what they grow. Evidence suggests that smallholders will sacrifice some yield benefits from improved varieties for the other benefits that local varieties provide. This calls for breeders to recognise that yield-enhancing traits are not the only traits that farmers want. Breeders also need to take care to adapt new varieties to farmers' conditions, as those conditions may be very different from those on experiment stations.

In terms of conclusions about inorganic fertiliser use and input subsidies, it seems clear, as demonstrated by Durilhe and Barreiro-Hurle (2012), Sheahan and Barrett (2014) and Ricker-Gilbert and Jayne (2015), that ISPs have helped to raise inorganic fertiliser use among smallholders in SSA. However, there are two major challenges that threaten the cost-effectiveness and sustainability of these programmes. The first is that low response rates of maize to fertiliser and relatively high costs of implementing these programmes make it difficult for their marginal benefits to exceed their marginal costs. The second challenge is the need for ISPs to clarify their objectives and goals. Because fertiliser and seed subsidies require complementary inputs such as land and labour, these should be viewed as productivity-enhancing programmes first. However, in part because of their high cost and the substantial share of national budgets allocated to them, they are also often expected to reduce poverty and vulnerability as well. This double burden puts tremendous pressure on ISPs. Another challenge for ISPs is that they can crowd out other investments such as roads, education, and research and development, which may have higher long-term returns.

Regardless of the issues raised in the previous paragraph, input subsidies are very popular politically, so they are likely to remain part of the agricultural development policies of numerous countries in SSA for the foreseeable future. Given that, the following steps should be taken to improve ISPs and make them more cost-effective and sustainable. First, there is a need to improve transparency in the way in which resources are allocated to ISPs, in order to reduce costs associated with corruption. Second, programme goals should be clarified and understood. For example, ISPs should focus on increasing production and productivity, so they should

target different households from those that should receive a social protection intervention such as a cash transfer. Finally, there is a need to move to a development strategy in which subsidies for seed and fertiliser are just one input in the production process. This entails adopting a more holistic strategy to improve soil fertility and increase response rates of maize to inorganic fertiliser. This could be done through a conditional subsidy, whereby households that are willing to adopt soil fertility practices are given a voucher to obtain subsidised fertiliser.

4. Smallholders' access to financial instruments

Steve Wiggins

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The third session tackled smallholders' difficulties in gaining access to financial instruments in developing countries. Four papers were presented and there was a concluding discussion.

- 'Credit markets in Africa' by **Craig T. McIntosh**;
- 'Availability and monitoring of agricultural credit' by **Wouter Gelade** ([2]) and Catherine Guirkinger;
- 'Farmers' access to agricultural inputs and finance' by **Augustine S. Langyintuo**;
- 'Agricultural insurance in sub-Saharan Africa' by **Francois Kayitakire**.

4.1 Introduction: the many challenges of finance for smallholders in the developing world

As economies grow and countries develop, formal financial services are increasingly used by households and firms. Such services allow households and firms to manage better their cash flows for payments, investments and savings, as well as to insure against risks. When well developed and functioning, these services should increase both levels of investment, since they can mobilise unproductive savings and, through insurance, reduce savings held as a precaution against risks, as well as improving the allocation of capital to uses with high returns.

In rural areas of the developing world, however, few households have accounts with banks and other formal financial intermediaries. In 2014, according to Findex (Global Financial Inclusion Database, World Bank, 04/15/2015 update), although 48 % of adults in rural areas of low- and lower middle-income countries had accounts with formal financial institutions, only 8 % had borrowed from them; for sub-Saharan Africa (SSA) the corresponding statistics are 24 % and 6 %.

Rural households, most of them engaged in farming, could benefit from formal financial services, not least to obtain funds for investment in agriculture and non-farm businesses. Loans are not the only financial service that can benefit rural households; savings, payments, and insurance are other key financial services (see Box 4.1).

Box 4.1 Financial services for livelihoods and development

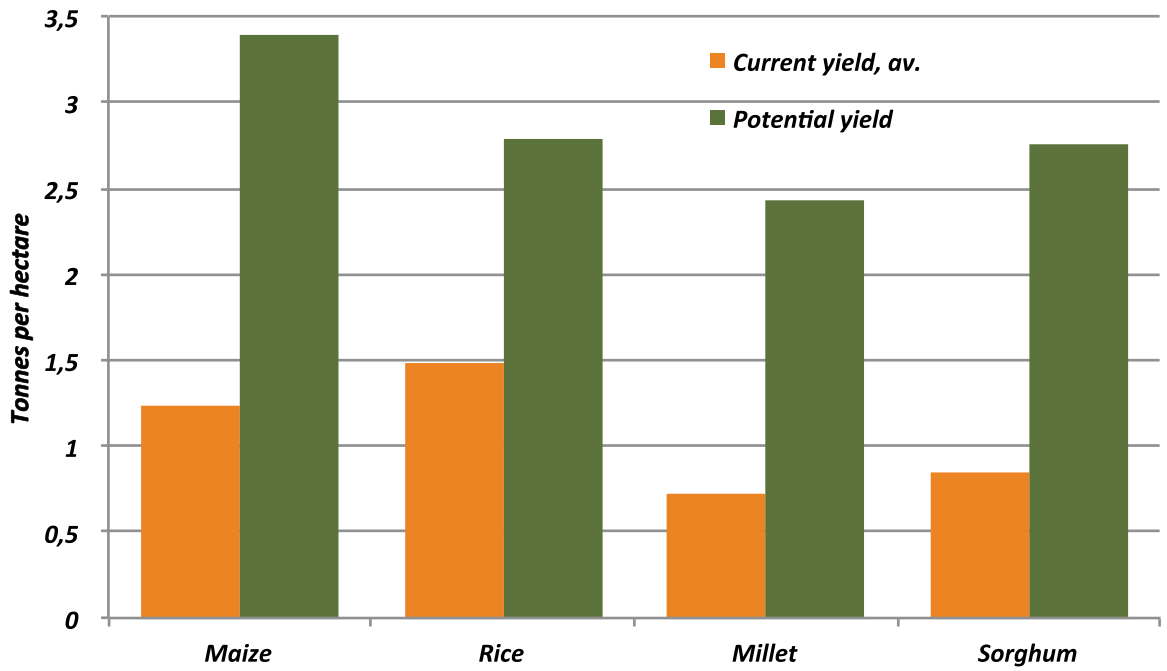
Most rural households need to manage their finances in four areas:

- saving for future investment, consumption, unexpected needs (medical bills, funerals, legal costs, etc.) and old age;
- borrowing for consumption, to meet an unexpected need, or to invest in farming or other rural business, including working capital as well as longer-term investments;
- making payments, such as school fees and utility bills, and receiving payments for produce delivered, wages or remittances from migrants;
- insuring against hazards both to personal and household well-being — ill health and medical bills, premature death, accidents, fire and theft – and to economic activities — bad weather, pests, diseases and low prices in markets.

2 Presenter of the paper.

Yet very few farm households are able to obtain loans for working capital and even fewer can obtain credit for medium- and long-term investments. Lack of credit is one reason why, in SSA, such large gaps are commonly seen between yields achieved on researcher-managed plots and those typically realised by farmers (Figure 4.1); and between the average farmer and the most productive farmers within villages (Figure 4.2). Lack of formal finance could, at worst, constitute a poverty trap whereby farmers on low incomes cannot afford to buy improved seed, fertiliser and crop protection chemicals that would allow them to raise yields and incomes ([3]).

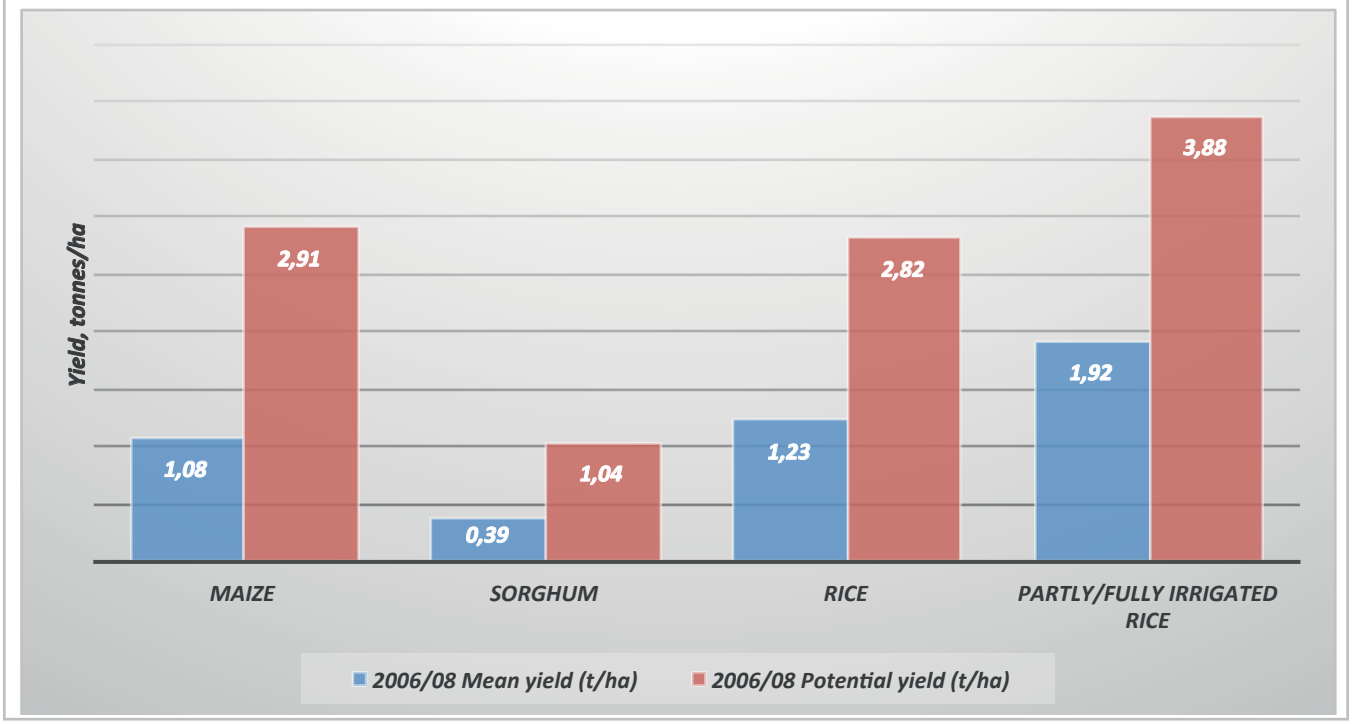
Figure 4.1. Current and potential cereals yields, rainfed cropping system, Central and West Africa, 2001



Source: Nin-Pratt et al. (2011) reporting data from Fischer et al. (2001)

3 Other reasons may also explain the failure to take advantage of existing technology: the improvements may not be applicable to all farms; inputs may be unavailable locally; when input costs are high and output prices low, the technology may simply be uneconomic; and risks may be too high for households on low incomes.

Figure 4.2. Cereals, mean yields, tonne/ha, 2006/08, farm household surveys in Ethiopia, Ghana, Kenya, Malawi, Tanzania, Zambia, Nigeria, Mozambique and Uganda



Source: Jirström et al. (2011)
Note: Potential yields are those achieved by the top 5% of farmers in villages surveyed.

Providing formal financial services in rural areas, and especially to farm households, is both difficult and costly for most formal FIs. Farming is dispersed in small units, which increases the unit administrative costs of transactions. Travel costs add to these, because some farmers live in relatively remote communities, far from the urban centres where most FIs have their branches. Transaction costs — the costs of gaining information prior to a deal, those of negotiating a deal and those of monitoring implementation of a deal — between FIs and their potential farm clients can be high. The FIs need to know the competence and character of potential borrowers, but that is hard to establish in the case of smallholders who have few formal records and no credit history. Borrowers need to understand the terms and conditions of loans, yet financial literacy is typically low among most rural households. Moreover, most farming is risky, riskier than most other economic activity: production can be hit by bad weather, pests and diseases; and output prices often fluctuate both seasonally and annually so that farmers may get less for their surplus produce than they had expected. Insurance against such risks, another financial service, is usually unavailable for small-scale farmers in developing countries because — just as with lending — it is subject to similar high transaction costs.

Given these difficulties for private provision of financial services in markets, in the 1960s and 1970s it was common for governments to provide agricultural credit, often through a publicly owned agricultural bank. These agencies typically offered farmers loans at relatively low interest rates, often too low to cover costs of lending.

Cheap credit, however, stimulated demand from farmers and thereby caught lending agencies in a bind. They could ration credit by administrative allocation to farmers on low incomes, or to those seen as creditworthy, but at high administrative cost; they could allocate credit socially or politically to favoured groups of farmers, but who then saw the loan as a favour rather than something to be repaid, thereby leading to high rates of default; or they could ration credit by conventional criteria of choosing those with credit histories and substantial assets that could act as collateral, which usually meant the credit going mainly to large-scale farms that had the requisite formal histories and collateral. In the first two cases, either costs were high or default was high, so the agencies depended on public subsidies to continue.

Moreover, they commonly either did not take savings deposits or were unable to offer attractive interest rates, so they remained dependent on flows of public capital. Without local savings, the banks were not seen as part of the local economic fabric. This perception encouraged defaults on loans.

By the 1980s, evidence mounted that public agricultural credit was costly and ineffective and often went to relatively well-off farmers who probably did not need the credit in the first place. Faced by a barrage of criticism, much of it coming from the Ohio State University (von Pischke *et al.*, 1983; Adams *et al.*, 1984), major donors, such as the World Bank, that had helped finance public credit in many countries withdrew support. In line with the thinking of the Washington

Consensus, which stressed liberal financial markets, the new accepted wisdom was that financial services should be provided first and foremost by private banks and FIs.

In the same decade, however, non-governmental organisations began micro-credit, later micro-finance, programmes, with the Grameen Bank in Bangladesh as a much admired flagship (Jain, 1996). At first it seemed that micro-credit principles, particularly lending to small groups of mutually accountable borrowers, would provide a widely applicable solution to the difficulties of providing rural financial services. To some extent they have, especially when it comes to providing small-scale rural business operators with working capital. Nevertheless, more than 30 years later, micro-finance services have for the most part steered clear of agriculture, for the same reasons that most banks choose to avoid the sector: high administrative costs, high transaction costs and high risk (Morduch, 2000; Meyer, 2015).

The search continues for ways to provide the 500 million or so smallholders in the developing world with the financial services they need. It remains one of the most demanding challenges faced in agricultural and rural development.

4.2 Credit markets in Africa

By and large, credit markets in rural Africa are weakly developed. For suppliers of finance, agriculture presents formidable risks that often apply simultaneously to most farmers in a region, as when drought strikes. Unit administrative costs are high because farms are split into small units, while smallholders lack a credit history. Assets to act as collateral are few, while collective tenure in many areas means that land cannot be offered as collateral.

The demand from farmers for credit may be weak as well, since they understand only too well that they face high risks and thus may not be able to repay their loans. Moreover, the timing of loans may not fit with agricultural cycles, so that, for example, banks expect repayment immediately after harvest, when output prices tend to be low. Farmers know, too, that increased production may push down prices in the shallow markets they serve, so that returns to loans may be too low. Smallholders may be highly risk averse, especially averse to loss of assets pledged as collateral to loans.

Credit, moreover, needs to be paired with better farm technology, although in some cases, while such technology may reduce variations in yields, the loan to finance its use may raise income risks.

Hence, the take-up of credit may be limited even when it is offered to smallholders. Several policy lessons can be deduced from experience:

Make collateral flexible and appropriate for farmers. Land is usually inappropriate as collateral, owing variously to collective tenure, the difficulty of claiming land when loans are not repaid, and the moral hazard of allowing farmers, who may not fully appreciate the risk, to pledge the household's single largest asset against a loan. Where loans are invested in machinery, leasing may be used, backed by registries of assets. Crop inventories may also be used as collateral, for example stored crops with warehouse receipts.

