The Food Puzzle

Pathways to securing food for all

WAGENINGEN UR
For quality of life

The Food Puzzle

Pathways to securing food for all

WAGENINGEN UR

For quality of life

The research programme *Global Food Security: Scarcity and Transition*, also known as the Knowledge-base 1 programme, is designed to develop knowledge, expertise and methods that can underpin policy and action on agricultural development and food security. The research programme is organised around four main areas – Scarcity in the food system, geopolitics and global trade; Scenarios on sustainable food security; Governance to accelerate transitions; and Productivity, innovation, value chain development and institutions. Climate change, water and biodiversity are cross-cutting themes.

Led by LEI Wageningen UR, the research programme *Global Food Security: Scarcity and Transition* brings together the Wageningen UR institutes Alterra, Centre for Development Innovation (CDI), Livestock Research, Plant Research International and Applied Plant Research (PPO), in close collaboration with international and regional organisations, the private sector and local actors on the ground. The research programme was implemented in 2011 and comes to a close at the end of 2014. It is financed by the Ministry of Economic Affairs.

In the book, the programme is referred to as the research programme Global Food Security or the research programme.

Preface

For a transition to a food secure future, the world's food systems will need to deliver more nutritious food from fewer natural resources. The research programme *Global Food Security: Scarcity and Transition* has been contributing to this challenge by providing tools and knowledge that can underpin policy and action on agricultural development and food security.

The programme has been focussing on exploring the pathways that overcome trade-offs inherent in food systems. Raising agricultural productivity and resource use efficiency will not suffice. The scarcity of land and water resources has given rise to concerns about consumption patterns, waste and losses. Also, price instability originating from shocks to the food system – due to, for example, extreme weather, pests, and *ad hoc* policies – and unequal income growth, perpetuates food insecurity.

A set of targeted interventions will be needed to arrive at pathways for sustainable production and consumption. This requires a bottom-up perspective delivered by action and strategic research on an agenda for change that has a particular focus on Africa and Asia and the role of private sector activities in realising change.

We believe that the integration of these perspectives, a puzzle in itself, provides meaningful guidance towards decision-making on agricultural development and food security.

On behalf of the contributors, I would like to express our gratitude to our numerous international research partners and other stakeholders for their collaboration in this research, and to the Dutch Ministry of Economic Affairs for providing support and core funding for the research programme.

Thom Achterbosch

Coordinator,
Research programme *Global Food Security: Scarcity and Transition*

Contents

Introduction

This book is about the work that Wageningen University & Research centre (Wageningen UR) has been carrying out under the research programme, *Global Food Security: Scarcity and Transition (*also known as the Knowledge-base 1 programme). It tells a story about how multidisciplinary teams of scientists and action researchers have come together to better understand the global-to-local underlying processes that lead to food insecurity and how the agricultural domain can make the transition to a brighter future. One of the main intentions of the book is to raise awareness about the programme's projects, their results and implications for future action. The programme has served to strengthen the resolve and commitment of researchers within the specialised research institutes of Wageningen UR to work with the private sector, government and civil society in finding alternative pathways to enhancing food security.

The food and nutrition challenge: More sustainable production and consumption

Food is essential to the sustenance of life, but the world's food systems and natural resource base are under increasing strain to provide food for all. Food security exists 'when all people at all times have access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.' (World Food Summit 1996)[1]. It is very much linked to agricultural production as well as issues related to 'food access and use' (Wageningen UR 2013)[2]. Nutrition security refers to everyone having access to not only food, but also to health care and hygienic conditions.

For many people, having access to a safe nutritionally adequate diet on a daily basis is a challenge, making it difficult for them to lead active, healthy lives. Population growth, urbanisation, diet change, the pressure on the ecosystem and climate change are among the factors contributing to greater uncertainty about future food and nutrition security.

Food and nutrition security is therefore increasingly being addressed as a global public good, and needs to be supported for the sake of security and stability for the global population. An estimated 842 million people or 12 percent of the global population in 2011-2013 (FAO 2013)[3] suffer from chronic hunger, and 2 billion people around the globe suffer from malnutrition due to insufficient or unbalanced diets (IFPRI 2014)[4]. And although the global supply of food is sufficient to feed the population and significant gains have been made in tackling the hunger problem, considerable differences in the level of undernourished people across regions remain.

Flat-out famine is now largely confined to regions of conflict, as recently seen in Sudan and now in pockets of Syria. Most of the countries where the state of food and nutrition security is 'alarming' are in sub-Saharan Africa and South Asia, where protracted hunger crises occur and most of the world's undernourished people are found[5]. Sub-Saharan Africa has the highest level of undernourishment, with one in four people estimated to be undernourished. Sub-Saharan Africa is not expected to achieve the Millennium Development Goal (MDG) hunger target[6].

The broader food and nutrition challenges are not only confined to the developing world but also appear in high-income countries. The agricultural production base has expanded enormously over the past decades, but this has come at a human and environmental cost. Maintaining agri-food's beneficial services in the face of ever-changing economic, social, political and environmental conditions will be increasingly challenging.
Food access is not guaranteed for all consumers. An added complexity is the double burden of malnutrition, where paradoxically undernutrition coexists with the obesity epidemic[7]. Food quality and safety have sometimes been compromised, and environmental concerns have grown. Further, short-term food crises (e.g., due to extreme weather conditions or disease outbreaks) and geo-strategic positioning will appear more frequently in global markets, which will affect vulnerable food consumers and producers, partly through unbalanced trade rules that favour agricultural exporters.

Both developing and developed countries stand to gain if there is strong commitment and a willingness to work together towards developing a food system that supports more sustainable production and consumption.

Scarcity: A wake up call?

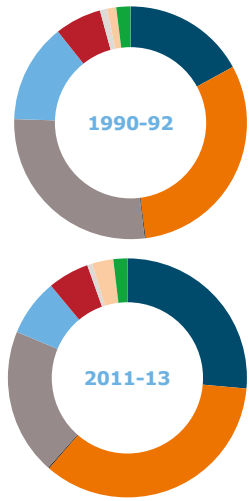
Many decision-makers are now aware of the fact that agriculture needs a strong push towards greater productivity. The most advocated pathway

Table 1 The changing distribution of hunger in the world

Number and prevalence of undernourished by region, 1990-92 and 2011-13

	Number (millions)		Prevalence (%)	
	1990-92	2011-13	1990-92	2011-13
Sub Saharan Africa	173	223	32.7	24.8
Southern Asia	314	295	25.7	16.8
Oceania	1	1	13.5	12.1
Eastern Asia	279	167	22.2	11.4
South-Eastern Asia	140	65	31.1	10.7
Latin America and the Caribbean	66	47	14.7	7.9
Caucasus and Central Asia	10	6	14.2	7.0
Western Asia and Northern Africa	13	24	5.1	6.3
Developed regions	20	16	1.7	1.3
Total	**1015**	**842**	**18.9**	**12.0**

Source: FAO, IFAD and WFP (2013) State of food insecurity in the world. Rome: FAO



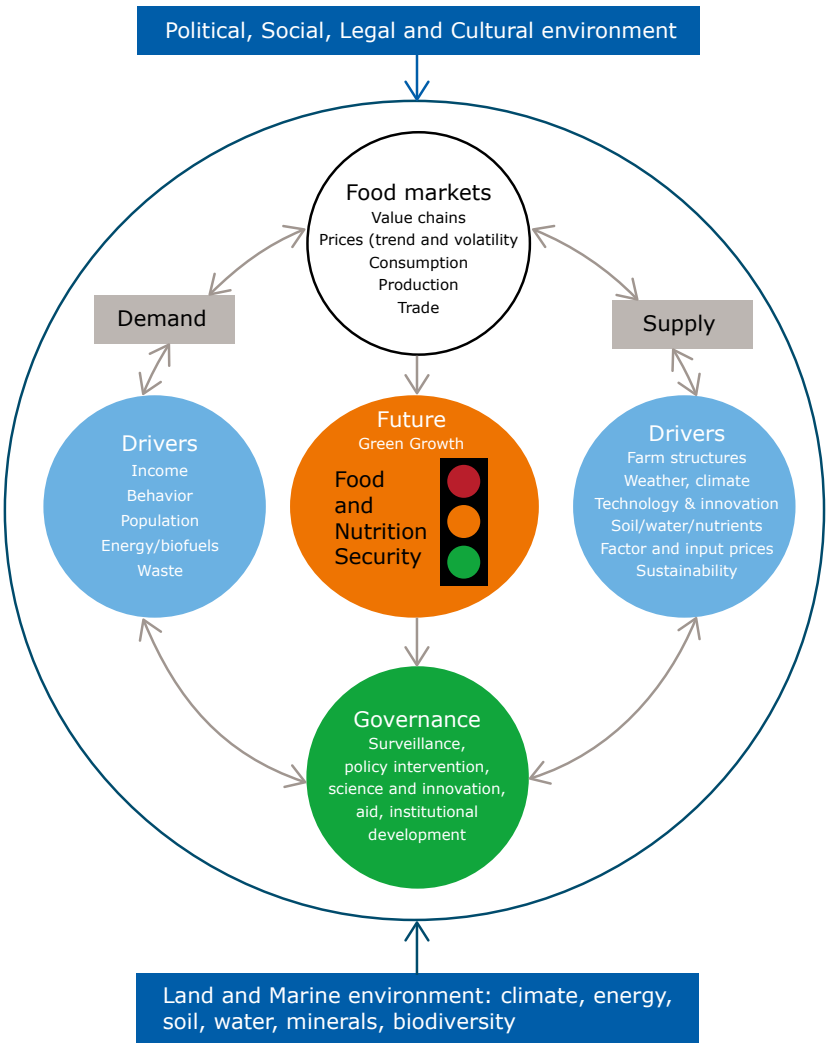


Figure 1 The broader picture

Source: Based on the FOODSECURE project

is to improve resource efficiency without increasing land area used for agriculture. This requires devising creative ways to make use of the available resources without depleting them or disrupting higher scale natural processes. A wide range of innovations will be required for a sustainable production base and for food systems to support adequate food consumption. The rising probability of market shocks may lead trading nations like the Netherlands to take action to pre-empt the risk of discontinuities in global sourcing. Sustained efforts are needed from policy-makers and the private sector to address agriculture's role in today's nexus around food security and scarcity.

Annual growth in demand for food, in terms of calories, is expected in the range of 1-2% per year until 2050 – quite comparable or even lower than what has been experienced over the past four decades (van Ittersum 2011[8]; Alexandratos and Bruinsma 2012[9]). But food systems have become very dynamic, and this adds to the challenge of sustaining the output growth that is required to meet the expanding demand. Factors affecting the demand have to do with population growth, rising affluence and changing consumption patterns, including the call for convenience or processed foods. On the production side, farmers face problems such as low productivity, extreme weather conditions, poor market access, missing markets for farm inputs, land and environmental degradation. Poverty and food insecurity have become deep-seated problems in developing countries, contributing factors include, soil depletion, nutrition insecurity, food losses and waste, and the ambiguous role of policies, land and environmental degradation, the land grab problem, climate change and the growing demand for renewable energy and biofuels. Figure 1 shows how some of these factors are inter-related.

Food prices
World food markets are increasingly interconnected, and shocks ripple swiftly through the system. For example, political instability in Ukraine, the third largest exporter of wheat, has brought some measure of uncertainty to the world's cereal markets, resulting in raised feed costs for Dutch livestock. Commodity prices have also increased, compounded by the fact that some agricultural crops are being used as a source of energy. So, in general, food prices have become more volatile. The recurrence of high prices of staple crops over the last decade have, in part, been responsible for social unrest and riots across the globe – most notably in North Africa where some autocratic governments have been toppled, giving rise to the so-called *Arab Spring*.

Land and environmental degradation
Since the middle of the 20th century, agricultural intensification with land-saving technologies has been the main engine of the growth in global farm output – between 1955 and 2005, arable land increased by around 15% whereas agricultural production tripled[10]. This has come at some cost to the environment – there is substantial degradation of land resources in many parts of the world – increasing desertification, soil erosion, salinisation and waterlogging serve to limit land productivity. Despite higher yields on land, there has been wide-scale clearing of forests over the last 40 years to make way for large, industrialised farms, which have led to a loss of biodiversity.

Land and water grabbing
While investments in agriculture are needed, large-scale acquisition of prime agricultural lands by foreign investors particularly in Africa and South America is expected to adversely affect agricultural production and food security. Land and water grabbing is a reaction to ever increasing scarcity and it is a way in which countries, communities and corporations try to secure raw materials. This is generally at the expense of local populations and small farmers who can be displaced and forced on to marginal lands to eke out a living. Strengthened land tenure systems are required, along with more comprehensive investment and research and development (R&D) policies based on local development needs. Improved governance mechanisms for natural resources will be required to address trade-offs, for example, landscape management has emerged as a new platform to address the trade-offs in public and private interests around land and water resources.

Climate change
Climate change is visible in the form of widening fluctuations in temperature and rainfall patterns. These changes are expected to hamper development processes and increase the vulnerability of already marginalised people and regions. The recent assessment report by Working Group II of the Intergovernmental Panel on Climate Change states that climate change is a threat to global food stocks, human security and will affect all sectors, regions

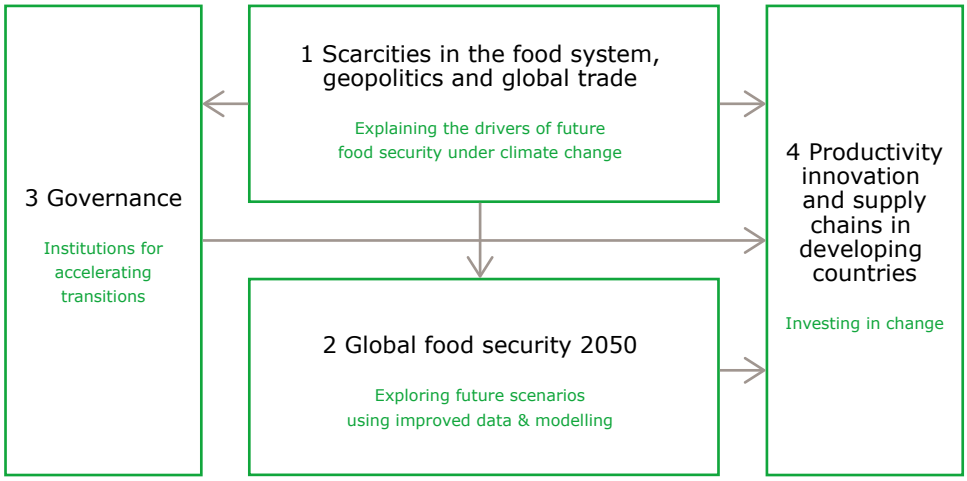


Figure 2 Global food security: Scarcity and transition research programme

and people. In Africa, the adaptive capacity of climate-sensitive sectors such as agriculture and fisheries is considered low, because of limited access to finance, knowledge, technology, and governance setting. More data and analysis are needed to examine the vulnerability of African regions and communities. Adapting to these changing conditions is inevitable. A climate-smart agriculture, combining food security and climate change goals, will be essential for future food security.

The bio-based economy

Developing bio-based economies or 'greener' economies based on bio-mass as the main raw material seems to be a plausible, even strategic alternative. According the EU's Research and Innovation and Science Commissioner, the bio-economy in the EU is worth Euro 2 trillion, and has already created 22 million jobs[11]. Nevertheless, big questions remain about the sustainability of this alternative, particularly regarding biofuels because of the large tracts of agricultural land used to grow crops for the non-food sector, and the increased pressure on land markets and forest resources that is associated with producing sugar or palm oil as a biofuel feedstock.

Urbanisation

UN projections suggest that the world's urban population will grow by more than 10 billion between 2010 and 2025, while the rural population will hardly grow at all[12]. Although the rates of urbanisation slowed down in most sub-regions of the world during the 1990s, and most metropolitan areas have not shown the expansion that was expected some decades ago, the majority of world's population is now urban. Urbanisation creates challenges for food supply because urban consumers typically consume less uniform diets and more processed food products. Also, the provision of safe and nutritious food into cities will often push transformations within the food distribution and marketing systems, and contribute to rising supermarkets and modern supply chains. Particular attention is required to ensure that local producers can benefit from the emerging market outlets.

Making the transition to a more food secure world

Although the challenges seem almost overwhelming, there is now an immense global effort involving national governments and the international community to support the agricultural sector. Following the food price hikes of 2007-2008 and 2011-2012, food security is increasingly being addressed as a global public good, which supports security and stability for the global population. The Committee on Food Security has been strengthened, and an agricultural monitoring and information system (AMIS) is now in place for greater market transparency in the face of volatile food prices and guidelines for responsible investment in land and agriculture have been tabled. There is also a renewed sense of commitment and considerable financial support has been made available to develop the sector. Concrete agreements like the Aquila Food Security Initiative (AFSI)[13] to address hunger and poverty, endorsed by 27 countries and 15 international organisations at the G8 Summit in 2009 and the Comprehensive Africa Agriculture Development Programme (CAADP)/ New Partnership for Africa's Development (NEPAD)[14] where several African governments agreed to set aside at least 10 percent of public funds to develop the agriculture sector are important steps in the right direction.

UN estimates call for an average annual net investment of US$83 billion to support expanded agricultural output in developing countries, an amount equivalent to double the current development assistance.[15] Donor governments (including the Netherlands) and governments in developing countries have focused more on leveraging investments from private companies. The private sector sector is consistently regarded a critical player in the shift from subsistence agricultural activities toward well-functioning commercial systems, where farmers can afford needed inputs and reach cash markets.[16] Private-sector engagement is also essential for 'scaling up' government-financed development projects, and for sustaining these projects after government funding is reduced or withdrawn. It has been suggested by the World Wildlife Fund that a mere 300 to 500 companies control 70% of food supply for the world's 7 billion consumers, which makes these companies major agents for change in the food system. Several companies, in particular the leading food and beverage corporations, have pledged their commitment to smallholder inclusion, sustainable sourcing and the strengthening of rural economies.

In the Netherlands, food security has become a spearhead of international cooperation in the agri-food, horticulture and propagation materials sectors and in development policy – this is intricately linked to the position the country holds as a key player in world markets, as exporter, importer and innovator. The Dutch government is therefore keen to promote a 'safe and stable world characterized by fair international relationships' (HCSS 2013)[17], by supporting global frameworks for agricultural investments, climate change and agriculture, and strengthening governance at various levels (e.g., the chairmanship of the Committee on Food Security and the various round tables for sustainable production).

In addition, the Dutch government has been facilitating companies that want to invest in agricultural development through its Private Sector Investment programme (PSI), Food Security and Sustainable Development Fund (FDOV) and its Dutch Good Growth Fund (DGGF), and its support to the Global Agriculture and Food Security Program (GAFSP) of the World Bank. Bilateral programmes on food security have been launched with China, Indonesia, Vietnam and several other countries. Through the Sustainable Trade Initiative, the government facilitates sustainable sourcing of agricultural commodities.

One particular way that the Dutch government has been strengthening food security is through the development of a knowledge environment to support decision- and policy-making in this area. For example, the government has been spearheading knowledge themes: climate smart agriculture, research alliance for greenhouse gas emissions, and the Oceans for food security conference. Substantial knowledge investments, particularly in the Consultative Group on International Agricultural Research (CGIAR), have also been made. Some of the knowledge challenges to support this transition pathway include how to: raise farm production while reducing the ecological footprint, maintain ecosystem services, develop climate-smart food systems, effectively promote good governance on the competition for scarce resources, upgrade smallholder farming systems and support innovation and upscaling successes in value chains.

The food puzzle: Finding solutions

The *Global Food Security: Scarcity and Transition* research programme, with the support of the Dutch Ministry of Economic Affairs, has been grappling with these food security issues and has been working on providing decision- and policy-makers with the 'right' tools and knowledge based on quality-assessed data to make sound decisions and formulate evidence-based policies. A primary concern of the programme has been the development of knowledge, expertise and methods that can underpin policy and action that can contribute to agricultural development and the finding of solutions to food and nutrition security. More specifically, the programme is contributing to the understanding of complexities and it is helping to make a more specific agenda for action. Special attention is being paid to countries in Africa and the role that the Dutch agri-food and horticulture sector can play in developing the agricultural sector in these countries.

The research programme comprises four main areas, focussing on concepts and theory, monitoring and data systems, and methods and modelling tools for foresight (Figure 2). One area explores geopolitical dynamics of scarce resources and climate change and how this impacts on global trade and the food system. The insights gained here support the work being carried out under Global food security 2050, where the focus is on developing an integrated framework to quantify scenarios as well as evaluate the potential effects of policies on food security.

The research programme also examines governance mechanisms aimed at improving the understanding of institutions and mechanisms for decision-making on innovation in agricultural supply chains and the upscaling of successful initiatives. The fourth area of focus has a strong international dimension, and examines agricultural production in developing countries, in particular. Key questions include: how can sustainable production systems be developed and maintained, what place is there for innovation and how to strengthen supply chains. Running themes throughout the research programme are learning and participation to support the establishment of a strong network.

An important aspect of the research programme Global Food Security is that it positions the food security debate in a unique way, where research groups form strategic alliances with the government, the private sector and local communities (in some cases) and can discuss and exchange ideas and collaborate closely in a public-private partnership (PPP). Crosscutting themes on biodiversity, climate change, and institutional change foster a multidisciplinary approach, and contribute to the understanding of complexities that can help shape transition and the creation of impact pathways to a more food secure world.

Putting the pieces together: The success stories

A concept that underpins the programme is the bringing together of science, action research and stakeholder participation to create the evidence-base for transition and change needed to solve the many food puzzles. Some of the flagship projects under the programme are briefly highlighted.

FOODSECURE addresses the question of future pathways for food and nutrition security and the role of policy in general and EU policy strategies, in particular. *More food on smaller foot* establishes sustainability thresholds for green growth with entrepreneurs in the Limpopo river basin in Southern Africa, and supports the Africa Union's CAADP agenda on agricultural development. In *Innovations and scaling*, Wageningen UR staff worked with farmers and entrepreneurs to gain valuable insights into how and when innovations can be stimulated and scaled. Each of these research efforts builds strongly on the knowledge support of the interdisciplinary research programme.

Partnerships are essential to the programme. Strong consortia have been established with other centres of excellence, particularly to work on European-funded projects. This has meant that research meets the highest standards, and that key research results are disseminated in the wider research and policy community. Programme results feed, for example, into other programmes such as the Water Agenda in Agriculture, which also dovetails into the CAADP agenda. The ability to connect different players along the knowledge is a major strength of the research programme, which has resulted in multiple public-private partnerships. Two examples illustrate this – the interest generated by the private sector and farmers in the vegetable seed project in Tanzania and partnership with Friesland Campina on the expansion of local sourcing of good quality milk in Africa and Asia, which required critical information from the programme on strengthening the services in the value chain. Other public-private partnerships under the Netherlands-African Business Council and under FDOV also benefitted from the research programme's ability to link the understanding of scientific concepts and evidence, and technical content with institutional processes.

Future action

The impact of the Global Food Security research programme is captured by the following vision:

To build the cooperation and the knowledge base that will help establish Wageningen UR as a knowledge partner in connecting global players to those at the local level, by linking basic science with action-oriented work and connecting technical work with economics and sociology – it's in the combination that Wageningen UR is strong.

Much work still remains to be done. The momentum gained from the multidisciplinary approach taken by the programme to address the many issues should be kept alive to ensure the continuation of the research agenda. Concepts and advances made by the *Global Food Security: Scarcity and Transition* programme have already had spin-off effects in terms of attracting funds for new projects under various investment facilities and subsidy programmes (e.g., the Netherlands Organisation for Scientific Research (NWO) and Horizon 2020). The scientists, action researchers and programme management team welcome the opportunity to continue collaboration with their funders, the private sector, and research community for solving the many food puzzles.

About the book

Knowledge Contributions to Solving the Food Puzzle represents an intense process of collaboration with a wide range of stakeholders. Seventeen chapters are presented under four themes. Individual chapters can be the result of more than one project. They also reflect an exciting mix of action and strategic research, which have spawned a range of perspectives and added rigour to the research. It is also important to note that some of the results presented are based on case studies, which have been used for learning and developing a conceptual framework. In other chapters, case studies have been used to test the methodologies developed. There is also an additional chapter on *Policy and partnerships* highlighting the networking role of the programme. A list of references is provided at the back of the book.

The book is aimed at all those concerned with food and nutrition security. The chapters are written in such a way so as to make them accessible to a wide range of stakeholders: funders, decision- and policy-makers, researchers and development practitioners. Each chapter can be read independently.

1 Source: www.climatechange2013.org/images/uploads/WGI_AR5_SPM_brochure.pdf
2 Wageningen UR (2013) *Food for All:Sustainable Nutrition Security.* Wageningen UR, Wageningen, The Netherlands
3 FAO, IFAD and WFP (2013) *The State of Food Insecurity in the World. The multiple dimensions of poverty.* Rome, FAO
4 Source: www.ifpri.org/pressrelease/ifpri-s-2013-global-food-policy-report-ending-hunger-and-undernutrition-2025-must-be-to
5 Based on the Global Hunger Index over 2012, an index that combines annual data on energy intake levels with long-term health outcomes that are heavily influenced by nutrition and public health standards. GHI is produced by the International Food Policy Research Institute (IFPRI), Concern Worldwide, and Welthungerhilfe
6 Source: www.wfuna.org/mdg-end-poverty
7 WHO: www.who.int/nutrition/topics/obesity/en
8 Ittersum, M.K. van (2011) Future harvest : The fine line between myopia and utopia. library.wur.nl/WebQuery/wurpubs/406495
9 Alexandratos, N., and Bruinsma, J. (2012) World agriculture towards 2030/2050: The 2012 revision. ESA Working paper No.12–03. Rome, FAO.
10 Source: Schmitz, C., Meijl, H. van, Kyle, P., Nelson, G. C., Fujimori, S., Gurgel, A., Havlik, P., et al. (2013) Land-use change trajectories up to 2050: Insights from a global agro-economic model comparison. *Agricultural Economics*, 45 (1) 64–84
11 European Commission- see:horizon-magazine.eu/E%20article/bioeconomy-new-revolution_en.html
12 Satterthwaite, D., McGranahan, G., and Tacoli, C. Urbanization and its implications for food and farming (2010) *Philosophical Transactions of the Royal Society B: Biological Sciences* 365 (1554): 2809–20. doi:10.1098/rstb.2010.0136.
13 Source: www.fao.org/investment/othercollaboration/the-aquila-food-security-initiative/en
14 Source: www.fao.org/investment/othercollaboration/the-aquila-food-security-initiative/en
15 UNCTAD, World Investment Report 2009. www.thechicagocouncil.org/UserFiles/File/GlobalAgDevelopment/Report/CCGA%20GADI%20Private%20Sector%20Policy%20Paper%20FINAL%20VERSION.pdf
16 Leveraging Private Sector Investment in Developing Country Agrifood Systems By Charlotte Hebebrand, May 2011, Study commissioned by the Global Agricultural Development Initiative
17 Source: HCSS 2013 - http://www.wageningenur.nl/upload)_mm/5/b/a/8c8a9685-df39-4e6e-a1e1-e9d1d1591a04_The%20Emerging%20Geopolitics%20of%20Food%20%285%20-%20final%29%20%283%29.pdf

Contributors
Thom Achterbosch *thom.achterbosch@wur.nl*
Karen Batjes
Jan Verhagen

1

Geopolitical dynamics of scarce resources

The recurring food price hikes in recent years, continued prevalence of malnutrition, increasing scarcity of natural resources and stagnating levels of productivity growth in agriculture have brought agriculture and food security to the stage of global decision-making. A common effort is required to make the transition to a food system that provides everyone with access to nutritious food and where farming and consumption are done on a sustainable basis, ecosystem services are maintained and supported by effective governance of competitive resources, food and commodity markets are stable and there are policies in place to sustain food security pathways. Building up a multi-disciplinary evidence-base on the scarcity of resources and their geopolitical dynamics will help support this transition.

Global trade or regional cooperation: A perspective from the Nile

In the period 2007-2008, failed harvests in two major grain exporting nations, the United States and Russia, stoked fears of an era of increasing global food insecurity. Work done under the research programme Global Food Security demonstrated that the political rationale of major grain exporters has been to impose restrictions on the exports of their wheat stocks to import-dependent regions whenever there is a rise in food prices (Rutten et al., 2013); in times of food scarcity, trade rules become biased towards the interests of exporting regions (Bureau 2013). As a result, delivery contracts for grain were breached and the food security situation in developing countries was severely affected. Sharp increases in staple food prices contributed to civil unrest and the toppling of regimes in the Middle East and North Africa.

One of the countries in the midst of all this turmoil was Egypt, a country with a burgeoning population, highly dependent on the Nile for its very existence. Despite, its geographic location and history, its set of options is very similar to those of other developing countries – cling to an increasingly unrealistic food self-sufficiency paradigm, remain dependent on global grain markets or strengthen its regional cooperation with countries affected in part by conflict. The possibility for strengthening regional cooperation with other countries in the Basin in order to promote a greater level of regional self-sufficiency is explored in this chapter.

The Nile Basin – looking for solutions

Historically, Egypt's food security and the Nile have been inextricably linked – low flows have meant meagre years, while high flows have led to times of abundance. The building of the Aswan High Dam has decreased river fluctuations, but with all of the downstream flow fully utilised, the fear of future structural shortages remains. Upstream of the Dam, the situation is different – in large parts of the Basin, there is abundant, though irregular, rainfall during most of the growing season. Here, the Nile was first of all a meandering river, carrying off excess water, rather than as a source of irrigation water.

Figure 1 Map showing the Nile Basin countries

Shifting political influence, increasing economic clout of countries upstream and growing populations are, however, rapidly changing the status quo. With more food needed, upstream countries are increasingly keen to utilise the waters of the Nile for hydropower and food production (Waterbury 2002). The tension this creates has even led to concerns about the threat of 'water wars' in the future. But is the traditional way of thinking about the Nile, as the sole source of food security for riparian countries, still valid? Why is there so much focus on 80 km^3 of Nile water, when in fact the Basin receives 2,000 km^3 of water per year in the form of rain? Is it possible that there are other solutions to a food secure future for the Basin and countries like Egypt?

It is against this backdrop that scientists at Wageningen UR developed a novel approach to assess where and how food production can be increased in the Basin and whether food self-sufficiency can be realistically achieved by 2025. With WaterWise, a hydro-economic model developed by Wageningen UR that integrates yields from both rainfed and irrigated agriculture in combination with the yield from hydropower, they explored various food self-sufficiency and regional cooperation scenarios for the Basin. The scenarios included the possibility for: national food self-sufficiency, upstream countries (Sudan, Ethiopia) developing their irrigated agriculture potential to the maximum, and regional cooperation where food and hydropower are produced where it is most cost effective. The model consists of three modules on water flows, crop production and hydropower and an optimisation routine to select the most suitable land use and hydropower options, given a certain level of investment. The latest FAO data on soils, land use and crop production, including the costs and benefits of each crop production type, were used to calibrate and validate the model.

Results clearly show that self-sufficiency is not an option for countries like Egypt and Rwanda (Table 1), but that future food security within the Nile Basin is possible if countries cooperate with each other. The researchers found that the key to solving the Basin's food puzzle lies in the development of climate-smart rainfed agriculture (defined as developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change (FAO 2013)) in the south – in the now war-torn regions of South Sudan and northern Uganda. Here, the potential for the much needed increase in food production is still considerable. Expansion of large-scale irrigation systems upstream, on the other hand, would mostly shift production between countries rather than increase the total production of the Basin and reduce, at the same time, total hydropower production.

Table 1 Food production as a percentage of required production under three scenarios

	National Food Self-Sufficiency	Upstream Hegemony	Regional Basin Cooperation
Egypt	85%	57%	78%
Ethiopia	100%	80%	80%
Sudan	100%	237%	223%
Uganda	100%	111%	111%
Other (including Rwanda)	66%	96%	98%
Basin	92%	103%	107%

Challenges: Regional cooperation or global dependence

If the scenario of regional cooperation were to materialise, it would require a new level of cooperation and integration of the economies within the Basin, to make the most of the comparative advantage of individual countries. It would mean that South Sudan and the Equatorial Lake regions would focus on producing food, Ethiopia would generate hydropower, while Egypt would provide agro-industry capital and access to urban markets in Egypt itself and in Europe, Russia and the Middle East. The integration of energy grids shows that cooperation in the region is possible, although for food more effort would be required, such as the revival of old trading routes via rail, road and river, the removal of trade restrictions and, probably most importantly, the building up of trust.

Nile barge transporting food

Despite all the immediate challenges, mistrust and misconceptions – strengthening regional production and cooperation among the Nile Basin countries is a way forward that will allow for diversification and reduce dependency on volatile global food markets, lessening the exposure to global food price hikes. But regional cooperation alone is not the solution; a reliance on regional production implies a vulnerability to regional climate extremes. Even though the Nile Basin is vast and diverse in climate, droughts or floods are likely to affect food production in parts of the Basin simultaneously. And countries like Egypt will become exposed to regular, but smaller, regional water and food scarcity shocks. However, during such periods of scarcity, the region would still have a safety net, the global market. If the region were to rely on the global market in the first place, it would mean that the safety net would no longer exist.

This study showed the possibilities and limitations of a first set of scenarios under current climate conditions. The optimum balance and mix between local, regional and global cooperation, self-sufficiency and dependency – especially within the context of an uncertain future involving climate change – will need to be explored further.

Contributors
Christian Siderius *christian.siderius@wur.nl*
Robert Smit
Thom Achterbosch

The balance between short-sightedness and utopian thinking

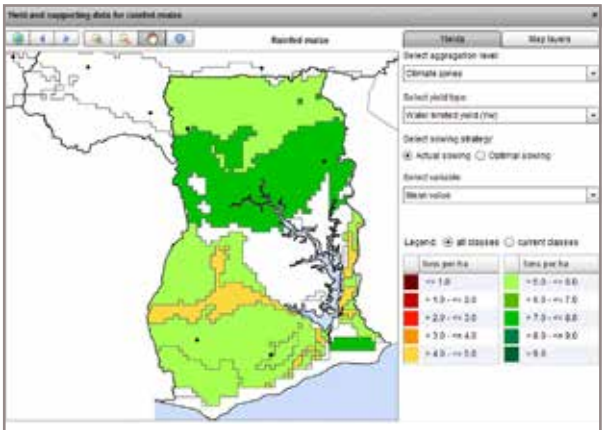
Perhaps the main reason why food provision is so high on the agenda today is that the world allowed itself to be lulled into complacency by the successes of the 1990s. Food prices were falling and, apart from some environmental problems, no clouds seemed to be on the horizon. Confident that we could feed a growing world population, agricultural innovation was neglected – a mistake that has been haunting us ever since.

The fairly dramatic price increases, especially of grain, between 2007 and 2008 were a wake-up call. The cost of food as a proportion of daily expenses had been decreasing for half a century but this might be coming to an end. This is not an acute problem for the Western world, which barely felt the increase in its disposable income. For people with limited purchasing power and an unbalanced diet, however, the price rises came as a hard blow.

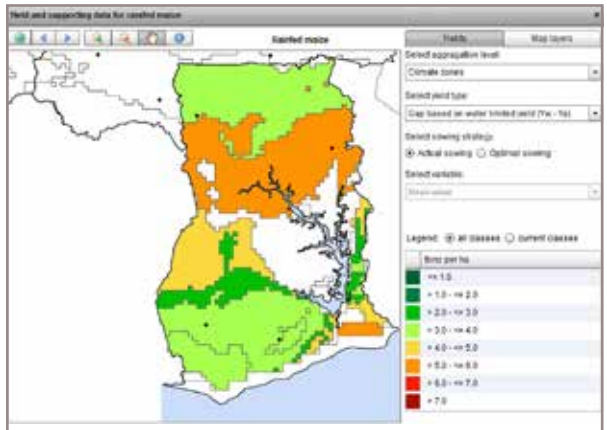
According to Martin van Ittersum, professor of plant production systems, the global agricultural system is undergoing a paradigm shift. Stagnating production growth, a rising world population, increasingly protein-rich diets, the development of biofuels, weather extremes as a possible harbinger of climate change, and market liberalisation are all current issues which require a response from politicians, industry and scientists. To call only for intensification of cultivation and a new green revolution is short-sighted and inadequate for tackling such a nexus of problems.

Based on a scientific perspective, Van Ittersum focuses on the difference between potential and actual farm yield, the so-called yield gap. How can we benefit from the growth potential of a plant? How high a yield is theoretically feasible in a given situation? What are the causes of the yield gap? How do we deal with the finiteness of certain inputs, such as phosphate? And how do we stay within ecological limits in the long term?

The crucial biophysical factors are nutrients, crop protection and the availability of water. In the Netherlands, a proper alignment of these factors since the 1960s has allowed a doubling of yield per hectare. In Asia, too, rice yields have increased substantially. In the Netherlands, new varieties combined with nutrients and crop protection were



The simulated water-limited yields



The yield gap (difference between water-limited and actual yields

behind this success, while, in Asia, it was mostly water and nutrients in combination with the new varieties. Nutrients will be the initial focus in closing the yield gaps in Africa.

Yield gap atlas

Van Ittersum is currently charting production possibilities and local shortcomings in a global yield gap atlas as part of an international programme funded by the Bill and Melinda Gates Foundation, among others. The first studies are already showing major differences: Relatively small yield gaps in the EU and Southeast Asia and large ones in sub-Saharan Africa and Eastern Europe. The studies conducted so far bring practical insights to light. For example, the yield gap in two rice exporting countries – Thailand and Vietnam – was found to be lower than in two other countries – Indonesia and the Philippines – which produce mainly for the domestic market. It was also found that the 'better' farmers had a lower yield gap, while using less fertiliser and labour per kilogram of rice. In two of these countries, such farmers had spent longer in school. Knowledge seems to be an important factor here.