Improve information on borrowers, by setting up credit bureaux, using records of mobile phone transactions to predict likelihood of repayment, and verifying identities by fingerprinting and other biometric measures.

Take into consideration agricultural seasonality, offering harvest-time loans so that farmers do not have to sell their crops immediately after harvest, when prices are usually low.

Share risk between lenders (portfolio risk) and borrowers (unavoidable risk such as weather).

Risk is, above all, the key issue in agricultural lending, so that insurance needs to be developed at the same time as lending. Up to 2010, index insurance looked to be a breakthrough for agricultural insurance. Today, however, the prospects look less bright. A plethora of trials on index insurance have shown no cases of weather-based index insurance moving to scale without a public subsidy. The question then arises whether it might be better to insure not the end borrowers, who sometimes struggle with aspects of index insurance such as the basis risk, but rather the intermediaries who offer the loans, who have the professional expertise to incorporate index insurance into their risk management strategies. It may not be necessary to have complete coverage of the portfolios of intermediaries for the risks to become manageable.

That said, weather-based index insurance may encourage farmers to take more risks, so that harvests become variable and, with that, wages become more variable as well. This indicates that risk needs to be considered across the system, so that, in this case, research and extension services might try to produce crop varieties that are more resilient to drought and other hazards.

4.3 Monitoring of agricultural credit

Experiences of the monitoring of agricultural credit were recounted, taking the case of credit for cotton growing in south-west Burkina Faso. All cotton farmers receive inputs — some of which are diverted to food crops — on credit from a monopsonistic cotton company (SOFITEX), with costs deducted at the time of sale. Farmers are organised in groups averaging about 15 persons, with joint liability for delivery of cotton to the company and hence for repayment of the inputs advanced. The groups do not, however, function as well as hoped: default runs at 10 %. It seems that group members know less of the business of other members than had been imagined. Moreover, groups find it difficult to monitor and impose sanctions on defaulting members.

Introducing external monitoring by agents of the cotton company of group members may help, since it brings in routine inspections of group members' fields that can detect problems and deter delinquency to improve repayments. The impersonality of such inspections overcomes the problems that group leaders face if they choose to investigate members, which may be seen as a breach of trust or a personal slight.

4.4 Farmers' access to agricultural inputs and finance

This session set out the factors that lie behind the yield gaps so often seen on the fields of African smallholders, the immediate causes of which lie in limited use of improved seed and fertiliser, high risks in dryland farming, insecure access to land, and limited mechanisation and access to agricultural finance.

Potential responses for input supply include the use of 'smart subsidies' (targeted at those who need the subsidy, limited in time), offering inputs in smaller pack sizes that allow low-income farmers to try them without risking too much investment, and developing the capacity of agricultural input dealers through training in knowledge of inputs and business skills, and through improving their access to finance.

To develop financial services for farmers, banks and other financial institutions need to consider financing along the value chain, to pay attention to cash flows — which implies more technical knowledge of farming and food enterprises — and to look to replace physical collateral in land, buildings and machinery by inventories through warehouse receipts, with use of commodity exchanges and crop insurance to reduce risks. Leasing may be a useful option for machinery, either as straight hire schemes or as hire-purchase.

Development of both input and finance markets needs appropriate public support. This includes reforming regulations and non-performing collateral laws; central banks providing credit guarantees where justified; and developing laws and regulations to allow warehouse receipts to be used and linked to commodity exchanges.

4.5 Agricultural insurance in sub-Saharan Africa

The challenges of index insurance were discussed, since drought is usually the main hazard to insure against. Many pilots have been run in Africa, but almost all closed down once public subsidies to the insurance companies ended. Lack of rain gauges has made it hard to run such schemes in some areas.

If index insurance is to progress, it may be by insuring higher up the chain, at the level of financial intermediaries, where understanding of insurance and the capacity to make good use of it are greater than in farm households. At even higher levels, the African Risk Capacity initiative of the African Union offers a way to insure governments against climatic hazards through payments against weather indices. With assured payments in case of climatic catastrophes, governments could act earlier and with more certainty to alleviate distress.

Insurance alone is not an easy sell to most rural households, but bundled together with other services it may be both more acceptable and more useful. A pertinent example is Kilimo Salama ('peaceful faming'), started in 2009, which by 2013 offered cover for 187 000 smallholders in Kenya, Rwanda and Tanzania. Most of the insurance has been bundled with inputs provided by the One Acre Fund. Insuring one acre costs USD 37, or around one-tenth of the harvest's value ([4]).

Lessons to date are that innovations are still needed to link insurance more closely to actual losses, and that approaches to insurance need to consider all levels of potential risk mitigation, from governments to reinsurers to retail insurers and to specific products.

Most of the subsequent discussion focused on insurance. Informal insurance tends to develop with burial societies, often seen as the highest priority, after which covering hazards of fire and ill health is the next need to be addressed. Agriculture comes further down the list of felt needs in most cases. Hence, we should not imagine that smallholders have a strong demand for insurance. Curiously, in Ethiopia, when social protection is provided to smallholders, under the Productive Safety Nets Programme, private demand for insurance increases.

Furthermore, indices based on weather require long records of previous climate: most reinsurers require 30 years of rainfall records before entering into a contract.

Subsidies are almost inevitable to allow agricultural insurance to function (as is the case for much farm insurance in the USA). That said, a well-designed programme may need only a small subsidy. One approach to this is for governments to assume the risk at the tail of the distribution, when catastrophic weather occurs, albeit infrequently (the African Risk Capacity initiative may be able to reinsure governments that do this). Once the tail has been covered, then commercial insurers can reprice their offer, knowing that they do not need to consider the rare catastrophes, but need deal only with lesser harvest failures.

4 The scheme is now called Agriculture and Climate Risk Enterprise Ltd (ACRE). According to its website, 'In 2014 a total of 233,795 farmers in Kenya and Rwanda insured over US$11 million against a variety of weather risks underwritten by UAP Insurance Kenya and SORAS Insurance Rwanda'.

4.6 Discussion

To reiterate, providing financial services for smallholders is a major challenge, with many dimensions. Inevitably not all of these were rehearsed in the session held in Seville. It is also a lively field, with many potential responses having been tried between 1990 and 2010 – and, indeed, with some being developed at the time of writing. Table 4.1 lists and classifies some of these initiatives.

Table 4.1. Responses to the challenges of rural financial services

Challenge	Responses	Examples
Remoteness of rural areas, atomisation of farming in small units	Village bank branches	Unit desa, BKI, Indonesia
	Agency banking through shops, filling stations, and the like	Equity bank, Kenya
	Use of cell phones for payments	M-Pesa, Kenya
High risks in production and markets for farmers	Insurance payments indexed to either rainfall or vegetation	ACRE, once Kilimo Salama, Kenya, Rwanda, Tanzania
	Specialist farm loan officers in FIs who understand agricultural enterprises and the risks involved	
High transactions costs in credit and insurance contracts	Biometrics, typically fingerprints to identify potential borrowers or insurance claimants	Successfully trialled in Malawi among paprika growers
	Credit bureaux to establish records of past credit history	
	Group lending, with mutual responsibility for repayments	Grameen bank borrowers, Bangladesh Cotton grower groups, SW Burkina Faso Self-help groups, many countries
	Village agents to identify competent farmers of good character	Dunavant cotton, Zambia
Collateral, in absence of land titles	Leasing of machinery	John Deere, Mexico
	Inventory credit through warehouse receipts	Uganda, Zambia, etc. — with varying degrees of success

Main sources: Meyer (2015), Kloeppinger-Todd and Sharma (2010).

The discussion was not able to enter into *segmentation of smallholders*. Depending on their assets and degree of integration into markets, different smallholders need different forms of financial services. Rabobank of the Netherlands has an outreach foundation, Rabo Development, for the developing world; one of the lessons learned is the importance of recognising differences in the financial needs among farmers (van Empel, 2010):

- For *emergent smallholders*, those who usually have some capital and above-average access to land and water, and who sell much of their produce, regular bank services through a branch in a district centre will be feasible. Such farmers operate at sufficient scale and have enough records of their transactions to be served economically as individuals by banks.

- For *semi-commercial smallholders*, who have fewer assets but who still sell some of their produce commercially, their access to financial services may be best provided through aggregation within the supply (value) chain — see second item in next list. Their business levels are too small to deal directly with bank branches, but when aggregated are sufficient to keep down unit administrative costs.

- *Subsistence smallholders*, who have very few assets and who focus their attention on meeting household needs for food. It is probably not possible to offer them commercial financial services. Self-help groups and village savings and loan associations — see first item in next list – are more appropriate. Social protection may be their best defence against hazards. It is probably a mistake to try to use formal financial services to relieve poverty directly: lending when people need a grant is a sure route to default.

Hence, for most smallholders, who are not in the fortunate but small group of emergent smallholders, two routes to better financial services can be seen, as follows:

- *Small, local groups* that can handle small-scale savings and loans. Village savings and loans associations and self-help groups are quite common in rural areas; they take in small, regular savings from members and then use this capital to offer small loans to their members and sometimes also to local non-members (Ritchie, 2010). Earnings may be distributed every year among the group, or else accumulated to build the capital of the group. Such groups may be federated into larger associations with the potential for more flexible handling of funds. At some point they may be linked to formal banks, but care is needed; when such groups are rapidly connected to major sources of capital, they may lack the management and governance to handle (much) larger flows.

- *Value chain approaches*, when an aggregator within the chain provides financial services (Dalberg, 2012). The clearest and simplest example of this is where a processor, retailer or exporter contracts smallholders to grow produce for it, in return for providing inputs in kind on credit. Other models have more actors. For example, input suppliers may advance inputs to smallholders using a line of credit from a bank, with some third party, which might be a farm association or a non-governmental organisation, facilitating the links and acting as guarantor of the loans. Machinery leasing is another possible tripartite deal between the machinery company, bank and guarantor (Nair, 2010). Warehouse receipts (Coulter and Onumah, 2002) are yet another variation on such arrangements, whereby crops are stored with a private warehouse operator that issues a certificate of deposit that can be pledged with banks to allow the grower access to working capital loans.

Such models overcome the disadvantages of small-scale operations, but they depend on considerable trust among the parties. The danger that smallholders sell their produce in side channels and default on loans cannot be underestimated. Such schemes thus work best where the chain gives the smallholder access to valuable markets that cannot otherwise be accessed, and hence where exclusion from the scheme consequently carries a high penalty. This usually implies that the chain is monopsonistic.

Devising appropriate services in the field needs *support at meso and macro levels*. At the intermediate, meso, level, the staff of FIs need training in providing the services that suit smallholders and otherwise assistance in developing their capacity. To overcome the costs of learning, initial public assistance may be justified. At the national, macro, level, rural financial services need an enabling set of laws and regulations that allow service providers and farmer groups to operate. Supervisory agencies need to be created for prudential regulation of rural banking. Last, but not least, policy needs to be coherent. If the government caps interest rates, announces mass credit amnesties or provides grants to all farmers affected by a drought, then private financial services will wither.

The final and most important point is that developing rural financial services has no blueprint. While successes can be seen in some cases, models may not be easily transferable. Promising schemes need to be adapted to local circumstances, and to be introduced gradually, to allow competence and trust to grow. Managing risks, both those coming from the farming environment of weather and markets, as well as those coming from temptations to default, as Craig T. McIntosh stressed, is a critical challenge.

5. Contribution of agriculture to reduction of malnutrition

David E. Sahn

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The opening speech and the fourth session dealt with the contribution of agriculture to reducing malnutrition in developing countries. Four papers were presented in total.

'Food and nutrition security and the role of smallholder farmers' by **Prabhu Pingali** in the opening session;

'Africa's food and nutrition situation' by **David E. Sahn**;

'The role of agricultural growth in reducing child malnutrition' by **Sébastien Mary** ([5]) and Sergio Gomez y Paloma;

'Nutritional diversity in changing food systems' by **Roseline Remans**.

5.1 Food and nutrition security and the role of smallholders

The first Millennium Development Goal (MDG), 'Eradicate extreme hunger and poverty', included a specific target of halving the percentage of people who are malnourished: from 23.6 % in the early 1990s to 11.8 % by 2015 (UN, 2015a). According to data from the FAO, we have made steady progress towards achieving that goal; at the time of writing, the most recent provisional estimates available were for 2011–2013 and put the proportion of people who are under-nourished at 14.3 %. However, as the population has increased, the absolute number of people who are hungry has not declined nearly enough to meet the MDG target. The FAO estimates that, currently, one in nine people worldwide, a total of 795 million, are under-nourished. Of those 795 million, 780 million (or 98 %) are in developing countries. Therefore, developing regions are roughly 300 million people off the World Food Summit (WFS) target, while they are very close to reaching the MDG percentage-based target.

Looking at trends on a worldwide scale masks significant heterogeneity in the progress made across regions. When the figures are broken up into four major developing world regions (Africa, Asia, Latin America and the Caribbean, and Oceania), it is clear that some regions have made progress in reducing both the percentage of malnourished people and the absolute number. For instance, Latin America and the Caribbean have met both the WFS target of reducing the absolute number of malnourished people and the MDG target of halving the percentage malnourished. On the other hand, the absolute number of malnourished people has actually grown in Africa and Oceania, while the percentage has not fallen much: from 27.6 % to 20.0 % in Africa and from 15.7 % to 14.2 % in Oceania. Finally, the pattern for both measures in Asia mirrors the worldwide pattern closely: above the WFS target for absolute numbers, and right on target for the MDG percentage. Moving to an even smaller scale also reveals greater heterogeneity between countries: 65 % of the world's malnourished population lives in only six countries. India alone accounts for 29 % of the world's undernourished people, followed by China (20 %), Pakistan (6 %), Ethiopia (5 %), Bangladesh (4 %) and Indonesia (3 %).

There is debate surrounding whether it is more appropriate to evaluate a country's or region's target using its absolute achievement, meaning how low its current percentage of undernourished people is, or using its pace of progress, which takes into account how high the percentage of malnourished people was when the MDGs were instituted. There is, of course, significant heterogeneity in starting points: in both sub-Saharan Africa (SSA) and South-East Asia, more than 30 % of the population was malnourished in 1990–1992; South-East Asia has been able to reduce that figure to 9.6 % at the time of writing, while the percentage remains stubbornly high in SSA, at 23.2 %. Only one region, western Asia, saw the percentage of malnourished people actually rise, from 6.4 % to 8.4 %. Thus, when looking at only the 'absolute achievement', it would seem that western Asia is outperforming SSA, but the 'pace of progress' metric tells a different story: the malnourished population reduced in SSA, but increased in western Asia.

5 Presenter of the paper.

Of course, even looking at country-level data is often not enough, as distributional inequalities persist, based on income and other demographic characteristics. Some countries, such as Bangladesh and Nepal, have a wide disparity in the percentage of children (younger than five years) who are underweight between the top 60 % of the income distribution range (roughly 28 % in Bangladesh) and the bottom 40 % (more than 45 % in Bangladesh). In other countries, such as Chad, Sierra Leone and Liberia, the gap between the bottom 40 % and top 60 % is much narrower: the share of underweight children in the top 60 % is no more than five percentage points higher than in the bottom 40 %. It is likely that similar disparities (and lacks of disparities) exist in all countries across various demographic characteristics, such as regional or ethnic boundaries, parental education and gender of household head, and not just across income.

In sum, looking back over the years since the implementation of the MDGs, it is clear that real progress on hunger reduction worldwide has been made. However, at the same time, only limited progress has been achieved on improving the quality of people's diets, in terms of reducing micronutrient malnutrition and deficiencies. Looking ahead to future challenges, neither policy makers nor economists have yet started to address the real and growing problem of overnutrition in the developing world, and the so-called wealthy diseases, such as diabetes, that come along with it. Micronutrient deficiencies can be challenging to measure, although the prevalence of childhood stunting is one means of assessing the severity of malnutrition worldwide. Many countries in the world, and most of the countries in South Asia, have very high stunting rates, in excess of 40 % of children less than five years of age. Given the inherent relationship between agriculture, food production and malnutrition, it makes sense to question what the role of agricultural growth and agricultural policies is in reducing malnutrition.

First, data from Webb and Block (2012) show that the association between prevalence of stunting and the rural population as a share of the total population appears to be quite different in countries that have strong policy support for agriculture and countries that do not. In the countries that have strong policy support for agriculture, the prevalence of stunting declines as the share of the population that is rural decreases. In countries that do not have strong policy support for agriculture, the relationship declines until about 40 % of the population is rural; after this point (i.e. for rural population lower than 40 %), the relationship begins to increase slightly. Although these figures do not indicate a causal relationship, it seems that agricultural policies are, at the very least, correlated with a different relationship between rural population share and prevalence of stunting from non-agricultural polices. Also, data from the FAO (FAO, 2015) show that in SSA there is a positive correspondence between a country's annual rate of progress towards reducing under-nourishment and its annual rate of growth in agricultural gross domestic product (GDP). However, the slope of this trend line is not very steep, and it is almost certainly less than 0.5 (i.e. a 1 % increase of GDP would imply a less than 0.5 % rise in the annual rate of progress in reducing undernourishment). The relationship is similar for countries in Asia, where the slope of the trend line is also less than 0.5. The FAO provides data that plot the relationship between the annual rate of progress in reducing child mortality under the age of five and the annual rate of growth in agricultural GDP (FAO, 2015). These show a stronger positive correspondence than the one between progress in reducing undernourishment and agricultural GDP growth for countries in SSA. The slope of this trend line appears to be roughly 0.5. However, the correspondence between the annual rate of progress in reducing stunting of children under the age of five and the annual rate of growth in agricultural GDP is much weaker than the other two relationships, and the trend line is nearly flat.

Nonetheless, despite the lack of robust associations, it is unlikely that hunger, nutrition and agriculture are totally unrelated. Recognising this, the Post-2015 Development Agenda explicitly links them in Goal 2 of the Sustainable Development Goals, which is to 'end hunger, achieve food security and improve nutrition, and promote sustainable agriculture' (UN, 2015b). If such a goal is to be achieved, it is likely that agricultural growth will have to be inclusive of farmers of all sizes and, especially, of smallholders. Smallholders (i.e. farmers who hold 2 ha or less of agricultural land) hold more than 50 % of the agricultural land in every developing region in the world, except for Latin America and the Caribbean. Their share of holdings ranges from nearly 80 % of agricultural land in South Asia to about 44 % in Latin America. The number of smallholders, and how that number grows or declines, varies according to the stage of structural transformation of a country. Countries characterised by low-productivity agriculture have a high proportion of agriculture in GDP, a low GDP per capita and a high number of smallholders. As countries move towards commercialised agriculture, the proportion of agriculture in GDP and the number of smallholders fall, while GDP per capita rises. All of the countries classified as having low human development also have low-productivity agriculture, whereas most countries classified as having high human development are characterised by having commercialised agriculture.

Finally, strategies that make agriculture, even smallholder and low-productivity agriculture, work to improve food and nutrition security should be implemented. These are measures that can improve nutrition and food security while a country is still in the low-productivity-agriculture phase of structural transformation. First and foremost, the emphasis should be on improving smallholders' growth in productivity but with a focus on food diversity, including promoting the area's traditional staple crops. This can be implemented through both high-technology mechanisms, such as bio-fortification and food fortification programmes, and low-technology mechanisms, such as home and kitchen gardens and backyard livestock systems. Investments should be made in technologies that save labour, especially female labour, as well as in post-harvest processing and storage

infrastructure to minimise post-harvest loss. Legitimising traditional rural markets by upgrades, and informal actors by investment, is another step towards making low-productivity agriculture work to improve nutrition.

For countries that have already begun to make strides towards high-productivity commercialised agriculture, referred to as countries with 'modernising' food systems, policy recommendations are understandably different. First, efforts should be made to streamline value chains by reducing the transaction costs of linking small farms to the urban demand centres. Diversification, especially of staple grains, is important as urban consumers begin to demand a more diverse diet. On that note, as countries modernise their agricultural systems, a key step is enhancing the supply of perishable food products, through infrastructure investments and improving the safety and quality of both perishable and non-perishable foodstuffs. Smallholders who remain in these modernising systems should be supported by providing straightforward access to markets linkages.

In conclusion, it is clear that agriculture occupies a unique role in improving food security and nutrition across the developing world. However, while its position is important, it is not unitary: agricultural development must be accompanied by other changes if progress is to be made. For one, complementary policies that induce behavioural changes in the population are crucial. These changes include continuing increases in educational attainment and the slow cultural progress that empowers and advances the rights, roles, and responsibilities of women. Agriculture relies on a healthy environment, so environmental policies are also complementary to agricultural ones. Finally, reducing malnutrition and increasing agricultural productivity are both hampered by poor health, which is driven by lack of access to clean water, inappropriate hygiene habits and a lack of sanitation. Providing the basic cornerstones of a healthy and disease-free lifestyle is a first step towards attacking both hunger and malnutrition through advances in agricultural productivity.

5.2 Africa's food and nutrition situation

This presentation covered several main themes, which are discussed below.

5.2.1 Improvement in nutritional status of populations

There has been considerable improvement in nutritional indicators in SSA since 1990, following a long period of relatively limited gains. The main indicators used are those that measure stunting, or short-term malnutrition using height-for-age, and underweight, measured using low weight-for-age. This improvement is observed in all the regions of Africa.

Despite these signs of encouragement, there remains much that is sobering in the statistics. Despite the fall in the percentage of stunted children under five years of age, the absolute numbers of stunted children have been steadily increasing, as the population has grown rapidly. Additionally, micronutrient deficiencies remain widespread and have important functional implications. For example, 57.1 % of pregnant women in Africa suffer from iron deficiency anaemia, and 2 billion people globally are iodine deficient.

Another major concern is the emerging epidemic of overweight. Today, overweight and obesity are linked to more deaths worldwide than underweight. For example, 38 % of adults are overweight in Zimbabwe, and in households where the children's mothers are overweight 35 % of the children were stunted. In Burkina Faso, in 2003, in households where the mothers were overweight, nearly one in five of the children were stunted. Thus, undernutrition and overnutrition co-exist in the same countries, communities and households.

Addressing the problem of overweight requires first an understanding of its proximate causes:

- increased intake of energy-dense foods that are high in fat;
- increasingly sedentary lifestyles accompanying urbanisation;
- modern supermarkets and food distribution and sales systems.

The policy responses to this epidemic are complicated, but revolve around education and public awareness, focusing on traditional diets and increases in physical activity; market regulations, ranging from labelling and limits on advertising to tax and food price policies to address movement of relative prices that favour animal-source foods, edible oils and other key global commodities, including sugar; directing agricultural policies away from emphasis on basic grains and oil seeds toward legumes, coarse grains and vegetables; keeping a focus on the first 1 000 days, especially fetal nutritional insufficiency and excessive maternal weight gain, as well as early feeding practices; and, finally, being cautious about unintended consequences and programmes designed to reduce malnutrition, e.g. the Oportunidades Program in Mexico, which may contribute to overeating.

5.2.2 Is nutritional improvement closely related to the pattern of growth in income?

Over the long term, there is a clear relationship between GDP and nutritional outcomes. This is easily illustrated in the Preston-type curve that plots nutritional status against GDP per capita (Deaton, 2004). Likewise, there is good evidence that growth in incomes over time will lead to nutritional improvement.

It is also the case that, for a given country, nutrition improvement patterns are not necessarily expected to be the same as income improvement patterns. Countries that do best on income may not do as well on nutrition, and vice versa, especially in the relative sense. Additionally, within countries, the income growth pattern, both average and across the distribution, may not be a good predictor of the pattern of nutrition improvement. Thus, while many African countries have had a decade or more of rapid income growth, including in the incomes of the poor, we are interested in whether or not the same countries have also had rapid improvements in nutrition and, likewise, whether or not nutrition improvements have also taken place in countries that have not witnessed increases in income.

Given these considerations, the question of how nutritional improvements are distributed across the income distribution is equally important. Additionally, there is a related question of whether or not there is a similar pattern in growth incidence curves for income (or rather expenditures) and what we may label nutrition incidence curves. That is, are changes in the distribution of expenditures and nutrition attainment similar to each other? This question is of particular importance because the evidence suggests that, while economic growth has picked up in developing countries – a welcome fact — concern remains over the distribution of participation in this growth. Thus, while the evidence is compelling that nutritional improvements are widespread, including in African countries that have not witnessed substantial improvements in economic performance — presumably reflecting the increased availability and utilisation of health care services and public health measures, which often are not directly related to higher income or poverty reduction — there is a legitimate concern about who is benefiting most from the improvements in nutrition.

Our results deliver a clear and important message: while we find that economic growth over the periods we examine tends not to be strongly pro-poor, the opposite is true of health and nutrition, at least when we look at the change in the gradient between expenditures and health outcomes. Put differently, the incidence of income growth and the incidence of health improvements are certainly not the same within one country. We therefore cannot predict what the health and nutrition improvement curves will look like based on the growth incidence curves that economists and those concerned with income inequality usually examine.

5.2.3 Policies to promote nutritional improvements

It is now widely recognised that the first 1 000 days of life, from conception to two years of age, are the most critical time period for protecting and promoting nutritional improvements. This reflects the fact that poor nutrition and related disease during this period contribute to low birth weight and, thus, high neonatal mortality and underweight infants. There is increasing evidence, however, that early childhood malnutrition has persistent and long-lasting health implications over the entire life-course. This may be manifested in worse cognitive outcomes, a diminished ability to do manual work, or higher levels of chronic non-communicable disease and obesity later in life.

5.2.4 Important agricultural pathways

There are still critical linkages between a successful agricultural economy, particularly the smallholder sector, and nutritional outcomes.

A strong smallholder agricultural sector is especially critical for access to jobs and rural livelihoods. While it is changing, rural households still rely primarily on agriculture for employment and income. The smallholder sector also plays a critical role in ensuring market availability of low-cost, safe and nutritious food. This occurs in the form of home production, but also in the form of providing wage goods to the growing urban population. Along those lines, the smallholder sector is particularly well positioned to reach the increasingly important goal of promoting dietary diversity, since it tends to grow more diverse crops than large commercial farms.

Productivity growth, however, remains a major and formidable challenge. It is particularly important for women, who have more limited access to technology, inputs, extension services and output markets. Related to that concern, it is of paramount importance to increase the productivity of crops that are cultivated by and important to women and their young children. This will require increased investments in basic rural infrastructure and labour-saving technologies for women. Furthermore, women have special vulnerabilities related to reproductive health, as well as unique responsibilities in the home, particularly in terms of child care. Thus, women's needs and the gender dimension of who benefits within the household from investments in smallholder agricultural always need to be kept in mind, especially in the context of improving nutritional outcomes.

Numerous studies have also documented the risk of undernutrition after weather and agricultural shocks, especially in rural areas (Hoddinott and Kinsey, 2001; Yamano *et al.*, 2005; Alderman *et al.*, 2006). For example, drought and civil unrest contributed to increased stunting in Zimbabwe. Similarly, drought and conflict contributed to persistent stunting in Rwanda. In another region of the world, there is evidence from Indonesia showing that shortage of rain and other shocks do not have to be substantial to result in increases in malnutrition if infrastructure is not sufficiently well developed (Maccini and Yang, 2009).

Finally, there remains a critical role for the smallholder sector to be involved in successful and targeted agricultural policies. These include, for example, bio-fortification of orange sweet potatoes that are enriched with Vitamin A; and efforts to bring about reductions in aflatoxin exposure of pregnant women, resulting in taller children.

5.2.5 Non-agricultural pathways to improved nutrition

Inevitably, the focus on the nutritional well-being of women and young children lends importance to adequate caregiving resources at the maternal, household and community levels, access to health services, and a safe and hygienic environment. Specific examples of such interventions may include:

- social safety nets;
- maternal mental health;
- child protection;
- water, sanitation and hygiene;
- family-planning programmes;
- early-childhood development;
- women's empowerment;
- schooling and education (cognitive and non-cognitive skills).

5.2.6 Returns on investing in nutrition

While much of the discussion focused on the role of agriculture in improving nutrition, the converse issue of the impact of nutrition on agriculture, and specifically on the productivity of the sector, was highlighted. The case for causality running from nutrition improvement to improvements in agricultural output and productivity was based on three major pathways. The first is largely biological and revolves around the idea that improvements in nutrition over the life-course have an important impact on the ability to be productive in the labour market. Despite the recognition that malnutrition reduces learning and productivity, and growing microeconomic empirical evidence as well as the macroeconomic studies that show the link between the physical well-being of the population and economic growth and output, most of the literature on the returns on investing in human capital remains focused on the impact of education on productivity, largely in the form of models of wage determination. This contributes to underinvestment in nutrition, especially early in life.

The second pathway is that improved nutrition and greater life expectancy lead to increased investment both in children and in businesses and enterprises, and thus, over time, to greater capital intensity and higher incomes. More specifically, poor health and nutrition of parents can lead children to leave school to substitute for sick parents, further exacerbating this downward cycle of poor health and economic stagnation. Parental illness or death not only limits productivity in the labour market, but also affects parents' ability to care for children, greatly increasing the risk that adverse health events will have long-lasting consequences. Furthermore, expectations of a short lifespan also reduce saving, and thus investment in physical capital. The challenging data and empirical demands of exploring intergenerational impacts of poor health and nutrition, however, have limited the availability of evidence on these relationships.

Third, improved nutrition is instrumental to Africa's benefiting from the demographic dividend that has been so important to Asia's economic growth. Such improvement in nutrition offers a similar potential to promote economic growth and vitality in Africa, as death rates start to fall, and there is an increase in the age of the working-age population relative to the dependent population of children and the elderly.

While the general arguments for the link between nutrition and productivity are compelling, they are of special importance for African agriculture for several reasons. The first is that productivity effects of health and nutrition are greatest in the populations with the most serious health problems. Certainly, Africa's rural and poor populations are generally at the highest risk, as the evidence suggests that health and well-being in rural areas lag far behind those in urban areas (Sahn and Stifel, 2003).

Second, the productivity consequences of poor health are likely to be worse in areas where hard physical labour is the critical input. African agriculture remains largely unmechanised and requires demanding physical labour. Sedentary lifestyles are taking hold in urban areas and small towns, even in Africa, but not in rural Africa, where the physical demands of agricultural work are compounded by related needs such as gathering water and wood for fuel, and people often have to travel long distances to seek services, whether they be health clinics, schools or the marketing of agricultural output.

Third, in rural areas there is a heightened risk of adverse events, such as weather and pests, or adverse market conditions, such as covariate shocks. More importantly, unlike in urban areas, the adverse effects of such events are compounded, since they jointly affect farmers' incomes and the prices of food, as well as directly affecting health through mechanisms such as increases in infectious disease.

Fourth, the importance of own production and self-provisioning puts farmers at greater risk of suffering adverse economic and productivity consequences of disease and illness. Wage and informal sector workers outside agriculture, who are purchasers of food, are less susceptible to lasting impacts of short-term illness on their livelihoods and food availability, whereas farmers might not be able to hire labour when ill, or to turn to purchases from local markets in areas where families rely primarily on home production.