Van Ittersum's research group also looked at the phosphate question, a concern because the mineral is both indispensable and finite. The picture seems less dramatic than many forecasted, however, in part thanks to the 'waste' of the past. The excess phosphate applied in a number of places actually formed a stock in the soil that can be made available in the future. In some places, particularly in Western Europe and parts of Asia, substantial replenishment will occur from the soil over the coming decades. The additional phosphate required may be less than the projected growth of food demand by 60%.

Tailored solutions

There is a general conclusion that Van Ittersum feels he can already draw from the current studies: To tackle the global food problem, solutions will need to be carefully tailored to local conditions. Intensification of agriculture, in the sense of more inputs achieving higher yields, will not be an end in itself. For a sustainably higher and more efficient production in some situations, including in the Netherlands, a more economical and precise use ofinputs may be an answer. In Africa, intensification will still be the solution to the yield gaps, but always in a way that is adapted to the local conditions.

To close yield gaps, technological solutions must go hand in hand with lifting social and economic constraints. This includes rights to land and to land use, critical infrastructure, and links to the world market for food and raw materials. Science can contribute to integrated studies in this field which map the whole range of problems and opportunities: Conversion from plant to animal, collective dietary patterns, or food waste – from post-harvest losses due to poor harvesting techniques and rot during storage, to preventing disposal and damage in the retail sector and by consumers.

In order to expand the opportunities for integrated research into farming systems and yield gaps, more than 150 scientists from around the world have been involved in the interdisciplinary research project SEAMLESS over the past years. This project developed research tools in several fields of science – agronomy, economics, environment, social science and IT – which can be used on different scales – on the level of the field, farm, region, country and world. SEAMLESS has ensured that the scientists can better understand each other in conceptual terms, allowing them to work together on solutions for the short and long term.

Food prices

In his research, Van Ittersum examined the delicate balance between short-sightedness (myopia) and idealised solutions (utopia). The myopic view focuses too much on food prices today: At the end of the last century they were low and lulled us into complacency; now they are high and a lot of new land is being reclaimed as part of a short-term solution to a long-term problem. Ideals such as organic agriculture can also lead to suboptimal solutions. The research programme is looking for forms of agriculture that score well on as many important factors as possible. Local sensitivity to the solutions is integrated in the research. How much of each input in terms of phosphate, crop protection and the like is actually needed? How does organic farming compare to the traditional approach? Can we invent biofuels that provide both a good energy output and profits to small-scale farmers without expanding acreage? These are all tricky questions, where the answer always must be sought at different scales and not lost in generalisations. Van Ittersum always strives to quantify the difference in yield and input use at the system level and illustrates this with both figures and maps.

Contributors
Martin van Ittersum *martin.vanittersum@wur.nl*

A global spatial framework for agricultural productivity

Burgeoning populations, changing diets and an upcoming bio-based economy have led to concerns that the world's food production system will be unable to cope by 2050 (Ray et al., 2013). Questions arise as to where we can produce crops most efficiently, in sufficient quantities and how we should go about doing this without jeopardising our biodiversity and the limited resource base that we have.

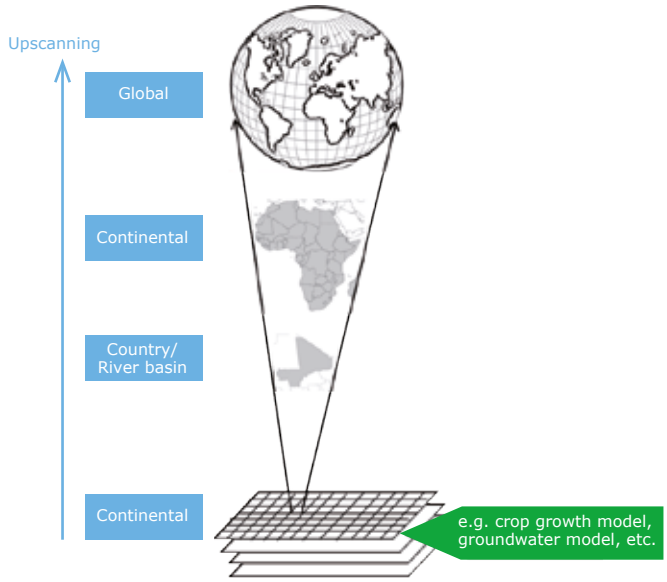
Researchers at Wageningen UR have been using their knowledge to find innovative ways of addressing these issues. They initiated a project to contribute to building the knowledge base by providing spatial insight into local and global crop production conditions to be able to explore options for sustainable crop intensification. A comprehensive tool, the spatial **F**ramework for global **R**esource **A**vailability and **M**odelling of input use **E**fficiency in crop production (FRAME), was developed to look at the agro-ecological options to increase crop production with the greatest input efficiencies, and illustrate this in a spatially explicit way to reveal local development options.

Using the databases: how they work

A large number of global spatial databases (weather, soil, land cover/use, agricultural management and socio-economic data) with different resolutions are combined with crop simulation models and empirical calculation rules in a coherent framework (Figure 1). Special expertise is used to link data to estimate crop yield potentials, required input use and to assess yield risks (e.g., due to weather variability). FRAME is being used in a number of different agro-ecological studies ranging from quick-scans of crop suitability for a given location to calculating crop water use in relation to regional irrigation water availability. Crop productivity is calculated based on knowledge of the locally available resources and water and nutrient input use efficiencies. By aggregating local results (mostly at a resolution of approximately 9x9 km near the equator, but recently also databases with 1 km^2 resolution are being used), national, regional and global consequences can be made visible in maps (e.g., Figure 2). In FRAME, the knowledge of local conditions is made explicit, and it allows for a further accumulation of knowledge as more information per grid cell becomes available. Methods for downscaling and upscaling have also been developed to allow for analysis at different scales.

An example: Intensification options for maize production in Africa

FRAME has been used to explore options for sustainable intensification of maize production in Africa. Firstly, rainfed potential maize yields were calculated and compared with actual yields. The difference between the two yields obtained is referred to as the 'yield gap' (potential minus actual). Additional information on, for example, fertiliser use, suggests that for maize to reach its full potential, it would require more inputs, like fertilisers. Secondly, the minimum amount of required nitrogen (N) fertiliser application was calculated based on local weather and soil conditions, crop characteristics, management and yield level. Finally, the efficiency of applying extra N fertiliser to produce more grain dry matter (DM) was determined. Figure 2 illustrates the spatial differences in fertiliser use efficiency of maize harvested areas in Africa. This information can help in, for example, land use planning (in terms of, e.g., where to grow maize with the highest fertiliser efficiency), in exploring options to improve fertiliser efficiency and in estimating the total amount of extra N fertiliser required for a targeted maize production at the national level.



Different databases with information at grid cell level on weather, soils land use and socio-economic characteristics. These data are used in models (e.g. for crop growth and groundwater flows) and calculated results form new layers of grid cell information.

Figure 1 A spatial Framework for global Resource Availability and Modelling of input use Efficiency in crop production (from Conijn et al., 2011)

Conclusion

FRAME is being used to assess some of the most important aspects of sustainable production – production potentials, yield gaps and efficient resource/input use. Information about the spatial and temporal variation in crop production and input requirements allows for better targeting of

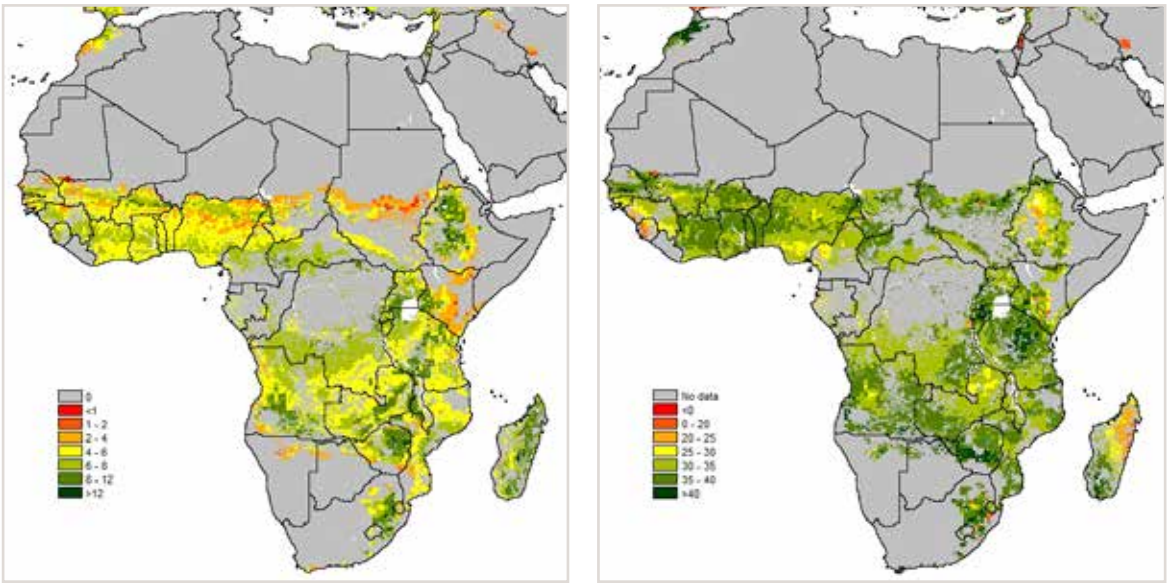


Figure 2 Left: Calculated grain yield of rainfed maize harvested areas in Africa (t DM ha_{-1} per harvest). Right: Amount of extra grain yield produced per amount of extra fertiliser N applied (kg grain DM/kg fertiliser N) for rainfed maize harvested areas in Africa (based on Conijn et al., 2013)

interventions aimed at improving local food security (*more with less*) and is supportive in developing risk mitigating tools such as crop insurance. FRAME has been used in a number of other projects such as for the European Union's Seventh Framework Programme for Research (FP7; Conijn et al., 2011), World Food Programme (WFP; Meijerink et al., 2012), International Fund for Agricultural Development (IFAD; Conijn et al., 2011), 'The Sustainability Consortium' (TSC; Haverkort et al., 2013; Evert et al., 2013) and to support the Dutch government to develop policies on sustainable agriculture (Hengsdijk et al., 2014).

Contributors
Sjaak Conijn *sjaak.conijn@wur.nl*
Huib Hengsdijk
Ben Rutgers

Market development and trade as drivers of food security: The case of India

In the past, global food security issues were often perceived as the domain of the leading industrial countries, United Nations agencies and international non-governmental organisations. This global landscape is changing – newly emerging countries (in particular Brazil, China, and India) are now also contributing in a significant way to the food security agenda. These countries account for a significant proportion of the world's population and are home to a large share of the world's undernourished people. They have experienced rapid economic growth, increasing their trade with the global economy in recent years. The impacts of policies undertaken to combat poverty and hunger in these countries and to boost production and trade affect the lives of millions.

In the past, global food security issues were often perceived as the domain of the leading industrial countries, United Nations agencies and international non-governmental organisations. This global landscape is changing – newly emerging countries (in particular Brazil, China, and India) are now also contributing in a significant way to the food security agenda. These countries account for a significant proportion of the world's population and are home to a large share of the world's undernourished people. They have experienced rapid economic growth, increasing their trade with the global economy in recent years. The impacts of policies undertaken to combat poverty and hunger in these countries and to boost production and trade affect the lives of millions.

The food and nutrition security situation in India is mixed. Although projections indicate that food grain availability is not a problem and that there is food grain security at the national level, widespread food insecurity exists at the household level. In addition to this, high food inflation and price volatility of non-cereal crops (e.g., pulses) pose a problem for the stability of food and nutrition security. Women and children, in particular, suffer malnutrition – around 40% suffer from underweight and 45% from stunting.

Researchers from Wageningen UR teamed up with partners in Europe (i.e., University of Leuven (KU Leuven), Research Centre on Animal Production (CRPA) and Leibniz Institute of Agricultural Development in Central and Eastern Europe (IAMO)) and in India (i.e., New Delhi office of the International Food Policy Research Institute (IFPRI) and the Indira Gandhi Institute of Development Research (IGIDR)) for the research project *Trade, Agricultural Policies and Structural Changes in India's Agrifood System; Implications for National and Global Markets (TAPSIM)*. The study was made possible with the support of the European Union (EU) and the research programme Global Food Security. The research aimed to determine future developments in supply, demand and trade for the main agricultural commodities and main trends in its high-valued agri-food chain. It assessed the impact of multilateral and bilateral trade policies, agricultural and rural policies, and structural changes on national and global markets.

The role of agriculture in the Indian economy

India is a large country with over a billion people. Since its independence in 1947, the country has made considerable progress economically and has demonstrated increasing resilience to economic shocks, such as during the global food, fuel and financial crisis of 2008-2009 (Gulati et al., 2012). The agriculture sector has, however, not performed as well as other sectors in the economy. Agricultural growth remained less than the targeted rate of 4%. The main reasons for this include the slowing of irrigation expansion, near stagnation of public investment, increasing cost of agricultural subsidies (such as the National Food Security Mission), poor access to credit, fragmentation of land, marginalisation of agricultural labour and environmental stress. Government policy also had a dampening effect on the sector, serving to discourage the private sector from engaging in a wide range of agricultural activities – from seeds to storage, and from processing to retailing.

The importance of trade and agriculture

During much of the period from 1970 to 1990, government support to the agriculture sector fell relative to the manufacturing sector as a result of an overvalued exchange rate and high levels of protection applied to the manufacturing sector through a combination of tariff and non-tariff measures. In the wake of rising crude oil prices and dwindling foreign exchange reserves, an economic reform package was adopted to help get through the Balance of Payments crisis in June 1991. Key reforms included the devaluation of the Indian rupee, reduction in the levels of protection in the manufacturing sector and liberalisation of the agricultural trade market. As a result, foreign exchange reserves began to build up and with the gradual removal of trade restrictions and the licensing system, trade increased. The liberalisation of rice exports was one of the most significant reforms.

Models used in the study and the effect of an India-EU FTA and a WTO agreement

The study explored India's trade policies, their implications and potential pathways for the future. To help the researchers in their assessment, two simulation models (a global and a national CGE model, Box 1) were linked and adjusted to meet the specific requirements of the project. Scenarios of an India-EU free trade agreement (FTA) were developed using various assumptions (Box 1).

Box 1 Simulation models and assumptions used

The models used included:

1 A global model: the *Modular Applied GeNeral Equilibrium Tool (MAGNET) model*. MAGNET is a computable general equilibrium (CGE) model that is widely used to analyse the external environment and policies covering the global economy, including bilateral trade relationships between all participating countries/ regions

2 The national *CGE model* of the Indian economy was used to capture specific details of the economy, such as the production structure, domestic policies, the different types of consumers (e.g., rural and urban household types which allowed for the assessment of trade and agricultural policy impacts on poverty)

Assumptions used to examine the effect of an India-EU FTA included: all tariffs being abolished, except for tariffs on sensitive products; the average import tariff rate by the EU for commodities from India and vice versa was reduced from 2% to 0.1%, and from 8.4% to 0.6% respectively. The average import tariff rate by the EU for commodities from India was reduced from 2% to 0.1%, and the average import tariff rate by India for commodities from the EU was reduced from 8.4% to 0.6%

The results indicated that an FTA will lead to an increase in India's gross domestic product (GDP) of around US$5 billion in 2015, and is set to increase further to US$50 billion in 2030 (equivalent to 0.7% of Indian GDP). The effect of an FTA to the economy in the EU is expected to be minor. A free trade agreement will lead India to increase its imports from the EU by slightly more than 50%, with the highest increases in processed food products. Increased exports from India to the EU are expected to come mainly from the manufacturing industry.

A World Trade Organisation (WTO) agreement to liberalise globally will only result in some small benefits for India and only in short-term benefits for the EU. The rest of the world is expected to benefit the most from such an agreement. The EU will benefit more from a global agreement to liberalise trade than India, although these benefits are expected to be less than 0.1% of GDP.

There are advantages to engaging in an India-EU FTA. The results indicated that an FTA is more beneficial to Indian rural households because of the extra income gained, while a WTO agreement will be more beneficial to those living in urban areas. In terms of wages, rural unskilled labourers are expected to benefit the most under an India–EU FTA regime. On the whole, however, both FTA and WTO redistribute income from rural rich households to the poor and middle income households.

Future outlook in trade policies

It is envisaged that food security concerns in India will remain paramount to any agricultural trade policy (Brouwer and Joshi, forthcoming). This is true particularly with respect to the grain sector. Despite the large reserves of foreign exchange and the ability to play on world markets, India is reluctant to completely open up its grain market. This is linked to fears on the part of policy-makers that with the liberalisation of agricultural trade, the domestic market will be flooded with imports – but this has not happened so far. Further, India has pursued a policy of price stabilisation by closing its markets for wheat and rice as world market prices peak. However, to placate domestic wheat and rice producers, India has been compelled to raise minimum prices, while subsidising consumer prices. This policy served to stimulate farmers to produce more wheat and rice, which eventually resulted in the spoilage of large stocks of wheat and rice, due mainly to inadequate storage facilities.

India's agricultural sector is becoming more diversified and its share of high value commodities such as horticulture, livestock and marine products is increasing. Although the export of these high value commodities has been growing for some time, India still remains a small player on the global market. The analyses suggest that India stands to gain substantially if more attention is given to stimulating private sector involvement combined with large investments to boost infrastructure and technological innovations, particularly in the seed and the processing sector. These improvements, if realised, will help raise the level of exports, address food insecurity within the country, and lift a large segment of the population out of extreme poverty.

Contributors
Floor Brouwer *floor.brouwer @wur.nl*
Gerdien Meijerink

Climate change and global water resources: Adaptation strategies for the agricultural sector

Over the last 50 years, the global irrigated area roughly doubled and the amount of water used by the agricultural sector increased substantially. Around the year 2000, a third of the global crop production was harvested from irrigated areas. In the same period, the construction of large reservoirs, with dams or other means, increased the volume of usable water. It was estimated that reservoirs supply water to 30-40% of the irrigated areas worldwide, contributing to 12-16% of the global food production (World Commision on Dams 2000). Both the expansion of irrigated areas and the construction of reservoirs have, therefore, been critical to the increase in global food production in the 20th century.

But there is reason for concern. There is a limit to the amount of freshwater that can be exploited sustainably. About one third of the world's population is already living in countries suffering from water stress. And global agricultural production will have to more than double in this century in order to meet the growing demand for food under more difficult climatic conditions. Increasing scarcity of irrigation water calls for adaptation strategies for the agricultural sector.

Irrigation water can constrain food production needed for a growing population

Researchers at Wageningen UR, in collaboration with international partners, investigated whether enough water resources are available to sustain a higher level of agricultural production and in which regions water scarcity is expected to be most severe. They also tried to find out which water sources were available to support irrigated agriculture. Tracking down water is, however, not an easy task as water moves around the Earth and atmosphere in a complicated cycle involving weather, climate, plants and trees, animals, and people. To understand how the complex interplay between climate change, land use change, population growth and economic development can influence water availability and demand, the researchers used a global hydrology and crop model called LPJmL (Biemans et al., 2011; Rost et al., 2008).