Fifth, related to the previous point, farmers and rural households live in areas with a greater propensity for market failures, particularly in credit and insurance markets, which makes their livelihood more susceptible to health shocks. These conditions leave much of Africa's rural poor caught in a low-level equilibrium of self-provisioning that, combined with a failure to be engaged in commercialised agriculture, reduces the prospect of escaping poverty. Reinforcing this low-level equilibrium are binding constraints on the time available to devote to the promotion of health, home making (such as care of children) and farm production. Thus, shocks,

whether they are health-related or other exogenous shocks, such as pests or adverse weather conditions, jointly have an adverse effect on health and agriculture.

A final point is that the link between health and productivity is particularly important for women. This situation reflects, first and foremost, women's predominant role in the production of food crops in Africa. Additionally, women have special vulnerabilities related to reproductive health, including the burden of childbearing, as well as social norms and behaviours that have resulted in women's bearing the brunt of HIV/AIDS in Africa. Finally, women have a unique set of responsibilities in the home, particularly in terms of child care. Health and nutrition shocks to women adversely affect not only their productive role in small-scale agriculture, but also their joint production role of caring for and attending to their children.

5.3 The role of agricultural growth in reducing child malnutrition

The question of whether or not economic growth, and agricultural growth in particular, reduces the incidence of child undernutrition has been discussed extensively across various disciplines without a strong consensus being reached. Additional questions, such as whether or not agricultural growth is more effective than growth in other sectors, also remain subject to debate. Of course, child undernutrition refers to a broad category of outcomes: one specific measure of child undernutrition is stunting, which has been linked to decreased physical and cognitive capacity (and lower productivity and wages, in turn). Stunting affects roughly 160 million children worldwide. Undernutrition overall is responsible for 45 % of deaths of children under five.

Even when considering a specific measure of childhood malnutrition, such as stunting, there remains debate on the impact of economic growth. Vollmer *et al.* (2014) used 121 demographic and health surveys from 36 low-income countries to see if changes in national per capita GDP, as a measure of national-level economic growth, are related to changes in three measures of childhood malnutrition: stunting, underweight and wasting, all for children between the ages of 0 and 35 months. The logistic regression models included a set of covariates, country and year fixed effects, and standard errors clustered at the country level. The authors also performed the analysis on a variety of restricted samples, as well as alternative specifications of both the outcome variables and per capita GDP, the dependent variable of interest. To control for the likely endogeneity of per capita GDP, the authors use the investment share of GDP five years prior to the survey as an instrument in one specification. While the authors found an association between a child living in a country with a low per capita GDP and a high value for each measure of child malnutrition, they did not find an association between changes in the per capita GDP and these measures. These findings are largely robust to the various specifications the authors implemented, including the two-stage least squares model and models run on regionally restricted samples. Thus, they conclude that there is a quantitatively very weak relationship between macroeconomic growth and measures of child undernutrition. They acknowledge, however, that these results could be influenced by distributional concerns and would make sense if the growth in GDP is concentrated at the higher levels of the income distribution.

This finding is by no means undisputed, however. Smith and Haddad (2015) consider national income to be one of the basic determinants of a child's nutritional status, along with responsive and responsible governance. They use data from 116 developing countries, with the condition that a nationally representative, high-quality data set on child stunting is available, to make an unbalanced panel for their analysis. By using a two-step approach, these authors are confident that they are uncovering a causal effect on child stunting, rather than an associative one. Their first step is to regress determinants of stunting in a hierarchical way, because the underlying determinants of stunting are caused by the basic determinants. Then, their second step towards causal measurements is controlling for unobserved heterogeneity using country-level fixed effects. Finally, they perform tests for omitted variable bias (the Ramsey RESET test), for accuracy of functional form (Linktest) and for the endogeneity of the determinants (Hansen's *J* test for overidentification). With all of these tests passed, the authors find all of their underlying determinants of childhood stunting to be significant ([6]). Although they find evidence of endogeneity for national income measures, they do not find any evidence that changes in income over a short period of time are endogenous; thus, they use the fixed-effects and first-difference models with that as the outcome of interest instead. They find a strong and significant negative effect of national income: a 10 % increase in national income results in a 6.3 % decrease in child stunting. National income, as a basic determinant of stunting, affects it through most of the underlying determinants, except access to safe water and gender equality, as well as directly. As a result, the authors advocate for policy responses that increase national income, in order to create an enabling environment to reduce childhood stunting, reaffirming the importance of income growth in direct contrast to the recommendation of Vollmer *et al.* (2014).

As there is no consensus on the role of overall economic growth on childhood malnutrition, it is not surprising that there is also no consensus on the impact of growth in the three main sectors of the economy: agriculture, industry

6 The underlying determinants they include are access to safe water, level of sanitation, female secondary school enrolment, gender life expectancy ratio, dietary energy supply and percentage of energy from non-staples.

and services. One of the most commonly accepted policy narratives is that these sectors, understandably, have dissimilar effects on malnutrition, and agricultural growth is the main driver of reductions in undernutrition. This argument is supported by many stylised facts, including the relevance of agricultural growth for the rural poor, supposedly strong multiplier effects, increases in demand for rural labour and decreases in food prices, which are relevant because the rural poor actually tend to be net food consumers. However, economists such as Dercon (2013) argue that the field tends to overstate the importance of agricultural development in reducing poverty, so policy makers are overly influenced into fighting the 'wrong battles' for the sake of increasing the support given to agricultural development. Dercon does not directly discuss the relationship between agricultural growth and nutrition in his paper, but he states in a footnote that that relationship is 'even more tenuous' than the one between agricultural growth and economic development.

Other researchers, who find negative impacts of increased agricultural activity, especially commercialised agricultural activity, on children's health outcomes, support Dercon's conclusion. For example, Brainerd and Menon (2014) find that the increased use of chemical fertilisers in India, associated with higher levels of agricultural activity, significantly increases infant mortality and neonatal mortality and significantly decreases height-for-age and weight-for-age *z*-scores. Their models include the expected individual-level covariates, as well as data on water quality. Additionally, they control for the likely endogeneity of the presence of fertiliser in the water using the interactions of cropped area and the planting month, to capture the period of time during which there are likely to be the most chemicals entering the water supply. Because the planting months vary across India, this provides a (potentially) exogenous source of variation in exposure to chemicals in water. Regardless, their findings point to an important health effect for children, which is related to increased levels of agricultural activity. Similarly, Headey *et al*. (2014) point to the economic growth experienced in Bangladesh that was driven by 'nonfarm diversification', in addition to agricultural growth, as a potential key determinant in Bangladesh's rapid reduction of child undernutrition. Thus, it is clear that agricultural growth cannot drive improvements in children's nutritional or health outcomes by itself; additionally, market access at a community level and trade openness on a national scale are both likely to play a role. At the same time, researchers must pay attention to the distribution of gains to ensure that they are being made evenly across heterogeneous populations.

Headey (2013) also uses a panel of country-level data to analyse the impact of economic growth in general, as well as the impact of growth in the agricultural and non-agricultural sectors, on reducing childhood stunting. The covariates are chosen based on a literature review as the factors that have a consistently significant relationship with nutrition, and they are grouped into four main categories: household income, maternal education, health and various demographic indicators, such as mother's age and birth order. Mary and Gomez-y-Paloma (2014) use a data set, which includes data from the demographic and health surveys, to capture the richness of the determinants of childhood malnutrition. They find, in agreement with Smith and Haddad (2015), that an increase in per capita GDP has a significant and negative effect on child stunting: based on their coefficients, a GDP growth rate of 5.5 % per year would reduce the prevalence of stunting by 1 % per year. Interestingly, Mary and Gomez-y-Paloma's sectorial results support Dercon's (2013) view that agricultural development is over-supported in the development economics literature. They find an insignificant, although negative, effect of growth in the agricultural sector, while growth in the non-agricultural sector has a significantly negative effect on the incidence of stunting. They do note, however, that there is no significant difference between these two estimates, given the size of the standard errors in relation to agricultural growth. This indicates that the effect of agriculture is heterogeneous or that there is a measurement error; probably, the culprit is both. However, the lack of a significant effect of domestic food production on national levels of stunting also supports the idea that agricultural development plays a small role in determining levels of malnutrition. Like Smith and Haddad (2015), Headey (2013) shows that economic growth also affects nutrition indirectly through intermediate factors such as fertility and asset ownership. The results of Mary and Gomez y Paloma (2014) also show that overall GDP growth reduces stunting, as does GDP growth broken into different sectors. These results are significant regardless of whether ordinary least squares or two-stage least squares with country-level fixed effects are used. They also show that disaggregating manufacturing from industry does not compromise these results; growth in both sectors (industry and manufacturing) decreases the prevalence of stunting.

The number of methodological issues related to these studies probably contributes to the lack of consensus on the role of economic and/or agricultural growth on nutritional outcomes. For one, any regression using country-level data cannot possibly include all of the factors that contribute to malnutrition, positively or negatively, and thus these regressions could suffer from omitted variable bias. This bias and the likely measurement error contribute to the endogeneity of these regressions; endogeneity that is unlikely to be resolved with country-level fixed effects, which is the most commonly applied solution, at least in the literature cited here. Even the proper specification of the outcome variable is disagreed upon; that is, whether regressions should include the prevalence of stunting or the logarithm of the prevalence of stunting on the left-hand side. Because these issues are not likely to be resolved until a finer level of data collection becomes the norm, it is unlikely that the questions of the role agricultural growth, as well as growth in burgeoning sectors, such as the service sector, plays in achieving nutritional goals will be answered in the near future.

5.4 Nutritional diversity in changing food systems

Diverse food systems are characterised by two main components: nutritional diversity, or consumption of a variety of foods at the consumer level, and agro-biodiversity, or the growth of a variety of foods at the producer level. As landscapes around the world transition in and out of agricultural uses, as well as between different agricultural uses, such as the development of high-productivity 'agricultural growth corridors' in Ethiopia and Tanzania from previously under-utilised or marginal land, questions arise about how to best balance diversity and growth. This is especially important because nutritional diversity and biodiversity are undoubtedly linked: there are 51 essential nutrients necessary for sustaining human life, and no one food source provides all of them. As certain foods are more abundant and efficient providers of different nutrients, it is clear that nutritional diversity should be considered as an important factor in planning agricultural and food systems. However, the questions of where in the system to integrate these concerns, and at which scale, remain open for debate.

This presentation introduces a method for evaluating the diversity of a crop production system, to complement those already in place for evaluating the diversity of individual diets and ecological diversity. This measure, nutritional functional diversity (FD), allows for the comparison of nutritional diversity based on farm production across different farms. It is based on what species are in production on a farm and the nutritional composition of these plants: therefore, a species that provides a unique nutrient or set of nutrients increases a farm's nutritional FD, so that nutritional FD declines as these species are removed from production. Thus, this metric can be used to evaluate the current status of nutritional diversity in three sites in SSA, which are representative of the cropping systems in place throughout the continent. Two of these sites, one in Malawi and one in Kenya, are maize-based; the last site, in Uganda, grows bananas as its staple crop. A geographically representative sample of farms was chosen from each village cluster, for a total sample of 170 farms. For each of these farms, all crops present on the farms were identified and their nutritional composition was documented and standardised.

Two matrices, species by trait and farm by species, were used to calculate the nutritional FD, based on, first, the nutritional distinctiveness of each species from every other species and, second, whether or not each crop is present on the farm and consumed by the household members. To evaluate functional redundancy, which refers to different plants that are nutritionally very similar, it is possible to compare the observed FD with a value of expected FD based on a randomly drawn group of species from the species pool. By repeating this drawing 5 000 times, a distribution of potential values of nutritional FD is created. If a village has a high expected nutritional FD but low observed nutritional FD, then there is likely to be a high level of redundancy, and vice versa: low expected nutritional FD with high observed nutritional FD indicates low redundancy. Four different FD variations were calculated: one with all 17 nutrients they evaluated, one with the four macronutrients, one with the six vitamins and one with the seven minerals ([7]). Additionally, the authors considered a standard set of household-level food indicators collected using pre-tested surveys, including months of inadequate household food provisioning, household food insecurity access scale (HFIAS), and household dietary diversity score, using 24-hour recall with 15 food groups. Thirty women in each community gave individual serum samples to assess iron and vitamin A deficiency.

Overall, there is a strong positive correlation between the total number of species present on a farm and the nutritional FD, regardless of the village. This increasing relationship begins to diminish at around 25 species per farm, indicating that any additional species do not contribute as much to the nutritional FD. Despite this relationship, two farms with the same number of species (e.g. 10) can have very different values for the nutritional FD (e.g. 23 and 64), despite having, say, seven species in common. The complementarity or substitutability of the nutritional endowments of the remaining three crops drives this difference. A similar relationship can be found between the macronutrient-restricted FD and number of species, but the vitamin-restricted FD appears to be very dependent on the kind of species rather than the number. There is not, however, any systematic functional redundancy in terms of the overall nutritional FD or the macronutrient-restricted FD, although there do seem to be sets of farms with systematically high functional redundancy in terms of the mineral-restricted FD (site in Malawi) and systematically low functional redundancy in terms of the vitamin-restricted FD (farms that grow mulberries).

Additionally, there is not a significant correlation between any of the nutritional FD measures and the household food security measures. There is also no significant correlation between the levels of iron or vitamin A deficiency and the FD values. Nonetheless, the nutritional FD is a useful and insightful tool for analysing and comparing agricultural diversity, an important metric of agricultural progress in regions suffering from malnourishment. However, a lack of data on the extensive margin of crop production, especially the area under production for each identified crop or plant, as well as the assumption of uniformity in the nutritional composition of each plant species, limits the scope of the work in this area.

Another issue related to both biodiversity and nutritional diversity is seasonality. It is well understood that food

7 The 17 nutrients were the macronutrients protein, carbohydrates, dietary fibre and fat; the minerals calcium, iron, potassium, magnesium, manganese, zinc and sulphur; and the vitamins vitamin A, vitamin C, thiamine, riboflavin, folate and niacin. These were chosen out of the 51 nutrients required for sustaining human life, based on both their importance for the human diet and the availability and reliability of data on each nutrient's presence in plants.

availability fluctuates seasonally, so it should come as no surprise that the nutritional FD does as well. For instance, the macronutrient-only nutritional FD varies from roughly 0.9 to 2.1 for some communities, depending on the time of year; while in some places the micronutrient-only nutritional FD varies from 1.5 to 2.5 throughout the year.

At a national scale, it is also possible to look at the variation in nutritional diversity across the world and explore if countries with more diverse food production systems have more diverse food supplies and what the relationship is between nutritional diversity and nutrition-related health outcomes.

Three measures of nutritional diversity are constructed using data on the amount of each crop or livestock product produced in each country, as well as the amount of each item available for human consumption per capita per day. Both of these values are available from FAOSTAT for most countries. The diversity measures used are Shannon entropy, modified functional attribute diversity (MFAD) and the percentage of energy coming from non-staple foods. Shannon entropy measures the abundance of each food item relative to all other food items by measuring the evenness of the distribution of food items. MFAD is similar to the nutritional FD described above, in that it measures the functional dissimilarities (i.e. nutritional content) of each food item to every other food item. Therefore, MFAD increases as there are more nutritionally dissimilar foods and does not increase when there are more nutritionally similar foods. These two measures, along with the percentage of calories from non-staples, provide a comprehensive overview of the nutritional availability and diversity in a country.

It is possible to then look at the relationship between these indicators, a set of related covariates and the following nutrition-related health outcomes: percentage of stunting, percentage of underweight, percentage of wasting and percentage of overweight.

Doing so shows considerable regional variation; for instance, food production in SSA has a high Shannon entropy measure but low MFAD and low levels of energy coming from non-staples. For the food supply (rather than production), national income measures drive nutritional diversity more than anything else, and regardless of the measure of diversity used. Higher-income countries have greater diversity in the food supply, and vice versa. The same significant relationship is not seen when looking at food production, however. In that case, there is variation between the three measures and only a weak relationship with national income. Thus, when controlling for both national income and per capita calorie availability, there is a significant negative relationship between food supply diversity and child stunting, child wasting and being underweight. These results hold regardless of what measure of nutritional diversity is used. However, the relationship between food supply and food production, in terms of diversity, is not stable, but instead depends on the national income of the country. Low-income countries show a strong positive relationship between diverse food production systems and diverse food consumption supply. There seems to be only a weak relationship between the two for middle-income and high-income countries, on the other hand.

Various recent studies, including those by Sibhatu *et al*. (2015), Luckett *et al*. (2015), Jones *et al*. (2014) and Hirvonen and Hoddinott (2014), question what relationship holds between household-level production diversity and household-level consumption diversity. Although Remans *et al*. (2014) found that on a national level this relationship was strongly positive for low-income countries, the consensus among these household-level studies is that the relationship is strongly dependent on market access. Market access can overcome less diverse home production systems. With these results in mind, increasing dietary diversity becomes a matter of strengthening market access.

Strengthening market access must be done in the context of an increasingly homogeneous food supply, as documented by Khoury *et al*. (2014). In analysing trends in the composition and abundance of different crop commodities that make up the food systems of 152 countries, Khoury *et al*. (2014) observed that, first, national food supplies from both plant and animal sources have increased per capita. The commodities with the biggest gains, in terms of country-level prevalence, were the major grains: maize, wheat and rice. While each of the 52 commodities studied increased in supply, national-level food supplies became more homogeneous across countries. The worry is that such a trend indicates the potential of losing important sources of diversity from local diets, as local alternatives are swamped by more standardised offerings. At the same time, a greater percentage of the world's population relying on certain food commodities begets the need for greater stability of the supply of these commodities. Therefore, the policy implications become two-fold: strengthening the ability of consumers worldwide to access these diverse and globally important foods while maintaining agro-biodiversity at the local scale. This is especially true given the non-nutritional roles agro-biodiversity plays, such as risk management, ecosystem services and cultural services. By including diversity metrics, such as those described above, it is possible to find solutions that expand both the diversity of food systems and their level of production.

6. Methods and tools for food security assessment at the micro level

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The closing session included three presentations aiming to provide an overview of methods and modelling techniques used to assess food security among small farm household in developing countries.

'Importance of modelling to assess the impact of smallholder farms in food security' by **Ashok Mishra** ([8]) and Maria Bampasidou;

'Policies for improved food security: lessons to learn from farm household studies' by **Stein H. Holden**;

'Micro-level impacts of food security oriented policies in Africa (FSSIM-Dev)' by **Kamel Louhichi** ([9]), Sergio Gomez y Paloma, Laura Riesgo and Pascal Tillie.

How to measure food security (quantitative or qualitative) has been a point of significant debate in recent years. For example, methods used to measure food security have varied significantly, based on surveyors' knowledge and/or variables included in the surveys. In addition, based on the measurement of food security, appropriate estimation techniques need to be implemented in order to derive meaningful results and policy implications.

6.1 Importance of modelling to assess the impact of smallholder farms in food security

According to the report of the Food and Agriculture Organization of the United Nations on the state of food insecurity in the world (FAO, 2015), about 795 million people are undernourished globally, 167 million fewer than 10 years ago. In spite of the substantial progress, the challenge of feeding 9.6 million people by 2050 adds more pressure on institutions to combat food insecurity. Based on the definition agreed upon at the 1996 World Food Summit, food security 'exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'. In 2004, the definition was adapted as 'Food that is available to everyone at all times, that they have means of access to it, that it is nutritionally adequate in terms of quantity, quality and variety, and is acceptable within the given culture' . Only when all these conditions are in place can it be said that a population is food secure (FAO, 2004).

The contribution of family farming and smallholder households to food security, nutrition, economic growth and poverty is remarkable. More than 90 % of the 570 million farms worldwide are managed by an individual or a family, and these farms produce more than 80 % of the world's food (FAO, 2015). Most of these farms are small, about 2 ha, and their activities vary from raising crops to animal husbandry, forestry, fisheries and aquaculture among others. Smallholder agriculture is not solely defined by the size of the farm (plot). In addition to the scarcity of essential production resources such as land and labour (farming at the family or the community level) one has to take into consideration potential limitations the households face in acquiring production inputs such as seed and fertiliser, credit, and information on new seeds and technologies that can have a positive impact on their productivity. On another

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note, the same households need to provide food for their members and their communities.

Smallholders are affected by food insecurity and also contribute to food security. In the literature, food security is addressed in four main ways, commonly referred to as the four pillars: food availability, food access, utilisation and stability. Given the multidimensionality of food security and the sensitivity of defining it, the four pillars have provided a structure for how researchers and other people perceive and measure food security over the past few decades. Models were developed to assess and/or proxy the impact of food security of smallholder households.

Discussions in the 1970s emphasised the supply side of food security, pointing to shortfalls in food availability (the first pillar), which was related to shortage in food supply and high food prices (see Figure 6.1). Modelling of food availability, which allows the derivation of a food security measure or proxy, relied on optimising the individual's utility (which can also be extended to the household or community level) based on production and consumption decisions, income and time constraints. Of particular importance in modelling the optimisation problem is considering the functionality of the markets, which is related to the separability of consumption and production decisions. When all relevant markets function, individuals can allocate production expenses and subsequently allocate income between consumption of goods and leisure (Strauss, 1983).

Econometric techniques used in the estimation of food availability include probit (e.g. Oluyole *et al.*, 2009), logistic regression (e.g. Feleke *et al.*, 2005) and general method of moments estimator (e.g. Larochelle and Alwang, 2014). Model parameters include (i) farm characteristics such as farming system, farm or plot size and land quality; (ii) household characteristics, e.g. size, wealth, age of household measures, education levels; (iii) technology adoption through seeds and fertiliser, among other indicators; and (iv) access to markets for credit, output and input subsidies. In the 1980s, food availability started to attract less attention, since progress was made with technology adoption, new seed varieties, better management practices and lower food prices. Recent studies revisit technology adoption, emphasising its impact on food security utilising new econometric techniques. Examples include (i) a double hurdle model to estimate probability of adoption with seed access constraints (Shiferaw *et al.*, 2008); (ii) treatment effects for tissue culture banana technology adoption (Kabunga *et al.*, 2011); (iii) matching techniques for improved seeds and fertiliser adoption (Vigani and Magrini, 2014); and (iv) Poisson model to estimate adoption of improved bean varieties (Larochelle and Alwang, 2014).

After Sen (1981), the focus shifted to the demand side of food security, bringing food access (the second pillar) to the forefront. Researchers focused on identifying means of access to food and also on assessing food access itself. The social unit of study is now the household and the individual rather than the global and the national stage. The main source of information to this day is the survey instrument. Extensive surveys are administered at the individual and household levels. In addition, policy and government actors take part in the research groups. The focus is on consumption instead of availability of food. Important measures are calorie intake and daily food energy consumption. In addition, studies look into the quality of food consumed (diet diversity) rather than the quantity of food consumed. Last but not least, household food expenditure decisions are documented, as well as gifts, and government support if available.

One of the most common methods used in assessing food access is the FAO method, which focuses on estimation of habitual dietary energy supply per capita at the country level. Use of food balance sheets allows identification of the supply of food commodities (i.e. quantity produced in a country added to the total quantity imported and adjusted to any change in stocks), food utilisation and food supply available for consumption (food utilisation distinguishes between quantities exported, fed to livestock, used for seed, losses during storage and transportation and food supply available for consumption).

Advantages of this method include the fact that data (secondary data) are available for most of the countries, updated yearly by FAO in collaboration with the World Bank to improve food security consumption data, and the wide variety of indicators for the four pillars of food security, which allows comparisons at regional, national and global levels. One of the concerns this method raises is whether or not the data collected can correctly address the food access pillar of food security. To be more specific, the assumption that calorie intake above a specific threshold is a good indicator of food security can be challenged, since food quality is not addressed. Moreover, the food balance sheets provide information on the availability of calories, not calorie consumption, which can lead to measurement errors (Pérez-Escamilla and Segall-Corrêa, 2008).

Another way to collect information on food access is by measuring the individual's dietary intake. Several studies use this method, since it allows food consumption and nutrient intake to be assessed thoroughly and measured directly. The main sources of information are food frequency questionnaires, the recall method (24-hour, 7-day, 30-day) and food records. This method allows intra-household consumption patterns and long-term trends to be mapped and understood. Conducted at individual level, it is more flexible and can address food security issues based on individual socioeconomic and demographic characteristics. Researchers are called on to take into consideration the possibility of large measurement errors, especially where information collected from participants relies on the recall method. Properly trained interviewers and good reporting strategies increase the cost of this method. In addition it may not be able to capture the vulnerability and sustainability of food security.

Household expenditure surveys are the third most commonly used method to collect information at the household level about food security. Outcomes include caloric intake per capita per household and dietary variety scores, with emphasis on expenditures on food and necessities, quantity of food produced and purchased, and food received as gifts or payments. Researchers report advantages of this method in terms of addressing the dimension of food access by reporting data on dietary quality (Smith and Subandoro, 2007), evaluation of household insecurity and evaluation of food and nutrition programmes (Rose and Charlton, 2001). These surveys do not address food consumption directly, which can leave room for error in measuring food security. It is also hard to control whether the food consumed comes from gifts, own production or purchase, which is a challenge from a logistic approach.

Three other measures of food access are recorded in the literature, namely the anthropometry index, HFIAS, food variety score, food consumption score and household dietary diversity score (HDDS). The anthropometry index allows the percentage of malnourishment in a population to be estimated taking into consideration individual characteristics. It provides measures for stunting (low height for age), underweight (low weight for age) and wasting (low weight and height). These nutritional outcomes reflect food distribution within households, individual health and activity levels, and quality of the environment, rendering it a good indicator of both chronic and acute undernutrition. To a certain point, many of the previous methods listed here include anthropometric characteristics that allow the mapping of nutritional security. On another note, the elaborate interviews and participant observations, as well as the in-depth measurement of individual characteristics, are costly for a measure that captures food security indirectly. The HFIAS is based on the household's own perception of access to food and is captured through nine questions reflecting anxiety and uncertainty about food supply, food quality and food quantity (Kabunga *et al.*, 2014). Lastly, the HDDS is a simple and easily administered method and classifies each food item consumed by the household into 1 of 12 different food groups. With a range from 1 to 12, a high HDDS reflects a diverse diet and suggests food security whereas a low HDDS is indicative of food insecurity.

Recent changing climatic conditions, extreme weather events, externalities and shocks led the discussion topics towards attaining food stability (the third pillar), increasing the need to assess the impact of socioeconomic and environmental conditions on food security. Changing environmental and climatic conditions are potential shocks that affect the sustainability of food-secure smallholder households and impoverish the condition of food-insecure households and communities. There is a need to better understand the effects of climate change and how that is related to the vulnerability of specific regions, price fluctuations and yield of key staples, and land use. As mentioned previously, food supply is related to food availability, land and adoption of technology. Models that combine inputs from all these dimensions are powerful tools to address agricultural systems, natural resource management and environmental changes simultaneously, along with their resulting trade-offs.

Although at this point food security and food safety are not directly captured by models related to climate change, new models can benefit from key components of the existing models. Researchers have long used crop-yield simulation models, for example bio-economic models, the International Benchmark Sites Network for Agrotechnological Transfer (IBSNAT) – International Consortium for Agricultural Systems Applications Crop Model (ICASA) and the Decision Support System for Agrotechnology Transfer(DSSAT); land-use models such as agent-based models; and the Nutrient Use in Animal and Cropping systems — Efficiencies and Scales Farm Simulator simulation model.

The International Food Policy Research Institute (IFPRI) has developed an international model for policy analysis of agricultural commodities and trade (IMPACT). This model is designed to examine the alternative futures for global food supply, demand, trade, prices and food security, specified as a set of 115 country-level supply and demand equations, where each country model is linked to the rest of the world through trade. The main advantage of the model is that IMPACT integrates information from climate models (general circulation models, or GCMs), crop simulation models (e.g. Decision Support System for Agrotechnology Transfer) and water models, in a consistent equilibrium framework. It supports longer-term analysis, and covers 44 commodities. Some limitations arise because the model may fail to capture short-run effects, some of the model communication is one-way, with no feedback links (e.g. GCM scenarios to hydrology models to crop models), and some links require feedback loops to be captured (e.g. water demand from the economic model and water supply). More recently, the International Institute for Applied Systems Analysis has developed a partial equilibrium model, Global Biosphere Management Model, which can be used to assess competition for land between agriculture, forestry and bioenergy. The model computes equilibrium by choosing land use and processing activities to maximise the sum of producer and consumer surplus, subject to resource, technological and policy constraints. It is global because it covers 53 countries and regions worldwide (EU-28 plus 25 countries and regions in the rest of the world).

Food security is multifaceted and one cannot separate the four pillars and study them individually. In the past we have seen several studies approaching the issue of food security one pillar at a time but still there is not a silver bullet. To capture the multidimensionality of food security we have to use a combination of measures. We see a need for bio-economic models that capture food security directly so they can better address risk perceptions through climate change. Attention should be given to the area of study, the characteristics of the population, and the climatic and environmental conditions expected in the area. In addition we should strive for models that emphasise the short run. The majority of the models are built on long-term conditions.

Lastly, food security is not a community or country issue; it is a global issue. Adding the global dimension to food security trade is an important component we need to address. IFPRI's model addresses some of these components.

6.2 Policies for improved food security: lessons to learn from farm household studies

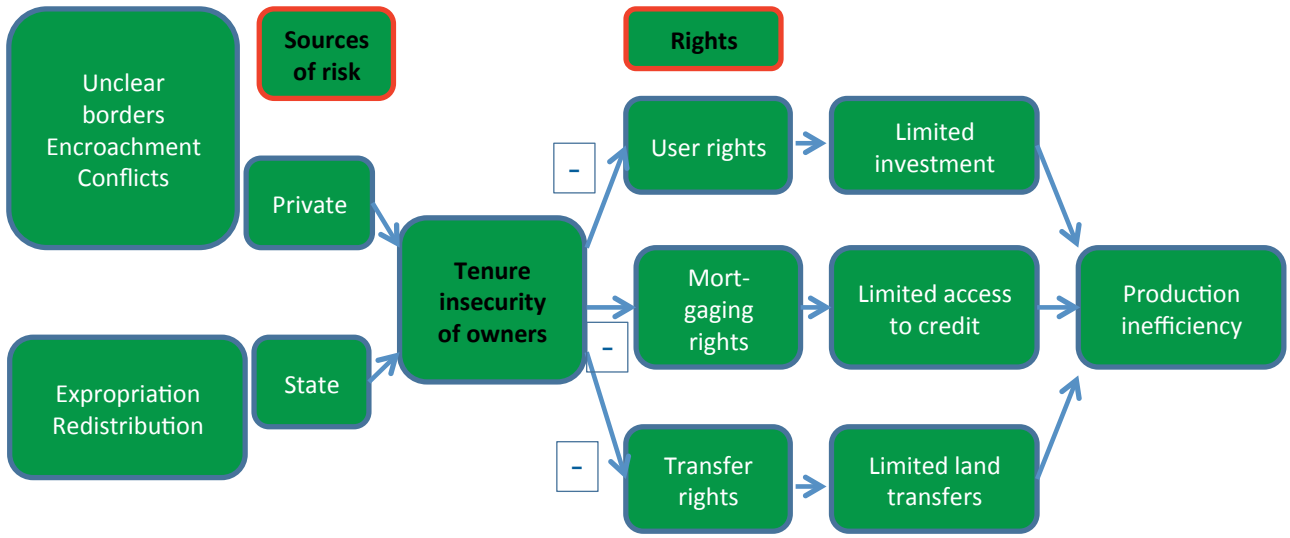
Land tenure and land policies have a significant impact on the food security and well-being of farm families in Africa. Holden (2015) in his presentation talks about the need for better land governance and the importance of tenure security. He then connects land tenure security to food security. Effective land governance systems that provide improved access and rights to land resources are a necessary condition for achieving food security and better nutrition. Governance of, and access to, land is the most important policy choice facing Africa. Holden *et al.* (2009, 2013) and Holden and Otsuka (2014) present a significant amount of research and collection of empirical analysis on land markets in several East African countries: Kenya, Ethiopia, Uganda and Malawi.