The researchers found that almost a fifth of total irrigation water worldwide is currently supplied

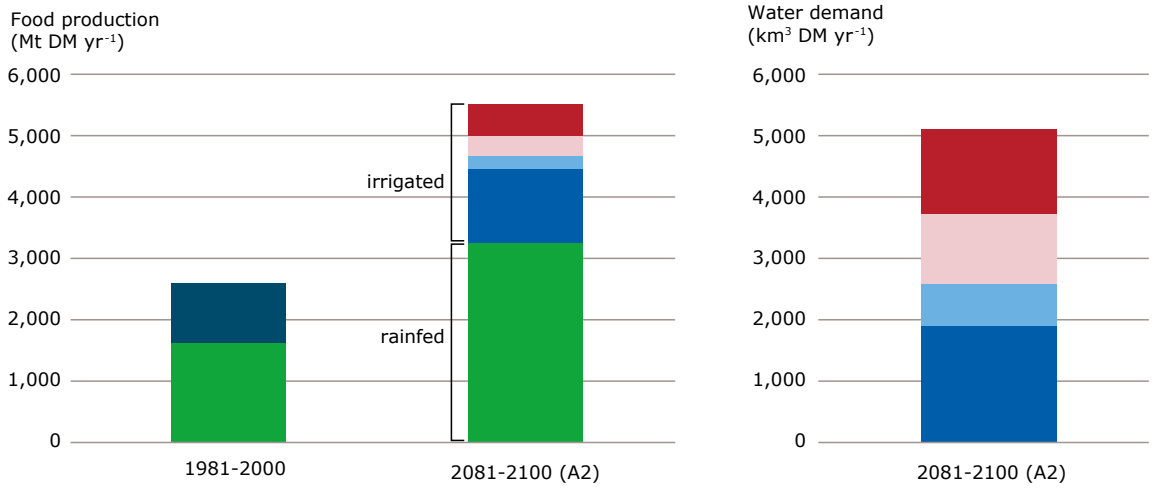


Figure 1 Left: Recent and future rainfed and irrigated food crop production (Biemans 2012). Right: The increase in irrigated agriculture will result in higher irrigation water demand. The colours show the potential fulfilment of this irrigation water demand from different water sources: dark blue from rivers and lakes, light blue from surface water reservoirs, pink from groundwater if supply can be sustained at current volumes, and red represents volumes that will be unavailable. The water shortage could lead to a shortfall in irrigated crop production (left)

directly from reservoirs (Biemans et al., 2011), substantiating that reservoirs play a very important role in global food production.

Global agricultural scenarios project that an increase in irrigated area between 30% and 45% is needed to increase food production (e.g., Fischer et al., 2005). Inevitably, this will lead to higher irrigation water demands. However, integrated analysis using the LPJmL model showed that with current reservoir capacity and inefficient irrigation in large parts of the world, not enough water can be supplied to sustain the required increase in food production in the future. Worldwide, these limitations could reduce irrigated food production to as much as 20% (Figure 1) (Biemans 2012).

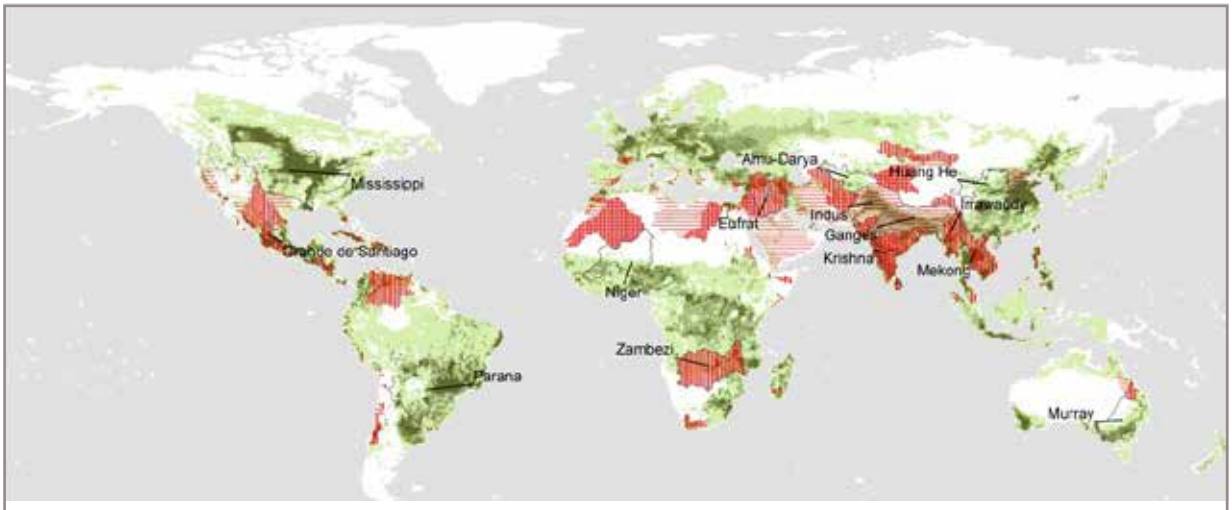
In some basins of Southern Africa and South Asia, irrigated crop production could be reduced by as much as 50% due to water shortages (Figure 2). At the same time, the effects of climate change are likely to have a major impact on water supply and demand at the local level as some regions will experience more rain than usual and in some regions it will be drier.

Adapting to limited water resources

The researchers also looked at potential solutions to future water shortages. If the yield on irrigated lands becomes lower as a result of the water shortages, either much more land will be required to achieve the production needed, or water use efficiency and water storage will have to increase. Potential solutions could include, for example, improved irrigation systems, drought-tolerant crops, brackish irrigation and other practices or technologies to help improve the management of water resources. Focusing on five rivers in Asia, it was determined that adaptation measures like improving irrigation efficiency and increasing reservoir size could help make up the shortfall (Biemans et al., 2013). However, the study also showed that the best solution may be different in each basin, emphasising the need for region-specific adaptation strategies.

Future action

LPJmL is a suitable tool to study the linkages between water availability and crop production. It was used to show that the current projections of the future food system are not 'waterproof', and that the agricultural system represented in those projections might overstate projected output on irrigated land by around 20%, which leads to an overestimate of the total crop production by around 8% due to irrigation water shortage. To meet future water demands, there is a clear need to factor adaptations into the way in which water systems are managed as part of sustainable agricultural practices. Improved irrigation efficiency and increased storage capacity in large reservoirs can clearly help to reduce water scarcity and improve food production.



Crop production areas (A2)
Basins with a reduction in irrigated crop production more than 20% due to water shortage
Basins where irregated crop production is more than 20% depending on groundwater
(only basins shown where irrigated production is more than 50% of total crop production

Figure 2 Vulnerable river basins where irrigated crop production could become at risk. In the red dashed areas, a loss of irrigated crop production of more than 20% is projected. In the pink dashed area irrigated, production depends, to a large extent, on groundwater and is potentially at risk if groundwater tables drop

Contributors
Hester Biemans *hester.biemans@wur.nl*
Ronald Hutjes

A review of food security scenario studies: Gaps and ways forward

With the recent renewal of interest in agriculture and global food security issues, food security has improved – 'food markets are becoming more balanced and less volatile in recent years' (FAO 2013). But what about the looming challenge of feeding 9 billion people in 2050 that is now high on the policy agenda? Will the world be able to feed itself then? How can policy-makers be better equipped to make more informed decisions and develop appropriate policies to meet these challenges?

To answer these questions, more and more studies on global food and nutrition security have emerged. Several researchers have used model-based scenarios to explore the effects of the main drivers (or factors) affecting global food supply and demand in the future. These studies provide different answers, giving rise to a number of new questions. What are the main assumptions and drivers underlying these studies? What are the data limitations? Are the outcomes comparable or do they diverge, by how much and why? What are the major gaps in the food security scenario studies and how can they be improved? These were some of the concerns that prompted researchers at Wageningen UR, to set up a study to compare and evaluate global scenario studies focussing on food and nutrition security.

The researchers collected information on all major global food security scenario studies published between 2000 and mid-2013 by international organisations, including NGOs and research institutes. The results from the 12 scenario studies (encompassing 43 individual scenarios) were combined into a database containing comparable information on major driving forces and food security related outcomes. The studies presented information on four key indicators of food security: (1) food prices, (2) calorie availability, (3) child malnutrition and (4) prevalence of undernourishment. Food prices and child malnutrition are highlighted here.

What studying the scenarios revealed

A review of the historical trends and future projections for cereal food prices illustrated that there is in particular a high level of uncertainty associated with future food price developments.

Food price estimates varied widely (cereal prices were used as proxies as they are closely linked, see Figure 1). Food price projections depend very much on the underlying assumptions of driving forces (those factors affecting the supply and demand of food). For example, prices tend to decrease or remain stable for global scenarios that take into account reduced inequality, global cooperation, lifestyle change and more efficient technologies. Prices increase under regional competition scenarios, which have typically inward-looking policies (e.g., trade barriers), resulting in slower economic growth and technical change. On average, prices are projected to increase to 227 US$/ton in 2050 (the blue line), ranging from 175 US$/ton (lower quartile (a quartile is a statistical term used to describe a range of data that is divided into four equal parts)) to 308 US$/ton (upper quartile, in dark grey).

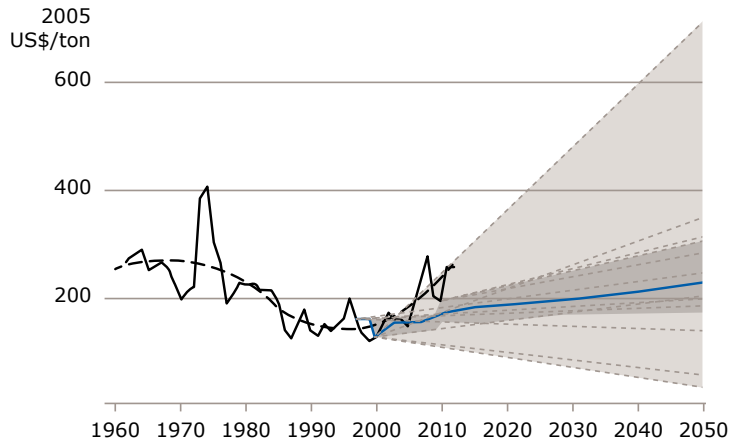


Figure 1 Cereal food prices - historical trend and future projections (Depicts information for wheat prices. For similar figures for rice and corn see van Dijk and Meijerink (2014) Historical price (solid black line), historical trend (dashed black line), scenario projections (grey dashed lines), median of all projections (blue line), total price range (light grey area) and interquartile range (dark grey area))

The scenario outcomes for child malnutrition are also diverse (Figure 2). Despite the marked variability in projections, the figures indicate that almost all scenarios foresee a downward trend in child malnutrition in the coming decades, reaching on average 105 million children in 2050 (blue line), ranging from 78.8 million (lower quartile) to 131 million children (upper quartile, in dark grey). It is important to note that the data used for this variable compares absolute figures of child malnutrition. These figures are difficult to compare across scenarios due to differences in assumptions on population growth. Unfortunately, data on the total number of children that is needed to calculate shares are not available.

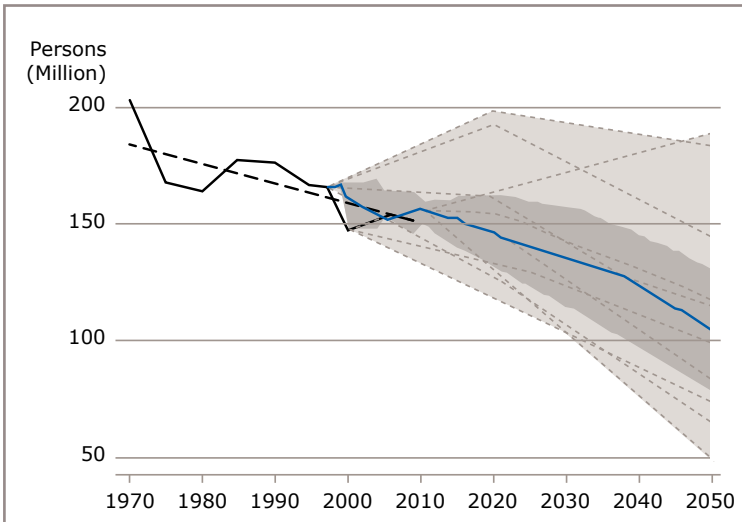


Figure 2 Child malnutrition - historical trend and future projections. Historical child malnutrition (solid black line), historical trend (dashed black line), scenario projections (grey dashed lines), median of all projections (blue line), total price range (light grey area) and interquartile range (dark grey area)

New drivers of food security outcomes

There are several underlying food and nutrition security drivers and cause-effect relations are complex. As a result, most scenario studies tend to simplify these relationships, only incorporating some of the multiple potential driving forces in their analysis. Figure 3 gives a graphic picture of the drivers of food supply and demand used in the scenario studies as well as those mentioned in the broader literature. The drivers highlighted in green were taken into account by most of the scenario studies, although the way they dealt with climate change, the increasing use of bio-energy and bio-materials, and the change in diets and consumer preferences was sometimes superficial. The driving forces indicated in the orange boxes have yet to be fully incorporated into scenario studies, partly because they represent new developments (e.g., alternative sources of food supply such as insects and algae) or because they represent a shift in thinking in relation to the food and nutrition security concept (e.g., the role of poverty and inequality).

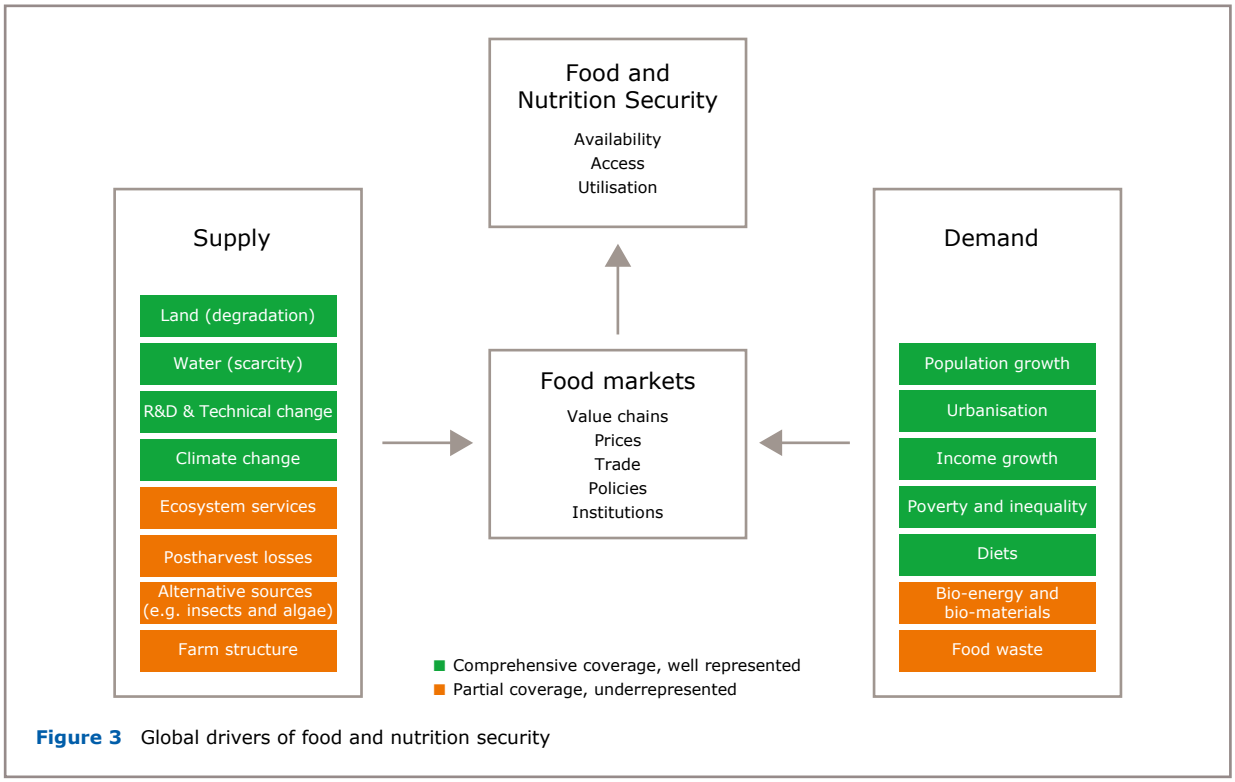


Figure 3 Global drivers of food and nutrition security

The way forward

The review of the scenario studies demonstrated that the studies restricted their focus to two of the four dimensions of food security: food availability and food accessibility, while food utilisation and stability were hardly covered. The reason for this has to do with the way the models have been built – they are well developed to simulate bio-physical and market dynamics but have limited capacity to analyse the household and individual aspect of food demand and food security.

The researchers also found that several new developments that impact on food security have not yet been wholly incorporated into the scenario models. There were only a few studies that looked at emerging issues such as biofuels and changes in diets, while other important drivers, such as alternative sources of food, farm structure, poverty and inequality and food waste have hardly been considered, although several efforts are underway. New scenario studies that focus on global food and nutrition security should, therefore, make an effort to include these new developments. This is the main aim of the ongoing FOODSECURE project (www.foodsecure.eu) funded by the European Union (EU) and the Ministry of Economic Affairs and led by LEI Wageningen UR

Contributors
Michiel van Dijk *michiel.vandijk@wur.nl*
Gerdien Meijerink

2

Global food security 2050: Exploring future scenarios

The pathways toward a more food secure future are based on sustainable and inclusive growth and adapting food systems to the challenges of malnutrition, climate change and resource scarcity. The approach of Wageningen UR is to solve pieces of the food puzzle by bringing together researchers (beta and gamma) in collaboration with a wide range of stakeholders, including other leading scientific institutions, the private sector, non-government organisations and local partners across the globe. This process gives way to compelling narratives and state-of-the-art scenario modelling of the interactions between ecosystem services and socio-economic outcomes – creating insights into the actors and drivers of change at the global, regional and national levels. The research has addressed several areas including the management of deltas and freshwater resources in the face of climate change, and the effects of targeted policies on vulnerable households and communities.

Adaptive delta management

As a follow up to the development of the Delta Plan for the Netherlands to help protect the country against the potential effects of climate change, a group of researchers from Wageningen UR has been building on that work, under the research programme Global Food Security, to develop appropriate methods to assist countries to manage their deltas in the face of climate change. But why are deltas so important? How can the methods developed help towards promoting food security and human livelihoods? These issues are being addressed in Bangladesh, Benin, Cambodia, Egypt, Myanmar and Vietnam.

Deltas are dynamic, productive systems where people have lived for millennia. They account for roughly 5% of the land area and are the most densely populated places on Earth. Some of the most fertile soils can be found there, making them extremely important regions for the growing of crops. Across the world they also support industry and livelihoods.

Deltas vary in size, structure and composition. On the whole, however, they are relatively young landforms shaped by the interplay of coastal and riverine processes and are of great ecological significance, comprising wetlands rich in biodiversity. Deltas are low-lying areas characterised by a mosaic of gradients between land and sea, fresh and saline waters, as well as exposed and sheltered environments. These patterns and dynamic processes form the basis of ecosystem services such as land formation, coastal protection and food for fisheries.