Holden *et al.* (2008) made the first systematic attempt to address emerging land markets and their implications for poverty, equity and efficiency across a number of African countries. The authors revealed that land markets are active in many African countries, but they have customary tenure systems. However, there is a fear among people that land sale markets will lead to landlessness and more unequal land distribution. Therefore, prohibitions of and restrictions on land sales are still common. In all these studies or collections of work (Holden *et al.*, 2008, 2009, 2013 and 2015), it is apparent that women have a prominent role in agricultural and land transactions and in credit markets. Additionally, in Ethiopia at least, the tenants are in better financial shape than the landlords. Nonetheless, we should note that land rental markets in Ethiopia are critical for re-adjusting factor proportions in the face of market imperfections. It is clear that poor landlords maintain control over the land markets by creating a sense of land shortage through selecting wealthier tenants.

Good land policy is central to productive land-based development across farm sizes and types, not only in Africa, but across all developing countries. In Ethiopia, the same tenant households use rented land with greater economic efficiency than land they own themselves. This is because tenants tend to use more fertiliser on their rented plots than on their owned plots, perhaps signalling contract renewal. The study also suggested that share-tenancy is not inefficient and may not be bad for growth. Finally, it is likely that high productivity on rented land may be due to over-fertilisation of rented land compared with owned land. Holden (2015) argues that effective governance systems create positive incentives that enable more efficient and effective investment in land, labour and capital, and improved practices in food production and nutrition.

Holden (2015) outlines the sources of land insecurity. These are (i) encroachment by neighbours; (ii) land grabs by powerful persons (elite capture); (iii) unclear or unrecognised (customary) land rights; (iv) state allocations of land to investors, without the consent of farm families; (v) expropriation by the state, for example land for public use, investment, elite capture; (vi) political conflict in areas such as Sudan and South Sudan. All these factors lead to insecure tenure. Holden (2015) carefully links the above issues to food security, in the form of lost production efficiency (see Figure 6.1).

Figure 6.1. Source of tenure insecurity and their impact on production efficiency

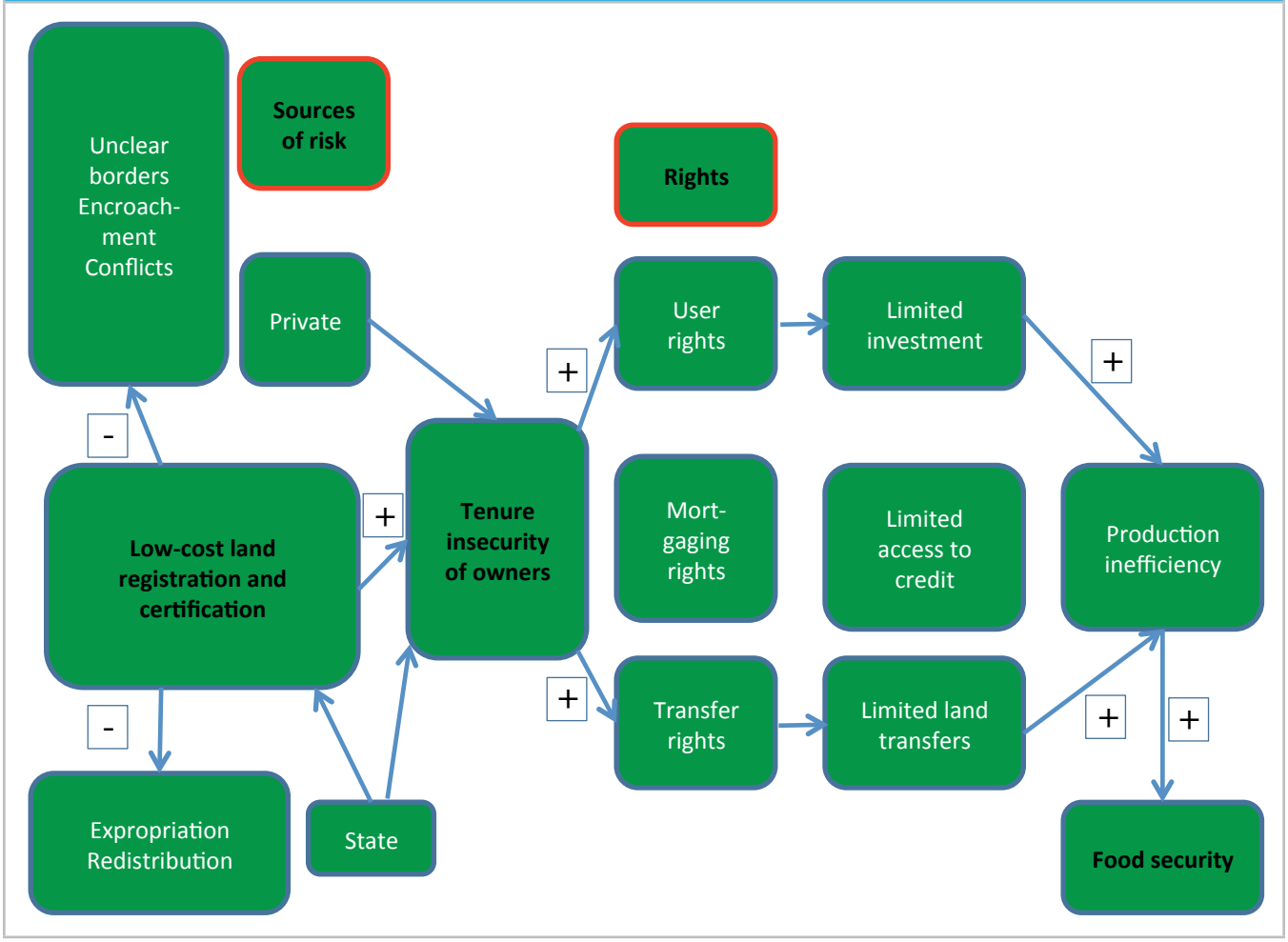


However, Holden (2015) cites examples of various successful land tenure reforms in Africa. For example, he points to the 'low-cost land registration and certification' programme in Ethiopia. Various studies (Deininger *et al.*, 2008, 2011; Holden *et al.*, 2009) show that the land certification programme has increased both investments in land and productivity. The programme has also reduced land border conflicts (Holden *et al.*, 2009) and land rental market participation (Holden *et al.*, 2011), which is especially beneficial to female heads of household. Finally, land certification reform has had a positive welfare impact on food security and nutrition, including female landlord households (Ghebru and Holden, 2013; Holden and Ghebru, 2013). Holden (2015) highlightes the importance of tenure security in seeking food security for sub-Saharan Africa (SSA).

Ghebru and Holden (2103), using panel data, studied the impact of land certification on food consumption in Ethiopian farm households and found that the duration of land certification (i.e. years of certification) had a significant impact on food security. However, when analysing the period ([10]) (2006–2010), the authors do not find any significant impact of land certification on food security. Nonetheless, the variable of farm size had a strong and significant impact on food security, emphasising the need to expand farming operations, by either renting or buying land. The authors also investigate the impact of the land certification programme on food security by land tenure (tenants, landlords and pure owner-operators). They find that the land certification programme (years of certification) had a positive impact on food security only for landlords and pure owner-operators.

10 The analysed periods include 1997–2010, 2000–2010, 2003–2010 and 2006–2010.

Figure 6.2. Impact of Low-Cost Land Registration and Certification on Food Security



Finally, one can conclude that land rental markets enhance the flexibility of agricultural systems and contribute to adaptation to changing external and internal conditions, including multiple sources of risk and shocks. They also enhance equity and efficiency, facilitate adaptation to climate change and promote agricultural transformation. Holden (2015) points out that the recent increase in demand for land in Africa calls for better land governance; good understanding of the local context is essential for designing better land policies.

Other issues that deserve much attention when talking about food security are risk preference, weather shocks and technology adoption. Holden (2015) emphasises that climate risk represents an increasing threat to poor and vulnerable farmers in drought-prone areas of Africa. Combining household survey data and a field experiment, Holden (2105) elicited relative risk aversion, loss aversion and subjective probability-weighting parameters of farmers in Malawi. He investigated the maize and fertiliser adoption responses of food-insecure farmers in Malawi, where drought tolerant (DT) maize was recently introduced. Some studies have found that more risk-averse people are likely to be late adopters of new technologies. For instance, Liu (2013) found that more risk-averse farmers in China adopted Bt cotton (a pest-resistant variety) later. However, one needs to assess how risk preference affects adoption of new technologies that are better adapted to drought conditions. Holden (2015) wanted to know how exposure to drought shocks affects adoption of more DT maize varieties.

Malawi ranks among the poorest developing countries in the world. In Malawi, as in other developing countries, food security is highly dependent on agricultural productivity. A number of studies indicate that the vast majority of rural households in Malawi are close to or below the subsistence threshold (Devereux, 1999). In Malawi, farm size ranges between 0.25 and 5 ha, maize is the staple crop and agriculture is mostly rainfed. Farmers observe significant rainfall variability; droughts in the form of dry spells in the rainy season are common. Hence there are net buyers of maize (deficit producers). The government of Malawi introduced a large ISP (FISP) that provides subsidised fertiliser and maize seeds to the farmers. Holden (2015) notes that farmers adopted DT maize varieties rapidly, but only when drought was imminent (see Table 6.1). The main driver of this adoption was the subsidy programme (FISP), which has distributed free seeds, in addition to highly subsidised fertiliser, to smallholder households since 2005/2006.

Table 6.1. Adoption of DT maize in Malawi

Year		Local maize	DT maize	Other improved maize varieties	Total
2006	No of plots	295	20	525	840
	% of plots	35.1	2.4	62.5	100.0
2009	No of plots	273	130	225	628
	% of plots	43.5	20.7	35.8	100.0
2012	No of plots	143	249	163	555
	% of plots	25.8	44.9	29.4	100.0
Total	No of plots	711	399	913	2,023
	% of plots	35.2	19.7	45.1	100.0

Holden (2015) assessed the impact of each variety on adoption and the intensity of adoption. He also assessed the impact of the intensity of fertiliser use on each type of maize. In the case of maize adoption he found that the perceived riskiness of technologies matters for adoption of maize varieties. For example, among farmers in Malawi, those with higher relative risk aversion were more likely to adopt DT maize varieties; however, interestingly, he also found the same results (almost the same coefficient) for adoption of local maize varieties by Malawian farmers. On the other hand, he found that the more shocks (drought years) there had been in the previous three years the more likely farmers were to adopt DT maize, and the less likely they were to adopt local maize varieties. Finally, Malawian farmers were more likely to adopt DT maize because they received seed vouchers.

Finally, Holden (2105) investigated the impact of farmer's riskiness on fertiliser use in all three adoption scenarios (DT varieties, other improved maize varieties and local maize varieties) and found that the perceived riskiness of technologies matters for adoption of maize varieties. In particular, more risk-averse farmers used less fertiliser in the production of local maize varieties than for other improved maize varieties. Subjective probability weighting (i.e. over-weighting of low probabilities) reduced the intensity of fertiliser use. The loss aversion parameter indicates higher levels of loss aversion than found in other studies (Tanaka *et al.*, 2010, in Vietnam; Liu, 2013, in China). Finally, higher average rainfall decreased the amount of fertiliser used for DT maize crops and increased the amount used for other improved maize varieties.

Several policy implications can be derived from this study. First, positive food security effects were associated with land rental market participation, which has been enhanced not only by the land certification programme but also by increased investment and productivity on owner-operated land. The rental market effect is stronger for tenant households, whereas landlord households benefit from both the investment and rental market effects, and the pure owner-operator households benefit only through the investment effects of the programme. Second, the supply of seed to local markets must be adequate to allow farmers to buy, experiment with and learn about DT maize. Third, when it comes to technology adoption, policy makers, the seed industry, NGOs and researchers should take into account the risk preference of farmers. Fourth, to make seed more accessible to farmers with limited cash or credit (another major barrier), seed companies and agro-dealers should consider selling DT maize seed in affordable micro-packs. Finally, greater adoption depends on increased awareness, weather conditions and irrigation facilities. Awareness could be raised through demonstration plots, field days, and distribution of print and electronic promotional materials.

6.3 Micro-level impacts of food security oriented policies in Africa (FSSIM-Dev)

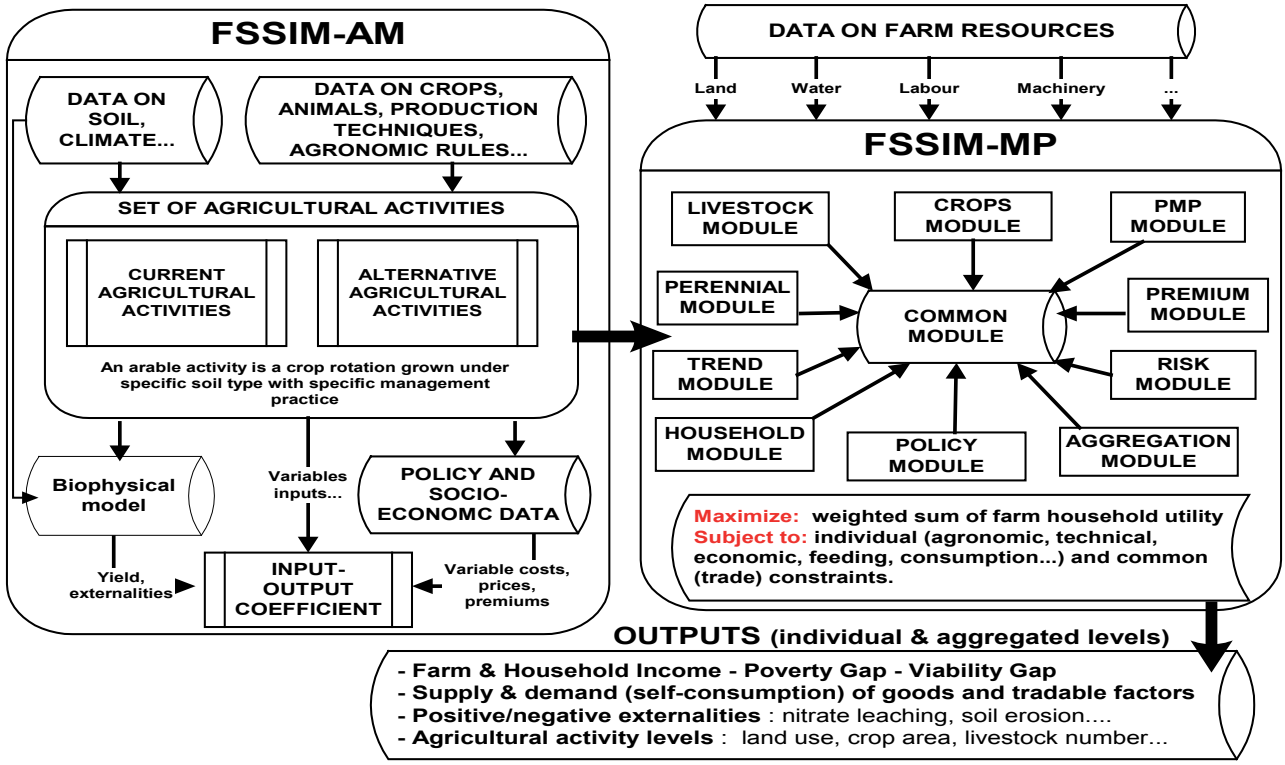
The European Union (EU) is the world's largest donor of aid to developing countries. In fact the EU spends more than EUR 55 billion per year, twice as much as the USA (about EUR 24 billion per year). Louhichi *et al.* (2015) note that the EU is one the top three donors in 20 out of 29 fragile and conflict-affected states in SSA. These countries include Chad, Mauritania, Niger, Sudan, Burkina Faso, Burundi, Cameroon, Eritrea, Liberia, Mali, Angola, Madagascar and the Central African Republic (OECD, 2014). Therefore, the EU has explicitly formalised, via its institutions, its needs for an impact assessment of its development policies on the livelihood of farm households and on rural poverty alleviation. In an attempt to assist the EU and its call, the Joint Research Centre Institute of Prospective Technological Studies (JRC-IPTS) has undertaken a major role in addressing the impact of EU aid on the well-being of recipient states, by developing tools that can, in a transparent, rigorous and repeatable fashion, make policies more achievable and their impacts higher in value.