So, most deltas are 'hotspots' of human activity, making them vulnerable to changes induced by a range of driving forces, both natural and anthropogenic. A vulnerability and resilience assessment of ten deltas worldwide by the Delta Alliance (2010), found that the most important driver of change in deltas is climate change. According to the study, climate change is expected to have significant impacts, in the medium to long term, on seven out of the ten deltas investigated. Possible impacts include rising sea levels, resulting in higher flood risk, salt water intrusion and coastal erosion, increasing temperatures, and changes in composition, distribution and extent of ecosystems. Although climate change is an important driver, there are, other, more immediate concerns – increasing population and economic growth, rapid urban and industrial development and subsidence – all combine to stress delta systems. Many of these changes are more likely to be felt in low-lying, densely populated areas of developing countries where the measures to adapt to these effects are limited. Inclusive, integrated approaches towards delta development, management and governance are critical, but how can these countries adequately address current problems and prepare for the potential effects of climate change in the future?

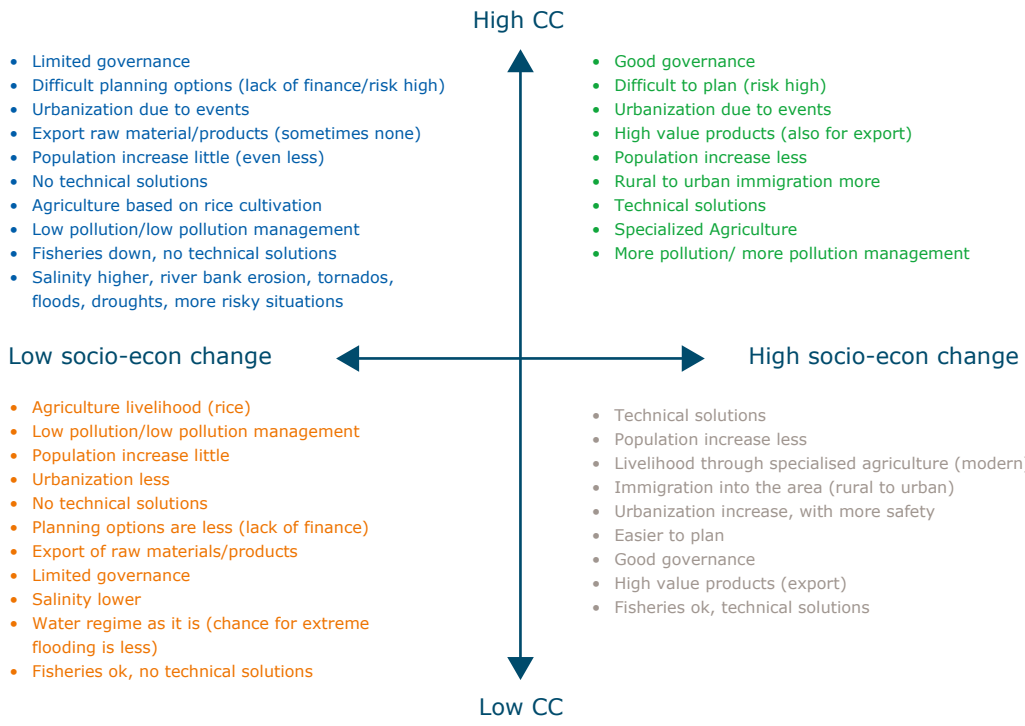


Figure 1 Storylines developed for four distinct scenarios for the Mekong Delta based on the scenario framework of the Dutch Delta Programme

The Framework for Delta Assessments has proven to be a useful starting point in gaining an insight into the strengths and weaknesses of existing delta management in the case study countries. Essentially, the framework is a scenario tool that considers the interactions between climate change and socio-economic conditions and their effects on, for example, local populations, food production and industry. It makes it possible to 'visualise' a number of developments in the medium to long term, serving as the basis for the formulation of appropriate strategies for the sustainable development of deltas.

The importance of inter-delta exchange of knowledge and expertise

Exchange of knowledge and expertise among deltas is considered to be crucial. As a consequence, there have been regional training workshops on the challenges and approaches in river delta planning in Ho Chi Minh City, Vietnam in 2012 and in Thanlyin, Myanmar in 2013. Some of the main objectives of these workshops were to:

- expose participants to the latest thinking of delta planning with specific focus on environmental and social aspects within the development context
- familiarise participants with the multi-level and multi-sectoral dimension of the topic – also by sharing the experiences of the participants from different backgrounds, with specific focus on rural/coastal and urban case studies
- familiarise participants with approaches on how to address these multiple dimensions – also considering uncertainty – and (institutional) conditions for implementing such approaches
- discuss examples of approaches and methods of delta planning drawing on European and Asian case studies.

During the workshops different scenarios were developed for the four combinations of high and low socio-economic growth and of high and low climate change (Figure 2). This was done for the Ayeyarwady, Ciliwung, Ganges-Brahmaputra-Meghna, and Mekong deltas separately as well asfor the upland, rural and coastal areas of the combined deltas. Also, different adaptation pathways were developed in order to achieve a given set of objectives (Figure 3). The participants were highly appreciative of the workshops, expressing the wish that they be repeated in the future in different host countries with different delta issues.

Currently, Wageningen UR researchers in collaboration with other international groups have been joining forces to adapt the framework to study deltas in Africa and Asia. They are driven by the belief that it is only through inter-delta exchange of knowledge and expertise that sustainable and innovative solutions for delta issues worldwide can

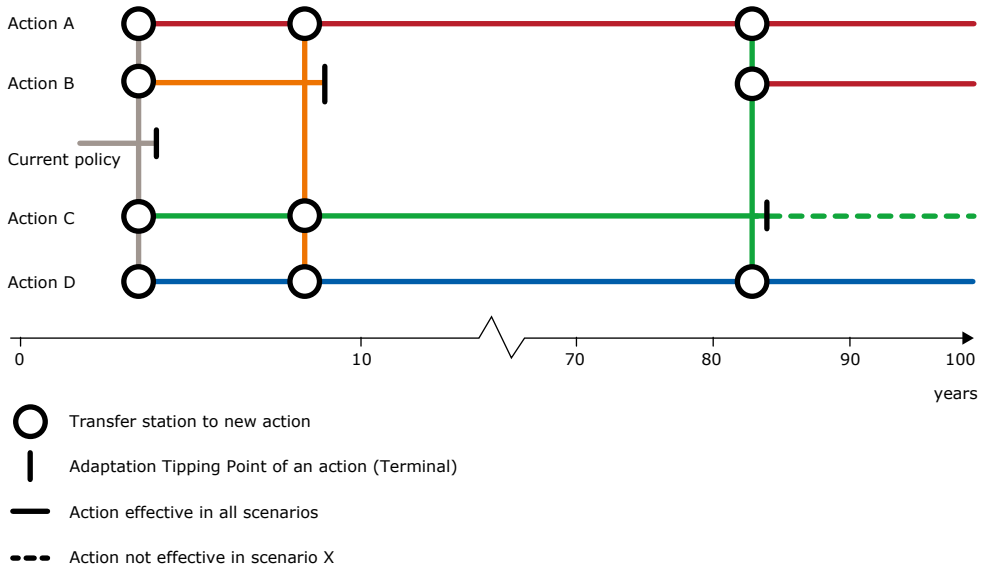


Figure 2 Principle of adaptation pathways
Source: Haasnoot (2013)

be found. It is within this context that the Global Water Partnership (GWP) and the Delta Alliance, with support from the Netherlands International Development Programme and the Dutch Ministry of Economic Affairs are developing a Global Programme of Action, the so-called *Enabling Delta Life Initiative*, to enhance climate resilience and strengthen the governance of deltas worldwide. To develop this initiative a number of workshops have been held with country representatives closely involved in delta management within their respective countries.

The story does not end here. The Framework for Delta Assessment is being used as a platform for global action in other areas, such as the Ganges-Brahmaputra-Meghna Delta in Bangladesh, L'Ouémé Delta in Benin and the Nile Delta in Egypt. Interaction with the different groups has shown that the Framework for Delta Assessments can effectively contribute to an increased insight into the strengths and weaknesses of existing delta management. However, additional work is needed to include institutional structures and governance issues.

Plans are currently underway to develop a comprehensive framework and toolbox for adaptive delta management as well as set up a community of practice. It is further envisaged that there will be more collaborative efforts to link up the biophysical framework with a socio-economic component to enable more robust decision-making on food security issues in the future.

Participants discussing different scenarios during the workshop

Contributors
Henk Wösten *henk.wosten@wur.nl*
Wim van Driel
Catharien Terwisscha
Wouter Wolters

Determining sustainable production limits for green growth

As countries develop and their populations increase, they exert pressure on the available natural resources, largely to meet the growing demands for energy, commodities, food and water. River basins are particularly vulnerable because they are rich in biodiversity and represent an important source of fertile lands for the growing of crops, timber, fuel and for fresh water. In many basins, people also often live and work in large concentrations. As a result, some ecosystems have become so degraded that groups of people and communities have been displaced, pointing to the strong need to improve the management of river basins in a sustainable way.

Scientists from Wageningen UR have been carrying out work to help build interactive scenarios at the local scale and basin scale in order to identify the limits to production growth and the pathways to sustainable intensification. The tools presented, developed in collaboration with the researchers from the various Wageningen UR institutes and other scientific bodies, support participatory planning processes and help determine demand for ecosystem services and environmental flow (Box 1). The Green Economic Growth approach is applied as one of the pathways to sustainable development for a more food secure future (Box 1). For this to be successful, a whole host of stakeholders, including policy- and decision-makers, water managers and smallholder farmers must play an active role in the process.

Sustainable production limits

Healthy ecosystems provide essential services that are vital to our very existence (Box 1). Maintaining a good balance in the ecosystem service is critical as actions to increase one ecosystem service may lead to the degradation of other services. River basins have different sustainable production limits and these limits change over the course of time. With each innovation and new agribusiness opportunity, total economic water productivity changes, leading to different multiple benefits and trade-offs.

Tipping points mark moments where additional pressure on resources can cause severe, sometimes irreversible damage to the environment and to the river basin, in particular, and set back sustainable

Box 1: Key concepts and terms in considering sustainability thresholds

Ecosystem services (ES): these are defined as the direct and indirect contributions of ecosystems to human well-being. The Millennium Ecosystem Assessment categorises ES into four main groups: provisioning services (e.g., food, water, raw materials, genetic resources); habitat resources (e.g., maintenance of life cycles of migratory experiences and genetic diversity); regulating services (e.g., air quality regulation, climate regulation, moderation of extreme events, regulation of water flows, erosion prevention); cultural services (e.g., aesthetic information, opportunities for recreation and tourism, spiritual experience, information for cognitive development) (Millennium Ecosystem Assessment 2005)

Environmental flows are described as '…the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems' (Brisbane Declaration 2007)

Green Economic Growth (GEG) is described as an effective strategy to stimulate sustainable economic growth in rural and urban areas to ensure poverty eradication, food supply security and improved quality of life for all without the overexploitation of natural resources of soil, water, biodiversity, energy and cultural capital. This involves looking at the best use of local resources to identify new opportunities and to search for the integration of value chains and new markets.
GEG has received worldwide attention within the context of Rio+20 (the United Nations Conference on Sustainable Development) and has been put forward as a tool to address the financial crisis as well as promote sustainable development (Alterra Wageningen UR n.d.)

development efforts. To avoid an overexploitation of water resources, the sustainability limits for production must be taken into account (Bogardi et al., 2013; Röckstrom et al., 2009). In situations where systems are close to tipping point, increased water consumption should be avoided by all means. So, if the demand for water resources exceeds availability, tough decisions have to be made on the most desirable use of water. Unfortunately, decisions about land and water resource allocation are at times made by governments in response to specific interests. In addition to this, the appropriate mechanisms to govern the allocation of scarce water are often missing. Knowledge partners are, however, well-equipped to bring the wider socio-economic effects of alternative land and water allocations into the decision-making process.

Assessing river basins

The framework outlined in figure 1 showing the principle steps for assessing sustainable production thresholds of river basins. It depicts how an inventory of information (gathered in part using participatory approaches) for local interventions as well as for measures at the basin scale can be used to predict water availability and family income, key parameters for sustainable and inclusive growth. Other key indicators such as soil fertility and biodiversity changes can also be determined.

The researchers have been using the framework along with a number of tools to compare impacts across alternatives, for example, to determine the consequences of land use change on water availability or the crop potential in a river basin. Four tools and how they have been used are presented:

Nile-AM

Wageningen UR (Alterra and LEI) recently developed the Nile Agricultural Model (Nile-AM) under contract from the Nile Basin Initiative (NBI), a regional inter-governmental partnership between the Nile riparians. This model is part of the Nile Basin Decision Support System (NB-DSS), which is a tool meant to support sustainable river basin development and more productive and sustainable agriculture in the region. Nile-AM integrates state-of-the-art descriptions of hydrological, biophysical and economic processes. It comprises two modules: a Crop Productivity model using the Food and Agriculture Organization's (FAO's) AquaCrop (FAO n.d.) at its core, and a modified (regional) version of the MAGNET model (Woltjer et al., 2011), a tool commonly used to simulate the impact of agriculture, trade, and land policies on global economic development.
Nile-AM has the functionality to define Agricultural Production Zones and to provide options for crop allocation. It considers the spatio-temporal water availability for agriculture and calculates final crop production. The modified MAGNET model is then used to determine the balance between agricultural production and demand, followed by a calculation of trade and its impact on other sectors of the economy. All the interactions between land, water,

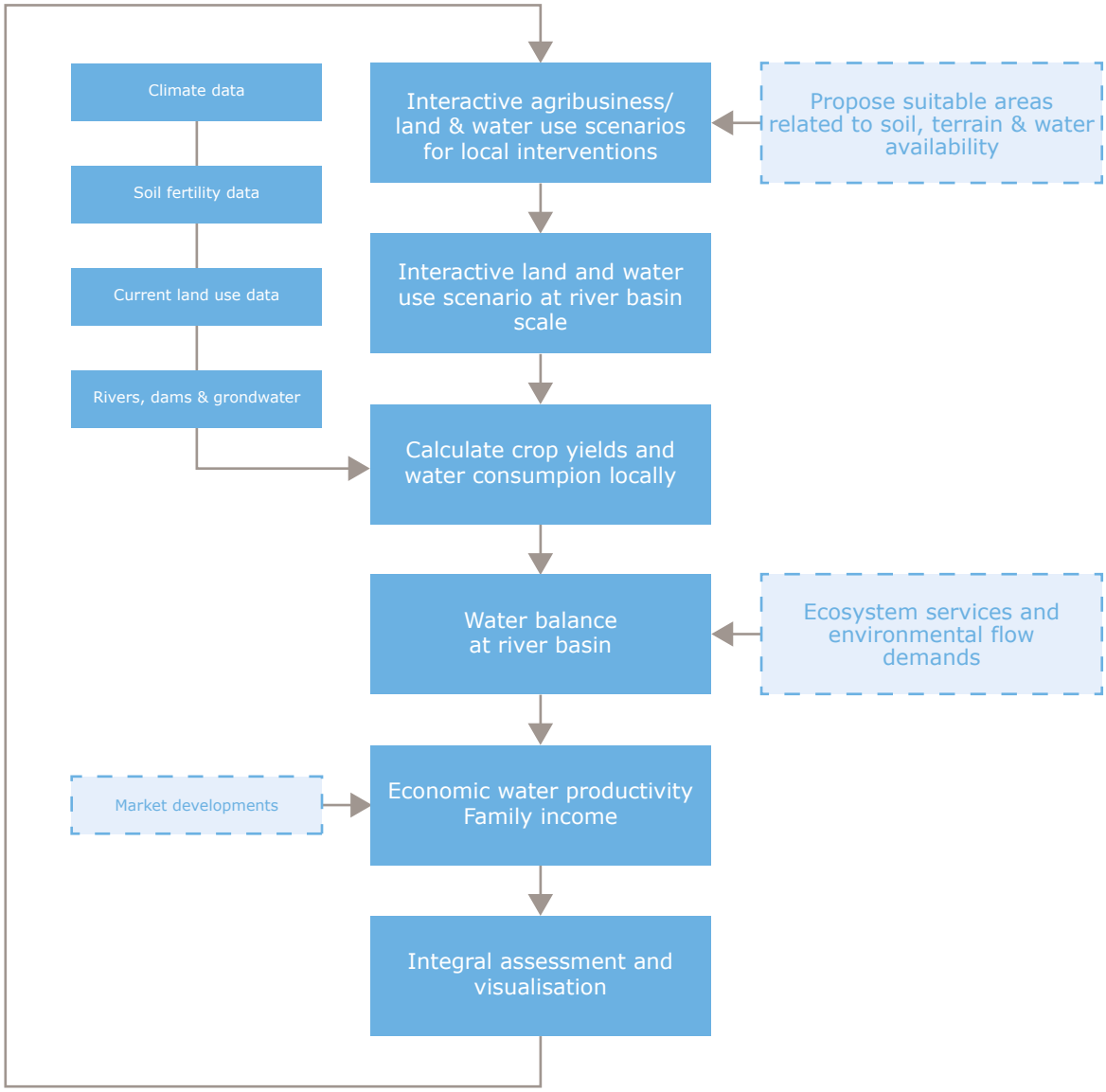


Figure 1 Integrating interactive scenario building with quantitative assessment tools is key to developing more realistic predictions on possible water consumption in the future. By addressing inputs on ecosystem services and market developments, the results from the scenario building can be translated into key indicators for inclusive growth. Reiterations need to be done when new opportunities for growth are detected.

and socio-economic development can be done interactively. Nile-AM is highly scalable and can be easily applied elsewhere. Its basic components are available in the public domain and are widely used by scientists and practitioners alike. As a result, there is an excellent support base as well as a high degree of confidence in the use of the model.

Description SIMGRO-WOFOST-QUEFTS

A chain of bio-physical simulation models was developed by Alterra for the Limpopo river basin (shared by Botswana, Mozambique, Zimbabwe and South Africa). The main aim of the models was to determine crop production potentials in order to support local economic development.
The Limpopo river basin can be characterised as river basin, where only a small percentage of the land is irrigated. Future extension and intensification of irrigated agricultural development may collide with nature conservation (e.g., well-known Kruger Park). The main challenge in this region, suffering from water scarcity, is to reconcile water demands from the various sectors with demands arising from new investments in agriculture. The model chain consists of a hydrological model SIMGRO (Querner et al., 2008, 2014), a crop growth model WOFOST (Supit et al., 2012), and the QUEFTS model (Janssen et al., 1999), which assesses the nutrients available to crops – all the elements needed to determine crop production potentials.

Description QUICKScan

QUICKScan is a participatory method, (supported by a software tool) used to enhance exploratory dialogue in a facilitated workshop-setting with

policy-makers, experts and other stakeholders. Typically, QUICKScan is used to scope, develop and assess alternative policy options and/or spatial plans. During the workshop, the impact of alternative options is visualised using the knowledge of participants.
QUICKScan was developed by Alterra and the European Environment Agency (EEA). It has been used: in the Netherlands for Dutch regional studies; to conduct several pan-European assessments for the European Commission (such as Green Infrastructure, Eco System Services, Natural Capital, Urban sprawl); for Mapping of Ecosystem services with several European member states. The method has also been used in Latin America (for soybean expansion), Africa (for social resettlement schemes), and Asia (for wetland conservation). For further details see: http://www.quickscan.pro.

Interactive water indicator assessment tool to support land use planning

Wageningen UR and WaterWatch developed a tool to support land and water managers in identifying and assessing scenarios for land development. The tool is an interactive, geographic information system (GIS)-based tool in a web-based environment. It uses various water-related indicators and is mainly intended to be used to support discussions. Stakeholders can use it to easily identify and evaluate scenarios and rapidly assess whether policy goals can be achieved or not. Ecological requirements have been included as 'ecological flows' as no consensus indicators are available. The data layers on which the tool is built comprise: land-use, rainfall, satellite image derived from actual evapotranspiration and biomass, market prices for produce, various production costs, and employment statistics. The instrument has been successfully applied in stakeholder meetings in the Incomati river basin, which is shared by South Africa, Mozambique, and Swaziland (Hellegers et al., 2012).

Interactive scenario building to support decision-making

Actual changes in water consumption are driven by land use change, and hence by those who invest in production, agribusiness, and in the innovation of value chains. Developing scenarios of sustainable production limits, which reflect future land use as realistically as possible, will help those in charge to make improved decisions towards promoting the sustainable development of river basins. Involving stakeholders in scenario building is critical, even though experience in participative modelling has shown that it is difficult to engage with them when it comes to the concrete development of quantitative scenarios. Classical approaches to inquiry, which involve discussing with stakeholders and then processing their answers as input into simulation runs and then discussing the results again with stakeholders, provide a lot of flexibility, but the iterations take time. GIS information systems, on the other hand, provide a good overview of the general trends and threats and assessment of scenarios, and are more interactive, but are often not specific enough to consider individual production systems and the agribusiness concept. They are therefore less suitable to predict the effect on local labour conditions and increase in family income. Existing tools are also more bound to pre-defined scales – they either focus on the detailed analysis at the field scale or provide overview information at the river basin or regional scale.

Interactive map tables can provide new opportunities to support participatory inventory of upcoming investment plans and land use changes, providing governments with the valuable information they need to make sound decisions. They provide new opportunities to link participatory scenario building with a underlying quantitative assessment at local scale and basin scale.

Modern visualisation techniques can also support the private sector to visualise planning, to identify positive impacts for regional development and to create stronger ownership to develop projects. Experience, however, is needed on how to involve the private sector in planning processes and in how to handle strategic and sensitive information to determine what can be shared and what cannot be shared. Further, 'win-win' approaches need to be developed so that the private sector can benefit from more reliable information for planning and so that the public sector can have a better insight into upcoming changes and demands for natural resources at the basin scale. Only then, can the sustainable production limits be defined for a specific intervention.

Contributors
Jochen Froebrich *jochen.froebrich@wur.nl*
Robert Smit
Koen Roest

on behalf of the More Food on smaller Footprint project team

Evaluating the impact of policy on food and nutrition security outcomes at the household level

Policy- and decision-makers need to 'take a look' into the future when formulating policies that are expected to have an impact on a population's food and nutrition security. It is difficult, however, to assess the impacts of policies on food and nutrition security outcomes because many factors that determine impacts are uncertain and interact at various scales and levels. Agricultural and food prices may change, for example, as a result of increased scarcity of fertile land, changing consumption patterns or a global macroeconomic downturn, affecting households and individuals in many different ways. Evaluating these impacts, however complicated, is crucial as it allows policies to respond better to the needs of various segments of the population and supports the development and implementation of appropriate global, regional and national strategies.

Researchers at LEI Wageningen UR have been working on developing methods that help to analyse the expected impacts of changes in policies and conditions on food markets and socio-economic groups in regions facing food insecurity. More specifically, LEI Wageningen UR, has been developing household and nutrition modules to enhance the analyses of its global economic simulation model, the Modular Applied GeNeral Equilibrium Tool (MAGNET) (Box 1), pertaining to food and nutrition security. This research project was developed jointly with the EU project 'FOODSECURE: Exploring the future of food and nutrition security', the research programme Global Food Security, and the Netherlands Assessment Agency (PBL).

Market drivers and food security outcomes

Different types of households are likely to feel the effects of economic shocks and changes in government policies in different ways because of differences in income and consumption patterns. For example, a contraction in a labour-intensive industry such as the textile industry will have a much greater impact on households deriving most of their income from this industry, compared with those engaging in, say, agricultural activities. Similarly, increases in the price of rice will typically affect poorer households that spend a larger proportion of their income on staples. Based on a careful selection of indicators on the socio-economic dimensions of food and nutrition security (for more details, see Laborde et al., 2013; Pangaribowo

BOX 1 What is the MAGNET Model?

MAGNET is a global economic simulation model used for impact and policy analysis. It can be used, for example, to examine the impacts of high food prices on food security, the consequences of a shift towards a more bio-based economy and the impacts of various trade agreements and reforms. The MAGNET model can include up to 134 countries/regions of the world, 57 commodities, including 12 agricultural commodities.

et al., 2013), such mechanisms can be used to develop quantitative scenarios for future food and nutrition security (Figure 1).

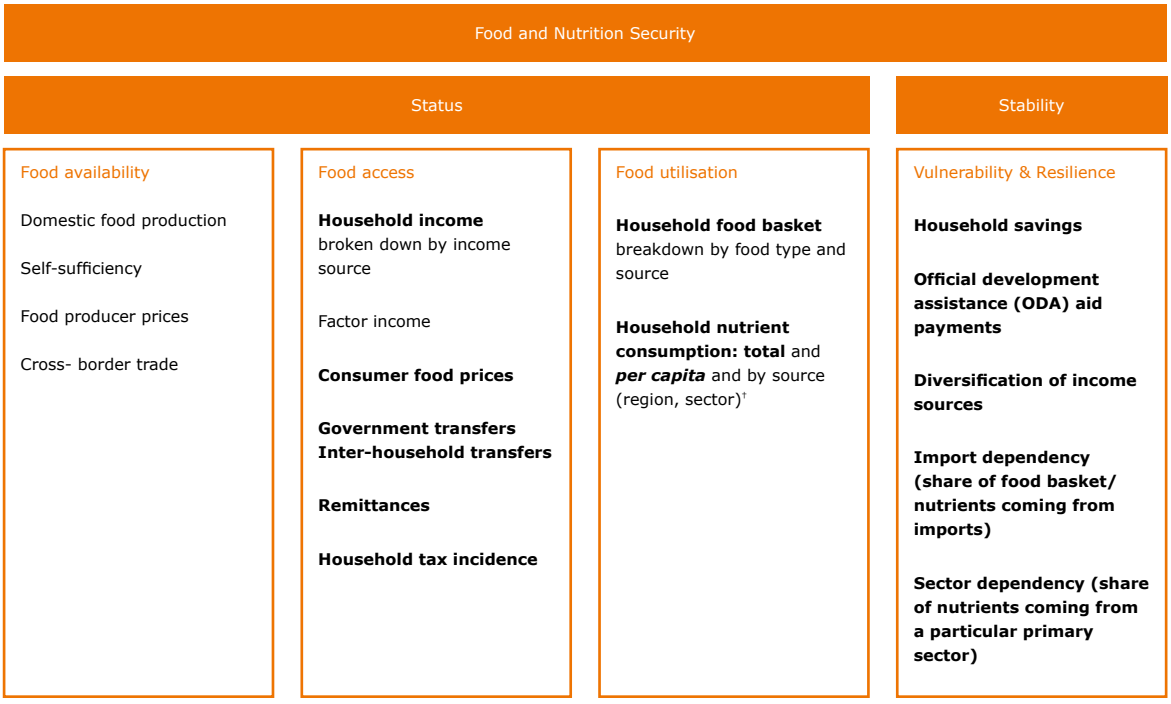
The MAGNET household module incorporates the theory and code of the MyGTAP model (Walmsley and Minor 2013; Minor and Walmsley 2013) to include multiple types of households grouped by income and consumption pattern (Kuiper and Shutes 2014). This allows the impact of economic shocks and policies to be assessed for different types of households and the identification of vulnerable household groups in selected countries. The method produces several indicators of future food security outcomes at the household level. The extended model also allows for an evaluation of the impact of government tax policies and subsidy programmes to redress undesirable social outcomes.

Naturally, there are substantial limitations to this broad-brush type of analysis. Analysts, therefore, make allowances for missing data on informal markets, gender and intra-household distribution and sanitation standards and other key factors in their interpretation of results on household-level food and nutrition security outcomes in the future.

Nutrients and the food basket

To improve the analysis of dietary change and food and nutrition security and health consequences at the global, national and household level, it is important that models incorporate more detailed nutritional impacts. For example, insufficient intake of macronutrients or micronutrients could have important negative health effects in the long term, resulting in so-called *deficiency diseases* (WHO 2004). Micronutrients, in combination with limiting fat, salt and sugar intake, have an important role to play in combating diet-related chronic diseases, such as heart and cardiovascular disease, certain types of cancers, diabetes, obesity, osteoporosis and dental disease (WHO 2004). These negative health conditions have various feedback impacts on the economy as changes in mortality and morbidity affect labour market supply, productivity, well-being (utility) and health care costs.

Agricultural economists are venturing into the nutritional domain by 'unpacking' the food products in the consumption basket in terms of their nutrient content – both macronutrients and micronutrients.



Notes: † When combined with the nutrition module (Rutten et al., 2013; the new indicators (shown in bold) are derived by including the MyGTAP code in the MAGNET model.

Figure 1 Food and nutrition security indicators in MAGNET

Opening up the consumption basket in terms of nutrient content can signal in advance whether the nutrient adequacy of diets will be affected by changes in the wider economy, and if so, where policy action may be needed. Most models, however, narrowly focus on macronutrient (i.e., calorie and sometimes protein) intake, which signals potential deficiencies (or affluence) in quantities consumed, ignoring micronutrient intake. These approaches also do not capture where nutrients come from, i.e., the linkages between agricultural production, food processing, food-related services, trade and food consumption.
The newly developed nutrition module in MAGNET (Rutten et al., 2013) traces the macronutrients of proteins, fats, carbohydrates and calories from farm to fork, taking into account trade, and is thereby able to calculate in more detail nutrient content associated with the private household consumption of food for all regions (Figure 1). It is set up for the inclusion of micronutrients in the future.

Taking it to the next level

The inclusion of multiple household types will allow for a range of poverty, food and nutrition indicators to be calculated for each household, while adding micronutrient data to the MAGNET model will facilitate the analysis of how macroeconomic shocks and/or policies impact upon diets, nutrition and eventually health (and what the economy-wide implications are of changing diets). It is envisaged that the results will be used to enhance policy- and decision-making at the various levels.
As part of a USAID-funded project, the extended MAGNET model is currently being used to evaluate the future of the poor in Ghana. In addition to this, the model is being used to assess the food security impacts of a global shift towards a bio-based economy and of reduced food losses and waste.

Contributors
Lindsay Shutes *lindsay.shutes@wur.nl*
Martine Rutten
Thom Achterbosch

Engaging stakeholders in developing food security scenarios

There is a long history of using scenario analysis in climate and environmental studies, but it is only recently that this approach is being used to assess future food and nutrition security. Scenarios are storylines with a coherent set of assumptions that together describe plausible futures. They provide a means of dealing with the complex and uncertain issues around climate change, income development, technical change, and consumption patterns in the formulation of policies that are dependent on future expectations.

Researchers at Wageningen UR have been developing and using highly participatory scenario approaches to improve their understanding of food and nutrition security issues so as to involve and guide decision-makers at the national and global levels. Two scenario exercises are presented that show how stakeholders have been involved in different ways: as owners of a vulnerability problem among local fishing communities in India, and as opinion-makers to inform exploratory scenarios on global food security.

Participatory Vulnerability Analysis: Engaging fishing communities in Kerala, India

In India, the fishery sector plays a strategic role in food and nutrition security, especially in the coastal communities. Kerala, a state in the south-west region of India, is an important producer and exporter of fish. The fishery sector contributes substantially to the socio-economic development of the state and the country as a whole; however, it is believed to be at risk as a result of uncontrolled fishing. Climate change is expected to exacerbate this situation and adversely affect the livelihoods of those living in the coastal communities.

A Participatory Vulnerability Analysis (PVA, e.g., Smit and Wandel 2006) was conducted in Kerala in order to understand and assess the main drivers related to the vulnerability of fishery resources and climate change as well as determine how individuals perceive and respond to this changing situation. The research was part of the Indo-European Research Facilities for Studies on Marine Ecosystem and Climate in India (INDO-MARECLIM) project. It was sponsored by the European Union (EU) and the research programme Global Food Security and co-ordinated by the Nansen Environmental Research Centre India (NERCI) in Cochin, Kerala, India.

Here, the PVA methodology as developed by ActionAid (Chiwaka and Yates 2005) was used. The method was set up as a disaster management tool to carry out in-depth analyses in local communities to find out what makes them vulnerable and to seek

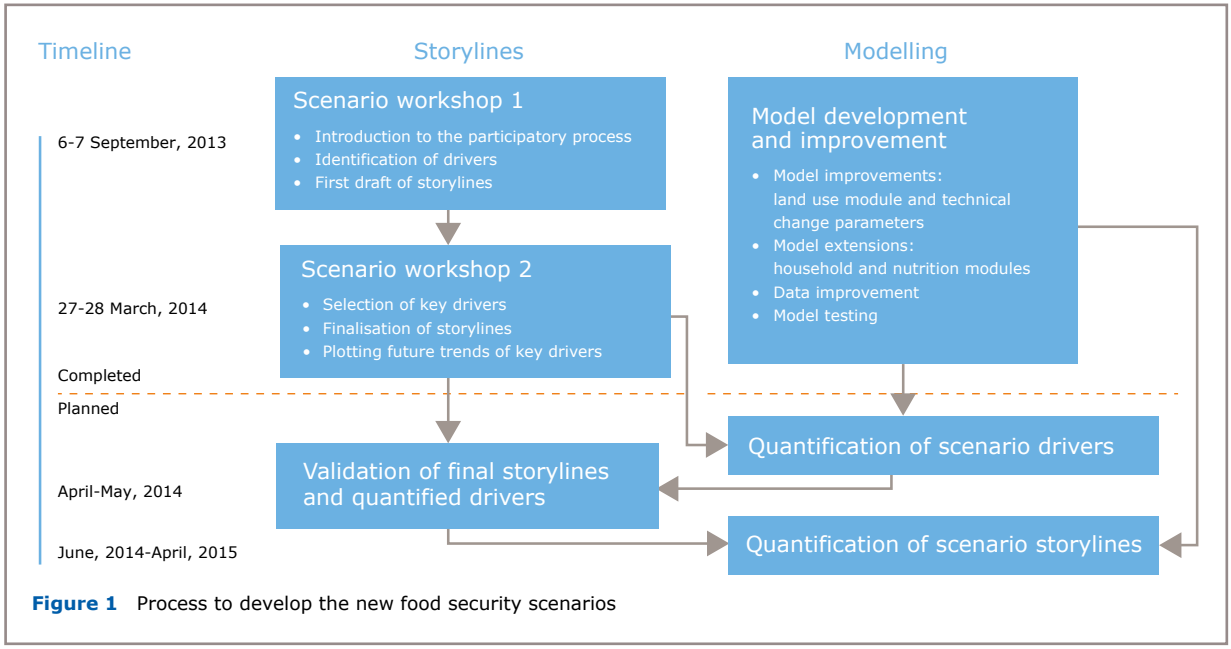


Figure 1 Process to develop the new food security scenarios

ways of helping them to cope with disasters. The tool is used to help people determine the causes of their vulnerability and develop an action plan. In the case study, the PVA involved analysing timeline data on the fishing communities, assessing how seasonality affects vulnerability, determining the institutional landscape and how the vulnerabilities affect or will affect the lives of the people in the communities. To gather data, well-known tools were used such as focus groups, timeline and trend analysis, seasonal analysis, and the problem tree analysis. As a result of using this process, the main factors identified as affecting the sector were: overexploitation and overcapacity associated with an increase in fishing effort and the mechanised unit; increased sea surface temperature; changes in the intensity and frequency of monsoon rains, and increase in salinity.

All of the groups studied were of the opinion that certain fish populations will continue to decline. However, their level of awareness regarding the potential future risk of climate change differed. The extent to which climate change might have an impact on their livelihoods did not seem to be of concern to them. Many in the community were more concerned with day-to-day survival.

During the focus group discussions (van Riel 2013), participants were asked the following scenario question: 'In the case of an extreme flood or tsunami event, how would you respond, what resources and/or systems are in place to cope with this?' Their response was that: 'We live for the present only, what happens will happen and we will face it then'. They continued by saying that: 'Awareness programmes need to be put into place and we need to be better educated and made aware of the impact of climate change on our lives and fishery resources'. The exercise has motivated the fisherman to get more schooling for their children.

The analysis showed the need to improve current management plans and strategies for dealing with the impending scenarios associated with climate change.

Story and Simulation scenario development on food security with opinion-makers

The Story and Simulation (SAS) approach is being used (Alcamo 2008), with support from the EU under the FOODSECURE project and the research programme Global Food Security, to develop and analyse a set of detailed scenarios of global food and nutrition security up to 2050. This methodology has also been used in the past to develop scenarios for the Millennium Ecosystem Assessment (MA) (Carpenter et al., 2005) on global ecosystem services and for the Intergovernmental Panel on Climate Change (IPCC) (Nakicenovic et al., 2000) on greenhouse emissions.
The strength of the SAS approach is in the way it combines participatory qualitative and analytical quantitative methods of scenario building. The core of the SAS approach is: (1) the development of 'storylines' that describe potential futures during a series of workshops and meetings with the active involvement of key stakeholders, and (2) the quantification of the storylines with the use of modelling tools to make the various pathways explicit by means of numerical data. The 'ideal' SAS procedure involves ten steps, including feedback loops and iterations to revise the

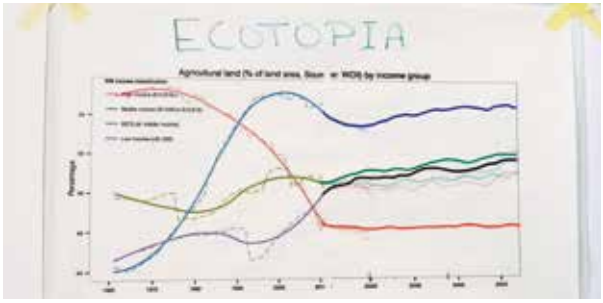


Figure 2 Example of output from the FOODSECURE Scenario workshops

storylines and model quantification and enhance their coupling (Alcamo 2008).
An important advantage of the SAS approach is that it gives stakeholders the opportunity to influence the development of scenarios and verify the applicability of the models. The active involvement of key stakeholders such as policy-makers and experts in the scen€ario building process also adds to the legitimacy of the scenario exercise. Further, the fact that state-of-the-art computer models, which have undergone peer review, are used in combination with expert knowledge means that scenario narratives are checked for consistency and that the results of the analysis are more credible.
The main constraint in using the SAS approach has to do with the difficulty encountered in translating qualitative knowledge into quantitative knowledge and back again. Scenario storylines consist of rich narratives and/or even diagrams and pictures that describe a complex system of global and local drivers. To transform this information into quantitative information that can be used in the model is quite challenging and sometimes bold assumptions have to be made.