To study the above objective, Louhichi *et al.* (2015) developed a farm household model (Farming System Simulator for developing countries, FSSIM-Dev) to use in the context of low-income developing countries, in particular to (i) improve knowledge of food security and poverty alleviation in rural areas; (ii) analyse key features of different farming systems, focusing mainly on (semi-)subsistence farms; and (iii) assess the potential impacts of national and EU cooperation policies, high food prices and alternative cropping systems/technologies on farm productivity, welfare and poverty level. Using this approach, Louhichi and Gomez y Paloma (2014) modelled and simulated the impacts of rice seed policy on the livelihood of smallholders in Sierra Leone. They used the farm household modelling approach, generic and modular setup, where production and consumption decisions were made simultaneously. The model captured key features of agriculture in developing countries. These included non-separability of production and consumption decisions, effects of transaction costs on market participation, heterogeneity of farm households, interaction among farm households for factor markets, seasonality of cropping activities and resource use.

The basic idea behind the FSSIM-Dev model is the dual character of farm households. In particular, food surplus/deficit is created as a difference between food and cash crop production and food demand at home. Recall that both food production and food demand are affected by prices. Additionally, price is a function of international markets and trade, infrastructure and market efficiency. In short, the FSSIM-Dev model maximises farm household income subject to resource constraints (including land and labour), cash, market clearing conditions, linear expenditure system, price bands and complementary slackness conditions. In general, FSSIM-Dev is a comparative static and non-linear optimisation model that relies on both the general household's utility framework and the farm's production technical constraints, in a non-separable regime. Farm household income is composed of agricultural income, income from marketed tradable factors and off-farm income, from which the amount of money spent on purchasing goods and services is subtracted. Further, agricultural income is composed of the value of commodities sold plus the value of self-consumed commodities minus accounting costs, implicit (unknown costs) and the value of tradable factors that are rented in (see Louhichi and Gomez y Paloma, 2014).

Figure 6.3 shows the two main components of FSSIM-Dev: a data module for agricultural management (FSSIM-AM) and a mathematical programming model (FSSIM-MP). FSSIM-AM aims to set data on farm resources (land, labour, water and machinery) and to identify current and alternative activities and their input and output coefficients (both yields and environmental effects). Once these activities have been generated, FSSIM-MP chooses those that best fit the farmer's behaviour, given the set of resources and the technological and political constraints, and forecasts the farmer's responses to new technologies, as well as to policy and market changes. FSSIM-MP involves various modules (i.e. crops, livestock, household, policy risk) at different levels. Louhichi *et al.* (2015) reiterate that the model outputs could possibly be scaled up, depending on the requirements, and linked with other models. This includes several layers, from field level through farm households to regions and then national level.

Figure 6.3. FSSIM-Dev design

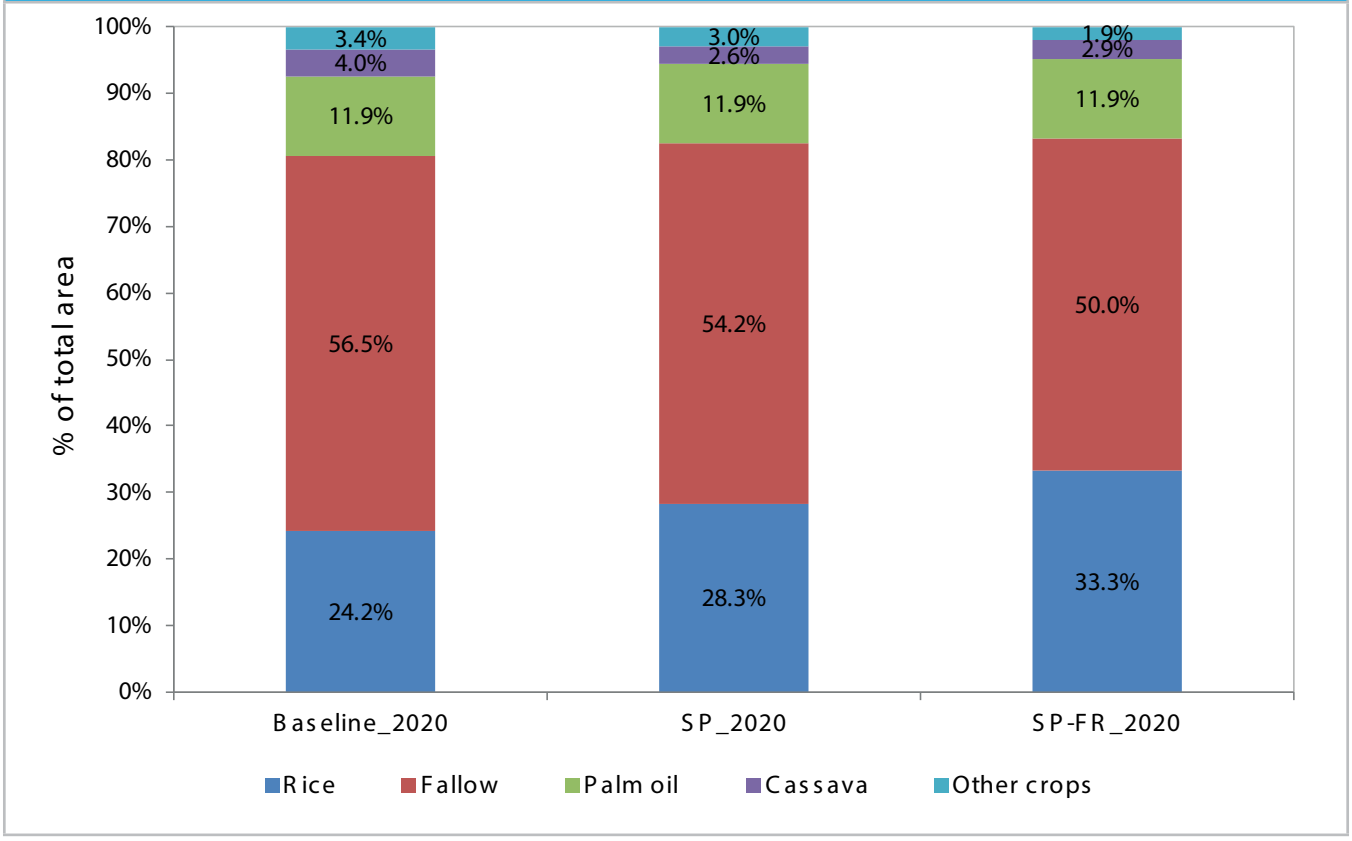


Source: Louhichi and Gomez y Paloma, 2014.

Using the above structure, Louhichi *et al.* (2015) have investigated several policy impacts in several African countries. For example, they have investigated the impact of providing high-quality rice seeds on the livelihood of 400 representative smallholders in northern Sierra Leone.

The aim of this policy was to increase rice production and improve self-sufficiency. The indicators used to assess the impact of the policy were (i) farm household income; (ii) land use; (iii) production; (iv) consumption; and (v) degree of poverty at farm/regional level. Using 2009 as the base year, the authors predict the scenarios for 2020. Figure 6.4 shows land use change based on the FSSIM-Dev model.

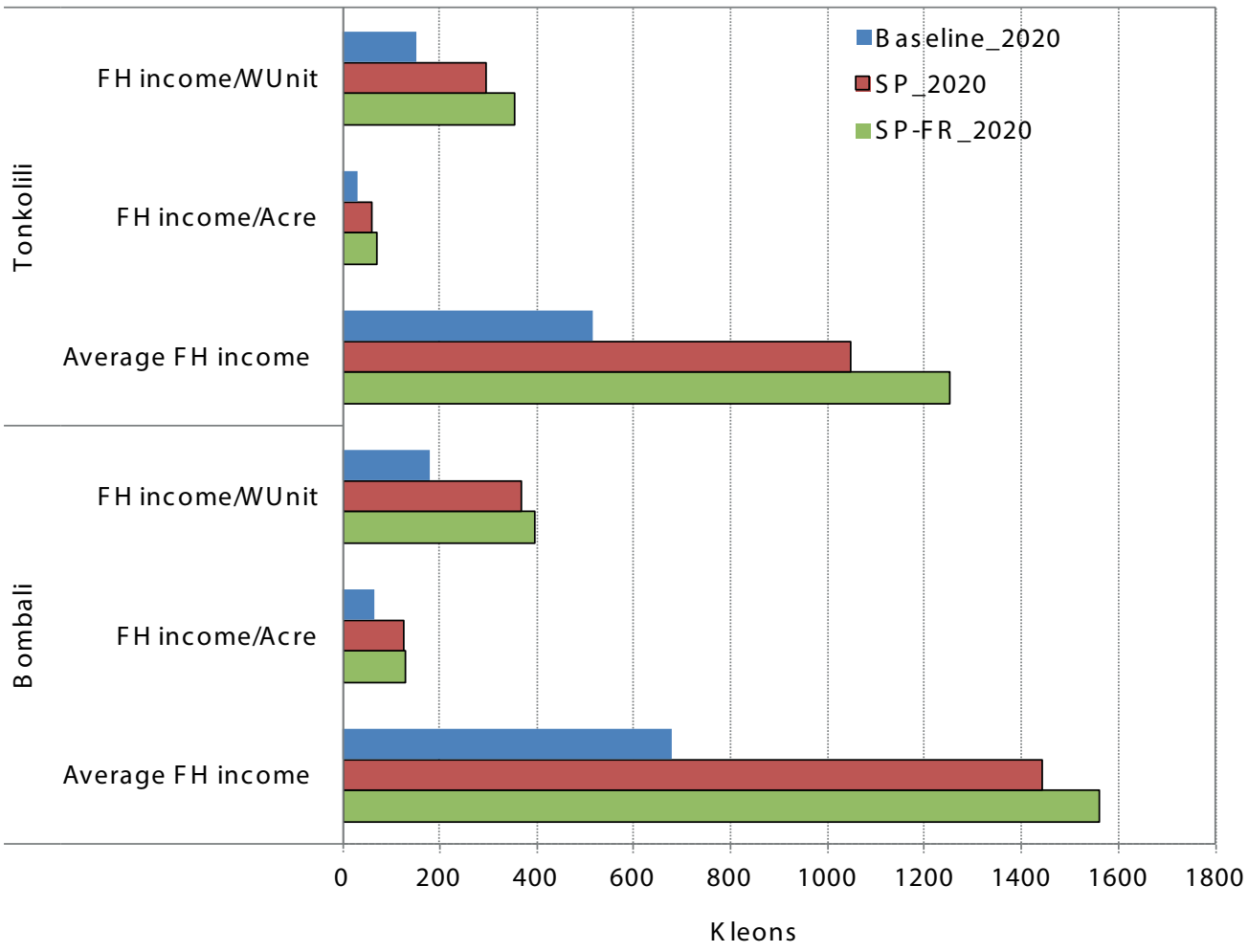
Figure 6.4. FSSIM-Dev: Northern region, Sierra Leone (2020)



Source: Louhichi and Gomez y Paloma, 2014

Figure 6.4 reveals a slight increase (SP_2020) in total acreage of rice, at the same time as a loss of acreage of fallow, cassava and sweet potato. On the other hand, for a policy of using high-quality rice seeds and reducing the number of years in fallow, it predicts an increase in rice area from 28 % to 33 %, a decrease in fallow from 54 % to 50 %, a small increase in the share of cassava (from 2.6 % to 2.9 %) and a decrease in the share of acreage allocated to other crops (from 3 % to 1.9 %). However, under all three scenarios (see Figure 6.4) the share land allocated to palm oil remains the same (11.9 %). The authors note that this increase in total acreage leads to an increase in total production and consumption of rice and other goods. The authors show, using model simulation (FSSIM-Dev), that by adopting high-quality rice seeds 25 % of farm households in northern Sierra Leone become net sellers of rice, 10 % become self-sufficient in rice and 17 % become net buyers of cassava.

Figure 6.5. FSSIM-Dev: Northern region, Sierra Leone (2020) - Viability Assessment



Source: Louhichi and Gomez y Paloma, 2014

Finally, Louhichi and Gomez y Paloma (2014) used two indicators to assess the economic impact of the simulated scenarios: farm income and poverty gap. The authors found that the seed policy, taken alone or combined with the fallow reduction scenario, boosted farm households' income and enhanced their food security but is not sufficient to fight poverty. Figure 6.5 shows that the average farm household income at the district level increases in both policy scenarios (SP_2020 and SP_FR_2020) by around 109 % and 136 % respectively. They found that the increase was higher in the Tonkolili district under the SP_FR_2020 scenario (143 %). Louhichi and Gomez y Paloma (2014) argue that the main reasons for the increase were an increase in rice production and a decrease in production costs due to seed subsidies.

Louhichi *et al.* (2015) reveal that they have already started a new project aiming to use an improved version of the FSSIM-Dev model to assess the impacts of relevant national and EU cooperation policies in a number of priority African countries: Ivory Coast, Niger, Ethiopia, Rwanda and Tanzania. Some of the data collection will be done by IPTS and in other cases they will use data from the World Bank's Living Standards Measurement Study — Integrated Surveys on Agriculture (LSMS-ISA).

7. Conclusion

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This chapter summarises the main lessons learnt during the workshop and outlines a group of recommendations for improving the food security of smallholder farms in developing countries, and in particular in sub-Saharan Africa (SSA). Given the high level of expertise of workshop participants, these lessons will be of great value for researchers, policy makers and stakeholders dealing with food security issues in SSA. These lessons are grouped into five categories following the number of sessions included in the workshop.

7.1 Role of smallholder farms in food security

Smallholder farms still lead agricultural production in developing countries, and are a key piece in any policy design aiming to improve food security and reduce the poverty gap. Despite their importance in agricultural development, the workshop highlighted that some small farms may not be able to contribute to growth. Farms facing hard constraints such as being located in high population-density or remote areas, being too small and/or facing unfavourable conditions (e.g. low rainfall, high temperatures and low soil quality) would not be able to achieve viable livelihoods and efficiency even if they adopted new technology. Such farms may be helped to exit farming through specifically designed social protection programmes. By contrast, smallholder farms facing soft constraints such as access to inputs, technology, credit and markets should be targeted by support policies to overcome some or all of these limitations.