Towards new food security scenarios

Figure 1 gives a visual impression of the main phases of the SAS approach process. Two workshops were held in Bruges and Prague to develop storylines for four scenarios. The workshops brought together 20 high-level representatives from a number of organisations and businesses in Europe and other regions, including the Organisation for Economic Co-operation and Development (OECD), Copa-Cogeca, European Commission, Biovision Foundation, Ethanol Europe, Oxfam, Action contre le Faim and BioCoop.
Workshop activities included structured assignments and working group discussions to identify key driving forces of global food security as well as develop comprehensive storylines for four potential futures, towards 2050. Key drivers that were selected included: population growth, technical change, income per capita, land use and change in diets. Even though participants underscored the relevance of global drivers and solutions, they were also interested in a plausible scenario around a more local food supply.
Parallel to the stakeholder process, modelling teams have been preparing and improving on the computer models for the quantification of these drivers and scenarios. In total, three different models (combinations) will be used to quantify the scenarios: (1) MIRAGE (International Food Policy Research Institute (IFPRI)), (2) GLOBIOM (International Institute for Applied Systems Analysis, (IIASA)) and (3) MAGNET-IMAGE (LEI Wageningen UR and the Netherlands Environmental Assessment Agency (PBL)). All of these models have global coverage and can make projections on, for example, agricultural production, food prices and consumption, given assumptions on a number of driving forces.
In the next phase, the future trends of the main drivers, which were plotted for each scenario by the stakeholders (Figure 2), will be quantified at the country level for each of the scenarios. When this is completed, a webinar will be organised with the stakeholders to validate the final storylines and the related set of quantified drivers. The final phase will involve the modelling of the four storylines with the models that feature in the project.

Future developments

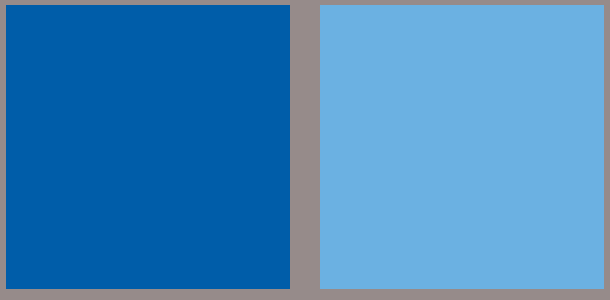
Both scenario exercises show the importance of engaging with stakeholders in the process of grappling with future uncertainty around food security and climate change. The vulnerability analysis highlighted the challenges fishing communities face in Kerala. The analysis also pointed to the need for state authorities, the affected communities and other key stakeholders to come together to discuss future climate change related events so that they can take appropriate action to mitigate their effects as well as develop food security strategies. Within the FOODSECURE project, it is envisaged that the scenario storylines and model outcomes will be used for an exercise with policy-makers from EU countries to discuss and evaluate potential policies that can positively contribute to global food and nutrition security. As a follow-up to these activities, representatives of local communities and the European Commission or other 'global players' will participate in a scenario exercise for exploring and discussing their stakes in future food and nutrition security.

Contributors
Michiel van Dijk *michiel.vandijk@wur.nl*
Eddy Moors
Tanya Singh

3

Governance towards sustainable action

Many communities around the world are facing an overexploitation of their natural resource base and are finding it difficult to access and benefit from the transformation of markets for food and resources. Understanding how governance mechanisms of institutions and the mechanisms for decision-making on innovation in agricultural supply chains work will contribute to the development of ways to enhance the management of natural resources and improve the lives of people living in rural communities. New approaches to governance have been emerging to address the competition over scarce resources, which combine the production chain approaches with a landscape approach to managing resources, taking into consideration the needs of local communities and competing interests. At another level, the private sector, development agencies, researchers and smallholders have been working together to support the development of sustainable inclusive businesses and innovation in agricultural supply chains and the upscaling of initiatives.



From Product to Place: A landscape approach to governing agri-food systems

Concerns about the pace at which global agri-food production chains and other extractive industries have been using the Earth's finite resources led to the design and implementation of roundtables, governance mechanisms aimed at ensuring that value chains based on tropical commodities become more environmentally sustainable and socially inclusive (see insert). However, after operating for more than a decade, they have not been wholly successful. Major areas under palm oil, soy and sugar production in, for example, Brazil, Indonesia, Liberia and Paraguay, are still grappling with uncontrolled deforestation and there are struggles with local communities about the use of the land and land tenure rights (Bodegom 2013).

The lack of success of roundtables has had to do with conflicting interests (Box 1). Less obviously, it is argued that the design of roundtables is incomplete. Commodities are primarily seen within the context of a functional value chain, i.e., from producer to consumer, rather than as part of a landscape where people live and work and where different stakeholders compete for space and natural resources. Separating production systems from their spatial context suggests that the complex reality is being ignored. A stakeholder dialogue based on a landscape approach is suggested as a solution for managing the competing claims for natural resources within these systems more effectively (van Oosten 2013).
Does this then mean that the roundtable approach will become redundant? Are there other alternatives that can be used to adequately manage the natural resources taking into consideration the existing landscape? And, if there are no alternatives, is there a way to improve on the existing system? These are some of the questions that researchers at Wageningen UR have been trying to answer in their research on landscape governance. To answer these questions, the researchers studied commodity roundtables in Paraguay, Indonesia and Brazil.

Roundtables

The Forest Stewardship Council (FSC) was established in 1993 for the certification of timber, followed later by the setting up of commodity roundtables. Roundtables have been facilitating dialogue between civil society and industry actors aimed at achieving sustainable standards where workers, local communities and natural resources are better protected. There are currently 11 roundtables, organised around specific products (e.g., soy, palm oil, cotton, cocoa). Membership is restricted to producers, buyers and civil society; state bodies are excluded from roundtables so as to ensure their autonomy.

Field research at study sites in Indonesia (i.e., Halimun Salak, East Kutai, Sungai Wain), included a stakeholder analysis and other participatory methods (e.g., participatory mapping, ranking, scoring). The data was used to analyse the drivers, pressure, state, impacts and responses to competing land use claims within a framework based on earlier work carried out under the research programme Global Food Security (van Berkum et al., 2011). The research provided a means to better understand the interactions between society and the environment and identify possible solutions.

The landscape approach

The landscape approach aims to reconnect production chains to their spatial context – agriculture, land, water, forests and people are all connected (Figure 1). Working from a landscape perspective means that the complex multi-functionality of a landscape becomes central to the analysis, and this makes it hard to separate isolated production chains from their spatial context (i.e., the natural resource base, the socio-economic realities, the multiplicity of stakeholders, their culture, functions and knowledge). It also means that the spatial impacts of production chains become difficult to ignore. A main drawback of the landscape approach is that the issue of governance is hard to capture because existing governance mechanisms are based on political-administrative structures of states, which do not always correspond with biophysical boundaries and socio-culturally defined landscapes. Notwithstanding this, the researchers found the landscape approach useful in identifying problematic issues of governance and in helping to resolve them. They particularly looked at case studies in Indonesia.

Governing landscapes

Some basic similarities in all the cases studied included: incidents of clashes between large-scale agri-food and resource extraction industries and forest/nature conservationists or small-scale farmers; formal rules and regulations regarding land use were fuzzy; rules and regulations could be informally drawn up and agreed on by the various actors involved. In the case of West Java, the encroachment of expanding commercial agriculture and resource extraction threatened two national parks – Gunung Halimun and Gunung Salak – to such an extent that the National Park Authorities created an ecological corridor to join the two parks. In the process, however, approximately 100,000 inhabitants of local communities located inside the corridor lost access to their farmlands. A coalition of inhabitants and local non-government organisations (NGOs) strongly protested against this and a multi-party agreement was reached, following a multi-functional landscape approach (Henneman 2012). In another case study, vast areas in East Kutai, Kalimantan are being used for open-pit mining of coal. Mining companies are required to restore the areas mined to the original forest. Together with the inhabitants and local NGOs, the mining company created a multi-stakeholder platform, which took responsibility for designing a multi-functional landscape plan in line with the needs and desires of the various actors involved (Brascamp 2013).

Mosaic landscape in the Halimun-Salak corridor

Figure 1 A landscape approach

Figure 2 Landscape governance

A landscape approach refers to the management of complex landscapes in an integrated and holistic manner, incorporating all the different land uses within those landscapes in a single management process. Landscape governance refers to the process in which landscape inhabitants, policy-makers, civil society and private businesses decide on what the landscape looks like. This implies spatial decision-making beyond the formal political-administrative structures of states, as landscapes usually follow the biophysical and socio-cultural boundaries of geographical space (van Oosten 2013).

The cases illustrate that landscape governance involves multi-stakeholder arrangements at the landscape level, based on a multi-functional reality of place. Solutions to problems are sought through dialogue and negotiation involving global, national and local groups, drawing on complementarities rather than on competing land use.

Hybrid approach: A possibility

Roundtables have been successful in developing globally accepted standards on sustainable production, and consultation mechanisms along the production chain, so at the moment it is hard to tell whether they will become redundant in the immediate future. Agribusinesses and other extractive industries need to become part of the landscape they are sourcing from, and contribute to a harmonious spatial development of place. Landscape governance arrangements are, however, often poorly aligned with formal planning structures because the boundaries of landscapes often do not coincide with those of administrative constituencies of states. This does not take away from the usefulness of the landscape approach. The examples from Indonesia show how landscape governance can effectively move across political administrative boundaries, linking agri-food businesses and other extractive industries to stakeholders living in or depending on the landscape. It is therefore worth considering combining the two different perspectives into a hybrid approach. Currently, there are several initiatives in the making, claiming that such an approach could work.
Time will tell whether production chain approaches and landscape approaches can work together.

But one thing is for sure, there is an urgent need to re-connect agri-food chains and resource extraction industries to those geographical areas where the products are derived from. Having a bottom-up approach to stakeholder collaboration and public-private engagement at the landscape level will help connect the global to the local and enhance the sustainability of global agri-food chains for future generations to come.

Contributors
Cora van Oosten *cora.vanoosten@wur.nl*
Arend Jan van Bodegom

Going Beyond the Buy: The Business of Investing in Smallholders

The agri-food sector has the potential to play a pivotal role in stimulating local agriculture and in reducing poverty in many developing countries. However, building a vibrant agri-food sector to include smallholders is not easy. There are many challenges that make it difficult to do 'business' – climate change, land degradation, changing market structures and shortcomings in providing an enabling environment (i.e., access to credit, markets and technical assistance; a good infrastructure; supportive policy environment and land tenure security). For businesses to be able to continue to secure food supplies and grow in the future, a concerted effort will have to be made to find innovative ways on how to scale and boost food production and its distribution in an inclusive and sustainable manner.

Inclusive business is one way of creating profitable business models and strategies that help drive economic opportunities for those who would otherwise be left behind such as small-scale farmers, local agribusinesses and the rural unemployed (Woodhill et al., 2012). But what kind of support can be expected from international, regional and local food businesses to help these groups become effective players in the agri-food sector?

Development experts from the Wageningen UR Centre for Development Innovation (CDI), in collaboration with other researchers in the Netherlands and abroad, set up a project to analyse the innovative mechanisms of inclusiveness, how they can be integrated into existing business models, how they work and what their impact is at the business and community level.

They were inspired by the work carried out by the Sustainable Food Lab and Oxfam on inclusive business models, which identified principles that underpin sustainable trading relationships that reinforce corporate and smallholder value chains (Table 1). The Wageningen UR researchers drew on these principles to explore how applicable they were to small, medium and large enterprises and whether upscaling was possible. The LINK methodology (Lundy et al., 2012) was used to support the analysis of the ten business cases studied. This involved extensive field visits to different types of agricultural enterprises across

selected countries in sub-Saharan Africa such as Burundi, Ethiopia, Kenya, Mozambique and South Africa.

Incentives and mechanisms for inclusiveness

The research team found that the traditional business paradigm regarding supply, brand name and reputation is changing. There are now strong incentives for companies to move closer to farmers to ensure a consistent supply of produce.

By promoting inclusive business, several companies have been able to increase productivity, attract younger people to farming, respond to consumer demand, reduce operational/reputational risks, differentiate their brands even more to attract new consumers, and build strong localised supply chains. As a result, many companies have had to adapt the way they source, purchase and work with partners in the supply chain. They have had to change their corporate culture (i.e., moving from being competitive-minded to being partnership-oriented), find ways to attract investment to promote long-term sustainability and re-think their corporate or brand communications to integrate both the commercial and development benefits delivered through these changes. Dairy business hubs (DBHs) in Kenya represent one such example – they have been creating a large farmer supply base to be able to collect a substantial amount of

Inclusive business models are:

1 Accessible to smallholders, therefore they have more impact on poverty
2 Durable (relationships created last longer)
3 Stable (less volatile and risky)
4 Beneficial (they help farmers to build assets and skills, promote food security and profitability)

Table 1 New Business Model Principles and Possible Intervention Measures to Enhance Inclusiveness

Principles: Inclusive business model	Some areas of assessment based on the Link methodology	Interventions to enhance inclusiveness
Principle 1 *Chain-wide collaboration with shared goals and identified champions*	Identify: - champions in lead firms - regular flow of information (formal or informal) - whether there is alignment of goals/vision (commercial and development)	*Institute a gender component*: this includes women, youth and labourers. For example, women are especially good at working on crops that demand intensive farm management. Their participation in this area should therefore be encouraged
Principle 2 *New market linkages*	Ability to: - reach high-value markets - provide a steady and durable market for suppliers - expand core product opportunities, - operate without subsidy	*Critically review the business model regularly for new business opportunities*
Principle 3 *Equitable and transparent chain governance*	- Transparency - Traceability to farm level - Risk sharing function - Mechanisms include: governance models, shared ownership models, and contracts	*Increase transparency* through improving collaboration with other actors in the chain and involving more farmers on the boards of businesses
Principle 4 *Equitable access to services*	- Production-related services available and tailored to small farmers and accessible to women, youth - Facilitate access to additional services	*Strengthen the management skills* of growers, this in turn will serve to reinforce the relationship between growers and businesses *Set up a one stop shop for farmers* so that farmers can get important inputs (e.g., seeds, fertilisers, pesticides, veterinarian services, etc.) and training in agronomic practices *Support community projects* where possible to reinforce a positive company image
Principle 5 *Inclusive innovation (vertical co-innovation, process and product)*	- Mechanisms in place for getting farmer input and strategic information - Renewal of product/market, continuous evolution and diversification - Recognition of co-dependency	*Diversify the portfolio* so as to spread risks, lessen the dependence on agriculture and increase the impact on the economy
Principle 6 *Measurement of outcomes and acting on them*	- Informal or formal feedback mechanism along the chain - Regular explicit assessment process - Decisions based on assessment	*Determine the impact of inclusive business on the livelihoods of farmers* to see if their quality of life has improved

Milk collected from smallholder dairy farmers being offloaded at a local DBH, Eldoret, Kenya

milk so as to attract cheaper services and improve their negotiation position.

In the case of Mozambique Fresh Eggs (MFE), the company took a deliberate decision to partner with small-scale farmers to diversify and expand egg production. In 2005, the manager of New Horizons (NH), a poultry operation, decided to form strategic alliances with two other companies having a similar ethos, i.e., commitment to using business to combat poverty, to create MFE. NH manufactures chicken feed, Eggs for Africa provides the marketing expertise and Centre Fresh Egg Farm provides the financial capital and expertise to support smallholder involvement. MFE provides most of the material and equipment needed, the smallholders also contribute some of their own materials, such as bamboo, rows of cut grass and blocks. Strong technical support is also provided by MFE.

Special mechanisms that some of the different types of businesses studied have been using to promote inclusiveness include: the creation of cooperatives, the innovative business model, public private partnerships, outgrower schemes or contract farming. NH has an outgrower scheme arrangement with its smallholder farmers. The company has been involving women, sharing risks and profits, and providing daily supervision. A payment system to motivate smallholders has also been instituted to increase their earnings. At first, many of the farmers who joined the outgrower scheme as early as 2006 squandered their profits. This led to a neglect of their operations. To put an end to this problem, NH decided to actively engage those farmers' wives who were believed to have good management skills. This brought about noticeable improvements to the households' quality of life (Sopov et al., 2014).

Inclusive business model principles: Enhancing inclusiveness

The inclusive business model principles were useful in helping to assess and identify areas in SMEs that need changing to strengthen chain relationships and for upscaling. The researchers found two main drawbacks to the model, however. These included a failure of the model to take into account the importance of having a close relationship with smallholders and the need to take a holistic approach to the way farms operate as a whole to maximise income and food security. The team proposed interventions that could be used to enhance inclusiveness, depending on the situation (Table 1).

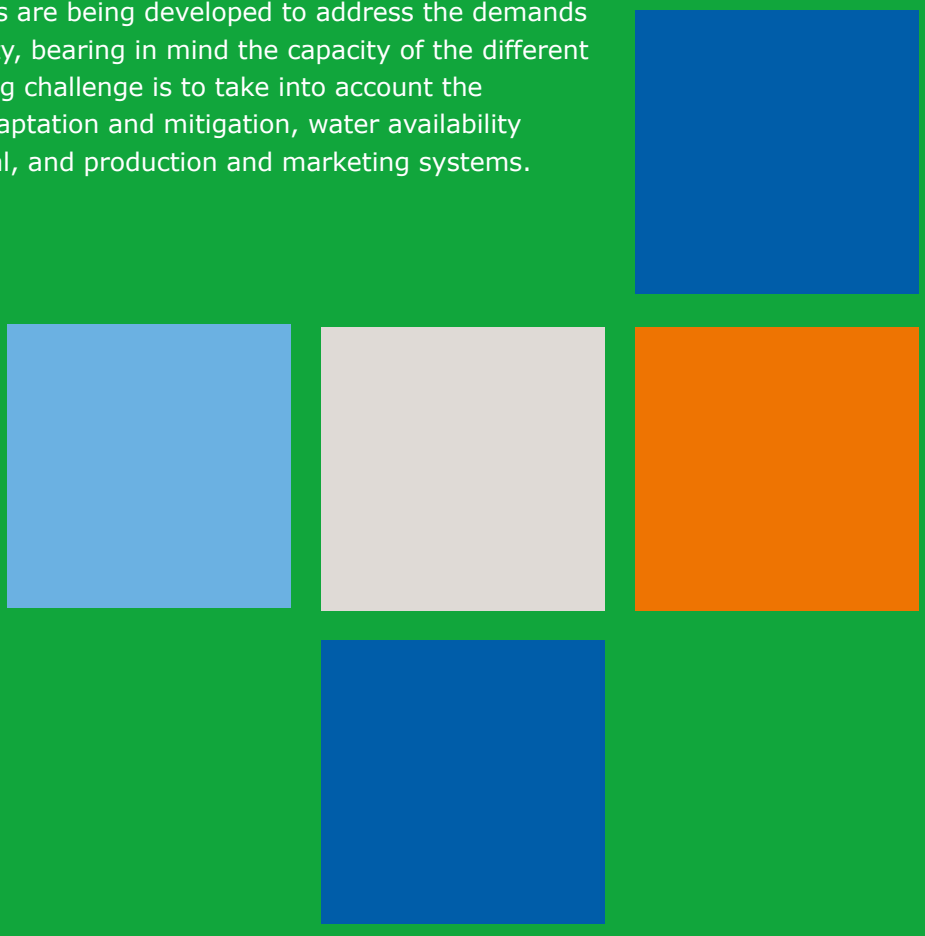
The case studies were presented at the 'Seas of Change' international workshop on Inclusive business models in Amsterdam (12-13 February, 2014), organised by Wageningen UR Centre for Development Innovation (CDI) for the business community, civil societies and research institutes. They provided useful insights on how to promote inclusive businesses among smallholders. Encouraging developments have been the interest shown by the Food and Agriculture Organization (FAO) in using the case studies for their inclusiveness business staff training and the positive reaction from small and medium-sized enterprises in Africa to the principles developed. Plans are underway to further 'spread the word' among business community and develop the case studies into teaching materials for higher education in developing countries. Policy research issues for the future include determining which aspects of inclusive business should be covered by public funds and the type of companies to support with donor funds.