As a first step to support smallholder farms, policies should basically promote land rights and land markets and ease access to markets. Improving access to markets entails an important effort, as it would include a mix of promoting diversification towards high-value farming products (those demanded by the market), improving post-harvest handling, and developing rural infrastructures and storage capacity. It is important to highlight that market access relates to both outputs and inputs, including improved production technologies.

Risk aversion of farmers in Africa is also a factor limiting their participation in markets. One potential way to palliate the effect of risk aversion is spreading market tools such as weather insurance or cooperative arrangements among farmers. Such instruments allow the risk that smallholders face to be reduced and consequently increase their participation in the market. Other potential non-agricultural measures are related to improving women's status or developing social protection programmes in rural areas.

Even if certain small farms (i.e. those facing soft constraints) may increase their marketed agricultural surpluses, this is not sufficient to feed the growing population. This is an important issue in urban areas where staple food is not increasing but diminishing. Food from larger farms or imports should then be the solution to feed the urban population, since structural transformation of smallholder farms is very slow and is expected to remain so in the foreseeable future.

7.2 Access of smallholder farms to agricultural inputs

Allowing smallholder farms to have a significant role in addressing food security requires easy access to input markets. There is evidence that, despite the growing adoption of improved seed by smallholders, there is still room for improvement. Improved recycling and storability make local seed more attractive than new varieties, showing the need to develop new seed adapted to real-world circumstances. Clear advances has been made in increasing the use of inorganic fertilisers, such as by targeted fertiliser subsidies, but there are some issues that limit their adoption by smallholders. Among others, one could highlight timing issues in distribution and application of fertiliser, limited supply of inputs, lack of small fertiliser packages or lack of credit to afford inputs. Last but not least, irrigation adoption remains limited in SSA because smallholders have difficulty building the infrastructures needed. However, irrigation must be viewed not in isolation as an initiative to increase yields but in combination with access to new seed varieties, inorganic fertiliser, pesticides and better soil management practices.

Promoting smallholders' adoption of technology requires overcoming a number of challenges. One of the main issues identified when analysing input use in SSA is that

smallholders do not have access to a complete technology package that includes all the individual inputs (i.e. improved seeds, inorganic fertiliser, pesticides and irrigation). Secondly, investments in technology require stable land tenure systems. Thus, land reforms seem to be necessary to motivate farmers to invest in their holdings. Finally, a debate on maintaining existing input subsidy programmes is still ongoing. Given their popularity, input subsidies are likely to continue in SSA even at the high costs some governments are facing. A number of initiatives can be adopted to make input subsidy programmes more cost-effective and sustainable, such as improving transparency, defining the goals of the programmes better or adopting holistic strategies such as linking fertiliser subsidies to adoption of soil fertility practices.

7.3 Smallholders' access to financial instruments

One of the constraints on smallholder's contribution to food security is the lack of access to finance. Formal financial instruments deal with implementation difficulties on both demand and supply sides. Supply-side issues are related to the high risks of African credit markets due to the problems of extension of formal banking, using insecure land tenure as collateral, high transaction costs or borrowers with no credit history. From the demand side, access to formal financial instruments is difficult for smallholders, in particular in rural areas, as a result of their financial illiteracy, the inconvenient timing of loan repayments (i.e. repayment is usually fixed for just after harvest, when output prices are lower) or farmers' high aversion to the risk of losing any asset. Lack of formal finance may imply that low-income farmers have difficulty gaining access to technology and consequently they cannot increase their yields and incomes (poverty trap).

A number of recommendations are given for policy makers to improve smallholder access to credit markets: (i) make collaterals for credit more flexible, using, for instance, crop inventories; (ii) establish credit bureaux to identify borrowers more easily; (iii) consider agricultural seasonality to set up a repayment period of loans; (iv) share risks between borrowers and lenders; (v) increase the participation of central banks in providing credit guarantees; and (vi) develop weather-based insurance in parallel with credit, to encourage farmers to take more risks.

7.4 Contribution of agriculture to reducing malnutrition

Smallholders contribute to global food security, and improving their performance also enhances the role of agriculture in reducing food insecurity and malnutrition in SSA. Despite the clear progress on hunger reduction worldwide in terms of caloric intake, limited progress has been made in reducing micronutrient malnutrition and deficiencies. Evidence suggests that growth in agricultural gross domestic product (GDP) contributes significantly to reducing mortality of children under the age of five in SSA. However, there is an ongoing debate on how agricultural GDP growth contributes to reducing under-nourishment and stunting of children under five. Some experts show that increases in per capita GDP reduces childhood stunting. However, whether or not agricultural GDP growth outperforms general GDP growth is debated. Some researchers support the view that the relationship between agricultural GDP growth and the reduction of under-nourishment is weak, and that there is almost no correspondence between agricultural GDP growth and diminution of stunting in children under five. The lack of consensus between researchers on the role of agricultural or more general economic growth on nutrition is far from being resolved, and seems to require more data to be tested.

Even if agriculture plays a limited role in improving malnutrition, it does not compromise the importance of the sector but reinforces the need to accompany agricultural policies with others such as education, sanitation and health programmes, women's empowerment, family-planning programmes, etc. Smallholder agriculture, in particular, may contribute to improving nutrition in basically three different ways: firstly, as a sector that may offer jobs to inhabitants of rural areas; secondly, by allowing people access to a variety of foods at a reasonable price, even in urban areas; and, finally, by adopting new bio-fortified varieties or crops with greater nutritional functional diversity.

7.5 Methods and tools for assessing food security at the micro level

How to measure food security has been a point of debate in recent years. The analysis is quite complex, since the multidimensionality of food security (food availability, food access, utilisation and stability) and the time span should be considered. The issue becomes even less clear if we want to measure nutritional quality when tackling food security.

The food availability dimension has been well analysed in the literature using two different approaches, the optimisation of smallholder's utility (ex ante) and econometric techniques (ex post). FSSIM-Dev is presented as a successful optimisation model to assess the potential impact of food-security-oriented policies on the livelihood of smallholdings in developing countries. This model, in contrast to others used in the literature, considers not only food availability (production) but consumption decisions, assuming the dual character of households as producers and consumer, the effects of transaction costs on markets, the heterogeneity of farm households, and crop rotations and resource use (land and labour).

The second dimension of food security, food access, has usually been assessed by estimating dietary energy supply per capita and country, individuals' dietary intake,

anthropometry indices, and food consumption or household dietary diversity scores.

The third dimension of food security, food stability, is difficult to measure, since it requires a long-run analysis that includes climate change effects on yields of staple crops, land use or prices. Some examples of models trying to integrate climate issues on a large scale are International model for policy analysis of agricultural commodities and trade (IMPACT) and Global Biosphere Management Model. Therefore, assessing food security requires a combination of measures to assess the four dimensions, for which the development of bio-economic models including climate change impacts seems to be a good solution.

Besides its impact on other dimensions discussed above, improving land tenure security is also crucial when analysing food and nutrition security. In SSA there are a number of issues to be solved to improve land security, since encroachment by neighbours, elite capture of lands, unclear land rights, state allocation of land to investors and state expropriation contribute to decreasing production efficiency. Better land markets also favour adoption of technology by smallholders, which can be a way to fight against adverse climate conditions such as droughts.

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Annex I. Agenda of the Workshop

Wednesday 9 September 2015		
14.00	Registration	
14.30-15.45	**Introduction to the workshop – Chaired by: John Bensted-Smith**	
14.30-14.45	Welcome and introduction to the workshop	John Bensted-Smith (JRC-IPTS)
14.45-15.10	Smallholder farms for Food and Nutrition Security: Challenges and opportunities	Sergio Gomez y Paloma (JRC-IPTS)
15.10-15.45	Food and nutrition security in developing countries	Prabhu L. Pingali (Cornell University)
15.45-16.45	**The role of Smallholder Farms in Food Security in Developing Countries – Chaired by: David Sahn**	
15.45-16.15	Importance of smallholder farms as a relevant strategy to increase food security	Peter B.R. Hazell (Independent consultant)
16.15-16.45	The contribution of subsistence farming to food security	Steve Wiggins (Overseas Development Institute)
16.45-17.00	Discussion	All participants
17.20-18.30	**The role of Smallholder Farms in Food Security in Developing Countries (cont.) – Chaired by: David Sahn**	
17.20-17.50	Role of smallholder farms in a changing world	Shenggen Fan (IFPRI)
17.50-18.20	Dependence of African policies on smallholder farms	Donald F. Larson (The World Bank)
18.20-18.45	Discussion	All participants
Thursday 10 September 2015		
09.30-10.50	**Access of Smallholder Farmers to Agricultural Inputs – Chaired by: Peter B.R. Hazell**	
09.30-09.50	Irrigation of smallholder agriculture in sub-Saharan Africa	Munir A. Hanjra (International Water Management Institute)
09.50-10.30	Access of smallholder farms to seeds and fertilizer use in sub-Saharan agriculture	Jacob Ricker-Gilbert (Purdue University)
10.30-10.50	Discussion	
11.20-13.20	**Smallholder Farmers' access to Financial Instruments – Chaired by: Ashok Mishra**	
11.20-11.40	Credit markets in Africa	Craig T. McIntosh (University of California, San Diego)
11.40-12.00	Availability and monitoring of agricultural credit	Wouter Gelade (University of Namur)
12.00-12.20	Farmer's access to agricultural inputs and finance	Augustine S. Langyintuo (International Finance Corporation)

12.20-12.40	Agricultural insurance in sub-Saharan Africa	François Kayitakire (JRC-IES)
12.40-13.00	Discussion	All participants
14.20-15.40	**Contribution of Agriculture to Reduction of Malnutrition – Chaired by: Steve Wiggins**	
14.20-14.40	Africa's food and nutrition security situation.	David E. Sahn (Cornell University)
14.40-15.00	Role of Agricultural growth in reducing child malnutrition	Sébastien Mary (De Paul University)
15.00-15.20	Nutritional diversity in changing food systems	Roseline Remans (Columbia University & Bioversity International)
15.20-15.40	Discussion	All participants
16.00-17.20	**Methods and Tools for Food Security Assessment at Micro-level – Chaired by: Jacob Ricker-Gilbert**	
16.00-16.20	Importance of modelling to assess the impact of smallholder farms in food security	Ashok Mishra (Arizona State University)
16.20-16.40	Policies for improved food security: lessons to learn from farm household studies	Stein H. Holden (Norwegian University)
16.40-17.00	Micro-level impacts of Food Security Oriented Policies in Africa (FSSIM-Dev)	Kamel Louhichi (JRC-IPTS)
17.00-17.20	Discussion	All participants

Annex II. List of Participants in the Workshop

External Participants			
FAN	Shenggen	International Food Policy Research Institute (IFPRI)	USA
GELADE	Wouter	University of Namur	Belgium
HANJRA	Munir A.	International Water Management Institute (IWMI)	South Africa
HAZELL	Peter	Independent consultant	USA
HOLDEN	Stein T.	Norwegian University of Life Sciences	Norway
LANGYINTUO	Augustine	Kenya Regional Office of the World Bank	Kenya
LARSON	Donald F.	World Bank	USA
MARY	Sébastien	DePaul University	USA
MCINTOSH	Craig	University of California, San Diego	USA
MISHRA	Ashok K.	Arizona State University	USA
PINGALI	Prabhu	Cornell University	USA
REMANS	Roseline	Columbia University & Bioversity International	Ethiopia
RICKER-GILBERT	Jacob	Purdue University	USA
SAHN	David E.	Cornell University	USA
VAN RHEENEN	Teunis	International Food Policy Research Institute (IFPRI)	USA
WIGGINS	Steve	Overseas Development Institute	United Kingdom
EC-JRC Participants			
BENSTED-SMITH	John	Institute for Prospective Technological Studies (IPTS) - European Commission (EC)-Joint Research Centre (JRC)	Spain
COLEN	Liesbeth	IPTS - EC- JRC	Spain
FERRARI	Emanuele	IPTS - EC- JRC	Spain
GARZÓN DELVAUX	P. Andrés	IPTS - EC- JRC	Spain
GOMEZ Y PALOMA	Sergio	IPTS - EC- JRC	Spain
KAYITAKIRE	François	Institute of Environment and Sustainability (IES) - EC- JRC	Italy
LOUHICHI	Kamel	IPTS - EC- JRC	Spain

M'BAREK	Robert	IPTS - EC- JRC	Spain
PROIETI	Ilaria	IPTS - EC- JRC	Spain
RIESGO	Laura	IPTS - EC- JRC	Spain
RONZON	Tevecia	IPTS - EC- JRC	Spain
TILLIE	Pascal	IPTS - EC- JRC	Spain

Annex III. Short biographies of participants in the workshop

Mr **John Bensted-Smith** has been working within the European Commission since 1983. He started in the Directorate-General for Agriculture followed by a short period in the Directorate-General for Development. In 1989–1992 he worked in the cabinet of Peter Schmidhuber, the commissioner responsible for the EU budget. In 1993–1994 he was in the Enlargement Task Force that negotiated the accession treaty for Austria, Finland, Sweden and Norway. From 1995 to 2000 he was in the cabinet of Franz Fischler, the commissioner responsible for agricultural policy and rural development. From 2000 to 2004 he was a Head of Unit in the Directorate-General for Agriculture. From 2004 to 2009 he was the director responsible for economic analysis, perspectives and evaluation. For a year he was then director responsible for bilateral international trade relations in agriculture. Since May 2010 he has been director of the European Commission's (EC) Institute of Prospective Technological Studies (IPTS) in the Joint Research Centre (JRC).

Dr **Shenggen Fan** has been director general of the International Food Policy Research Institute (IFPRI) since 2009. Dr Fan joined IFPRI in 1995 as a research fellow, conducting extensive research on pro-poor development strategies in Africa, Asia and the Middle East. He led IFPRI's programme on public investment before becoming the director of the institute's Development Strategy and Governance Division in 2005. He now serves as the vice-chair of the World Economic Forum's Global Agenda Council on Food and Nutrition Security, after serving as chair of the council from 2012 to 2014. In 2014, Dr Fan received the Hunger Hero Award from the World Food Programme in recognition of his commitment to and leadership in fighting hunger worldwide. Dr Fan received a PhD in applied economics from the University of Minnesota, and bachelor's and master's degrees from Nanjing Agricultural University in China.

Dr **Wouter Gelade** is a researcher in economics at the Centre of Research in the Economics of Development at the University of Namur, Belgium. His research interests include development economics, micro-finance and applied econometrics. Before working in Namur he obtained a PhD in computer science at the University of Hasselt, Belgium.

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Professor **Peter Hazell** grew up amongst small dairy farms in Yorkshire, England, and trained in agriculture and economics. His PhD degree is from Cornell University, USA. Peter spent much of his career in Washington, DC, working in various research positions at the World Bank and the International Food Policy Research Institute (IFPRI), including serving as director of the environment and production technology division (1992–2003) and the development strategy and governance division (2003–2005) of IFPRI. During 2005–2012, he was a visiting professor at the Centre for Environmental Policy, Imperial College London. Professor Hazell's extensive and widely cited publications include works on new methods of using mathematical programming to solve farm and agricultural sector planning problems; the impact of technological change on growth and poverty reduction; the appropriate role of agricultural insurance in developing countries; development of the rural non-farm economy; sustainable development strategies for marginal lands; and the role of agriculture and small farms in economic development. Professor Hazell has worked extensively throughout Africa, Asia, the Middle East and Central America, and is an elected fellow of the American and African Agricultural Economics Associations. He currently lives in Santa Barbara, California, where he struggles to balance a Californian lifestyle with independent consultancy work.

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