Contributors
Monika Sopov *monika.sopov@wur.nl*

4

Adapting agriculture and innovating supply chains in developing countries

Developing countries need to overcome substantial challenges to be able to improve the availability of and access to locally grown, nutritious food to everyone. There is a need for research and innovation to unleash the potential for agriculture as a stable source of food supply and livelihood. The process of adopting and scaling the needed innovations is not straightforward, careful attention is required to come up with solutions that fit the specific context. In particular, the role of smallholder farmers requires attention. Often in tri-partite settings, new agricultural systems are being developed to address the demands for increased productivity, bearing in mind the capacity of the different ecosystems. A continuing challenge is to take into account the interactions between adaptation and mitigation, water availability and agricultural potential, and production and marketing systems.



Climate-smart agriculture as a guiding principle for agricultural transformation

Extreme weather and other events associated with climate change represent additional challenges to the agricultural sector in developing countries and global food security. To address these issues, the agriculture sector will need to undergo significant transformation. Science has a pivotal role to play here in providing evidence of claims, trade-offs and synergies (Neufeldt 2013) to underpin appropriate policy and planning responses, and to identify innovations that can scale up to help make the transition to a climate-smart agriculture. For this to work successfully, however, it also means working at different levels (i.e., global, regional and national) with a wide range of stakeholders.

What is climate-smart agriculture and how can it help transform the agriculture sector and increase food security? Climate-smart agriculture (CSA) is concerned with moving the agriculture sector forward in order to achieve sustainable development (economic, social and environmental), while at the same time addressing food security and climate challenges. It is built on three main pillars (FAO 2013):

1. sustainably increasing agricultural productivity and incomes;
2. adapting and building resilience to climate change;
3. reducing and/or removing greenhouse gases emissions (GHGs), where possible.

Integrating climate change considerations into agricultural development planning provides a good entry point for the CSA approach. CSA is not based on a single technology or practice, rather, it requires site-specific assessments to be able to identify suitable agricultural technologies and practices (FAO 2013). For example, identifying climate-inclusive agricultural policies aimed at sustainable development with low vulnerability to climate change and low carbon emissions is part of what CSA is all about. It involves linking these priorities and stresses the importance of climate change as a driver of change for agriculture and at the same time acknowledging the role of agriculture as a driver of climate change (Verhagen 2014).

Not surprisingly, the word 'smart' in CSA refers to evidence-based agricultural development processes for short- and longer-term planning. To illustrate the role that CSA can play in increasing production in the face of climate-related challenges, a case study on growing potatoes in Ethiopia is presented.

Making agriculture more climate smart

Farmers are central to the attainment of CSA goals, so it is important to link and integrate these goals with farm-level activities. The enabling environment in which farmers operate is not limited to local conditions but can extend to regional, national governance, institutional arrangements, access to finance, technology and knowledge. The identification of local, national and regional barriers to adoption is critical, as they will determine the success of the options used.

In a short study focusing on farm-level intervention for CSA in potato production systems, a simple four-step framework was used (Figure 1). The first step of the framework aims at understanding the current situation including the development priorities; the second step focuses on the identification of management options that serve CSA goals. The next two steps of the framework address higher-level barriers and the strategies needed to overcome them. These last two steps require a good understanding of the socio-economic, institutional and political environment in which farmers operate.

It is only when the barriers are addressed through appropriate strategies that the earlier identified management options may become available to farmers.

Case study on growing potato in Ethiopia

Potato is an important global food crop, with a large untapped potential for improving nutrition security. The production of potato has increased dramatically in developing countries in the past two decades, and has now overtaken that in the developed world (Birch et al., 2012). In a recent study, researchers from Wageningen UR looked at specific potato growing areas in three countries with different environmental and socio economic conditions: South Africa, Ethiopia and the Netherlands. For farmers, the key objective was to be able to earn a living from the production of potatoes, so their main priority was to increase productivity regardless of the challenging climatic conditions.

Despite uncertainties in climate change scenarios, the anticipated impacts of climate change in Ethiopia are expected to be a shorter and drier growing season. This change will require adaptations in the current farming system in the Rift Valley (Ethiopia), such as the introduction of irrigation. This adaptation will result in a fundamental change in the potato production system as this will allow potatoes to be produced during the dry season. If water resources are available and used with care, such a transformation

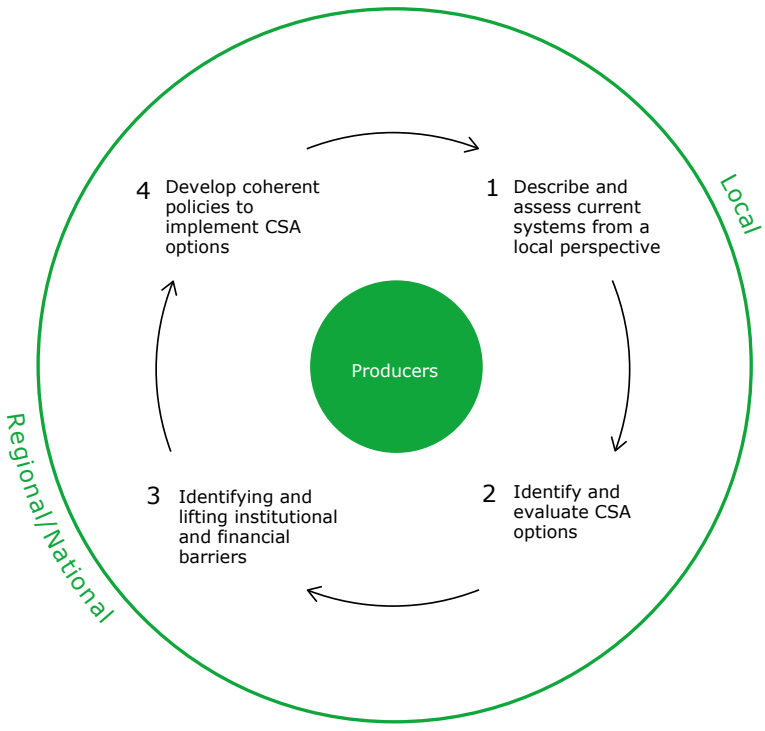


Figure 1 Simple 4-step CSA framework

of the potato production system could potentially create synergy. For example, less pests during the dry season could result in higher potato yields than in the wet season. However, there are also potential trade-offs such as the increased use of scarce water during the dry season and increased energy needed for irrigation.

Further, the potential of potato production to contribute to mitigating climate change is not expected to be significant. This can be attributed, in part, to the roughly 80% biomass harvested (for cereals this is about 50%), as well as due to the fact that the soil is loosened during the planting and harvesting of the tuber, making the accumulation of carbon in the soil difficult.

There are big yield gaps in the Rift Valley and attempts to reduce these will inevitably result in trade-offs among CSA attributes. To increase potato productivity in the Rift Valley, considerably more (fossil) energy-demanding inputs will be required such as (nitrogen) fertilisers, pesticides, energy, which will increase GHG emissions per unit of land. The challenge, therefore, will be how to achieve higher potato yields in combination with lower GHG emissions per unit of produce.

Many farmers just do not have the 'know-how' to improve their agricultural practices and are too poor to invest in irrigation schemes and crop breeding and to get access to the inputs they need. The adoption of the identified CSA options requires an enabling environment that includes institutional, technical and financial support from government and the private sector. The main contribution of CSA is that long-term thinking on productivity, adaptation and mitigation goals becomes an explicit and integrated component of sustainable intensification of agriculture which allows for higher scale interventions that help farmers to move forward.

Contributors
Jan Verhagen *jan.verhagen@wur.nl*
Ben Schaap
Mirjam Pulleman
Huib Hengsdijk
Thom Achterbosch

Advancing smallholder vegetable production systems in Vietnam and Tanzania

Rapid population growth and changing consumption patterns in response to healthier eating habits and rising incomes have been fuelling the demand for vegetables and fruits in many developing countries. Juxtaposed to this has been the loss of prime agricultural lands to sprawling urbanisation and land degradation consequent on deforestation in highland areas to satisfy fuel needs and expansion of agricultural land. Innovative ways to raise productivity on existing agricultural lands and to improve rural livelihoods are therefore necessary to continue to adequately feed local populations and stem the flow of people to the urban centres.

Experts from Wageningen UR have been working with researchers and smallholder farmers in two very different regions of the world, South East Asia and East Africa, to develop innovative ways to increase vegetable production. Project sites were set up in Vietnam and Tanzania and various scenarios considered using actual data gathered from the two countries to support their analyses. In Vietnam, they looked for the best way to improve yields taking into consideration local conditions such as the limited availability of suitable lands close to urban areas (because of the perishability of vegetables), labour, planting materials, yields and profitability. Alternatively, in Tanzania they monitored the way farmers produce seedlings and the profitability of growing vegetables there.

Vietnam: year-round supply of vegetables

In Vietnam, as in many other South East Asian countries, vegetables are often produced in rotation with two crops of flooded rice (i.e., rice grown in fields temporarily flooded with water) annually. This system has two main disadvantages – after the rice crop has been harvested, raised beds are constructed for vegetable production, and then flattened again for rice production; this practice makes the soil compact and less suited to vegetable production.

To overcome these problems, the team set about designing and testing for a sustainable year-round vegetable production system in the Red River Delta. It should be mentioned here that the proportion of land area cropped with vegetables is minor

compared with that cropped with rice. The results of the study were very encouraging and the initial reaction of farmers has been enthusiastic. Results showed that yields went up and that farmers could get good returns from growing vegetables. The returns would even be higher when the vegetables would be directly sold to city wholesale markets. The amount of labour needed to grow the vegetables also increased (Table 1). Planting vegetables year-round is therefore not only an effective way to increase farmers' income, it also leads to more employment opportunities in rural areas.

Land preparation in the Red River Delta, Vietnam

Tanzania: seedling and vegetable production

The use of high-yielding vegetable cultivars in Africa is a recent phenomenon and the use of many modern production methods is still considered too expensive by the average African vegetable producer. This is in contrast to South East Asia where the use of high-yielding vegetable cultivars and production technology, such as mulching and water- saving drip irrigation equipment, is increasingly the norm.

Testing the new systems in the field, Red River Delta, Vietnam

Tanzanian vegetable growers in the Arusha region currently produce seedlings in open field nurseries. Seedlings are later transplanted into the fields. Often the percentage of seedlings that can be used in these fields for production is low. With farm-saved seeds or other low-cost seeds, the cost implications of this practice are not so high, but when expensive high-yielding varieties are used, it is important that all or most of these seeds result in a productive plant.

Results of the 'African vegetables' project showed that it would be very difficult to increase the percentage of seedlings produced in open field nurseries. However, for seedlings that were first produced in trays in a small plastic house nursery constructed from locally available material, the percentage of seedlings that could be used in the fields increased dramatically. Calculations showed, for example, that if tomato was grown in this way using conventional seeds, around €40 per hectare

Nursery built from locally available materials

Table 1 Profitability of vegetable production in the Red River Delta, Vietnam

Vegetable production system	Profit per hectare per day at local prices (kVND)	Profit per hectare per day at city wholesale market prices (kVND)	Labour needed per hectare per day (hours)	Income for one day of work (kVND)	Potential income for one of day work (kVND)
'Profitability'	321	797	78	33	83
'Labour'	277	877	52	42	135
'Traditional'	168	406	40	34	82

Exchange rate: kVND = 1,000 Vietnamese Dong; 1 € = 23 kVND

Table 2 Profitability of vegetable production in the Arusha region, Tanzania

Crop	Profit per hectare per day at local prices (kTZS)	Labour spent per hectare per day (hours)	Income for one hour of work (TZS)
Eggplant	2.8	4.6	797
Cabbage	16.3	6.0	695
Carrot	17.0	6.4	619
Potato	15.2	5.6	601
Sukuma wiki	18.9	6.3	897
Tomatoes (non-staked)	27.4	9.3	583
Tomatoes (staked)	23.4	12.7	615
Average	17.7	7.1	681

Exchange rate: kTZS = 1,000 Tanzanian Shilling; 1 € = 2.2 kTZS

could be saved. The savings were even bigger for hybrid seeds – about €800 per hectare.

Production and profitability

At first it was difficult to get the farmers to record the data such as time spent in the fields, the amount and type of fertilisers used and planting materials. However, once they started recording the data and an analysis was made of the production costs and the returns, the farmers were amazed at the results (Table 2). The average earnings for a farmer (per hectare) on a daily basis can be up to three times the local daily wage for work done in the vegetable fields, suggesting that if farmers budgeted properly, they could possibly invest in modern production methods if they wanted to. The worthwhileness of doing this was even further underscored by the results from a collaborative project that showed that the yield of a traditional African eggplant cultivar could be increased from 8 metric tonnes per hectare to just under 30 metric tonnes per hectare by using only modern production methods. A spin-off of the project has been the changing attitudes of farmers towards keeping records, with many resolving to continue monitoring their activities.

Harvesting tomatoes

Land being prepared for planting by a smallholder farmer

Potential of the vegetable sectors in Vietnam and Tanzania

The case studies demonstrated the excellent opportunities for increasing the productivity either by increasing yield per hectare and by increasing the number of vegetable crops in rotation annually, or by doing both. Vegetable production therefore, has the potential to provide smallholder farmers with increased income and employment opportunities as well as to help stimulate rural development. However, to ensure future vegetable production capacity and the livelihood of farmers, attention must also be paid to the preservation of good vegetable production land in places close to sprawling urban areas and to proper soil and water management, especially in the mountainous areas.

Contributors
Arij Everaarts *arij.everaarts@wur.nl*
Jacques Neeteson
Pham Thi Thu Huong
Herman de Putter
Mathew Abang
Paul Struik

Strengthening farmer-firm relations in the food chain

In many developing countries, smallholders form the backbone of the agricultural sector. There is the concern, however, that they will not be able to supply sufficient food to help meet the needs of an expanding population in the future. Support is especially needed to improve their productivity and to strengthen their capacities to respond to the increasingly stringent quality standards imposed by markets. In many instances, smallholders do not have the means to respond to these demands. They lack adequate services – credit, inputs, market information and training – to be able to respond to the quantity and quality requirements of the retail and processing industry. More information on the outcomes of these supportive policies and projects are needed to support policy decisions and increase effectiveness.

Private companies have been providing support services to farmers either through contractual arrangements or through certification schemes that provide access to credit, markets and training. Often development aid is used to facilitate farmer-firm relations that link smallholders to markets or service providers. The Dutch government supports companies that want to source from smallholders through some special subsidy programmes, for example, through the Private Sector Investment programme (PSI) and the Food Security and Sustainable Development Fund (FDOV). Using public funds to support private sector companies means that there is a need to demonstrate that these funds have been used effectively and that the interventions have had a positive impact on development. However, it is difficult to measure this impact because there are so many intervening factors and numerous other actors that influence the outcomes of these farmer-firm relations, next to the support that is being provided. This has motivated Wageningen UR researchers to develop new methods to collect evidence and verify the impact of this support. As a result, knowledge tools were developed in three areas:

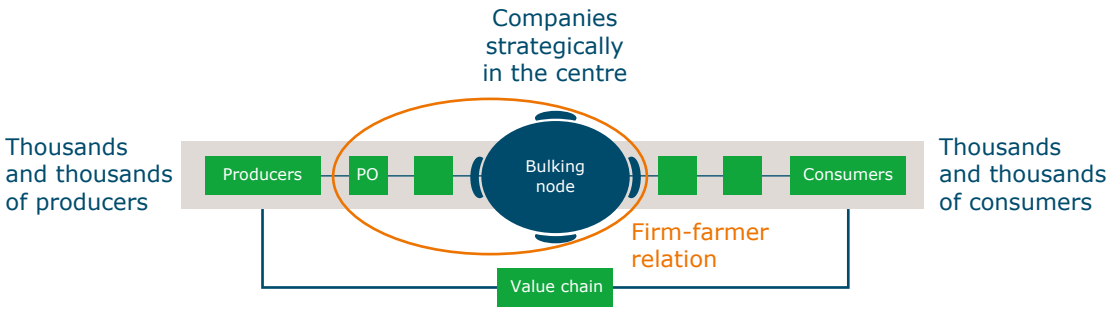


Figure 1 Encounters in the value chain

Key: PO – producer organisation (used interchangeably with the farmers' organisation)

1 Farmer-firm relations

Farmer-firm relations only work when there are benefits on both sides. The company provides access to an attractive market, for example, to supermarkets or export markets, and needs farmers to provide the produce. This creates a variety of forms of farmer-firm relations. The lack of trust between farms and firms can be a strong barrier to market integration. The commercial transactions in the value chain are based on economic interest, so farmers and firms have to be able to 'talk business'. This is not easy to do because there is often a wide cultural gap between the two groups. There is also a difference in market power. Firms tend to have far more resources and much more access to information than farmers, especially smallholders. In order to conduct profitable business and sustain their relations, farmers and firms need to have some mutual understanding of each other and there must be a minimum level of trust between them. To facilitate this, the Wageningen UR Centre for Development Innovation (CDI) developed the tool 'It takes two to tango' (Schrader et al., 2012). The tool uses detailed semi-structured interviews to gather information on each other's perspectives and interests, the results of which are discussed during workshops. It was developed using several business cases in Africa, in Benin, Ethiopia, Kenya and Rwanda. The tool helps groups of farmers and firms to gain an insight into each other's motivations, realities and perceptions. With the aid of a facilitator, the tool helps them to better understand each other so that they can decide to do business together. The resulting farmer-firm relations make it possible for farmers to access more remunerative markets, which stimulates local economic development and helps to reduce poverty.

2 Collective marketing

Researchers from LEI Wageningen UR studied the impact of grants on producer organisations of smallholder farmers in Bolivia. The aim of the subsidy fund was to stimulate the collective marketing activities of farmer organisations in Bolivia, for example, a processing plant or a storage facility. Evaluating this impact was challenging, especially as the businesses were in the start-up phase, when turnover and profits are still low. It was decided to focus the research on the impact of the funding on the capacities of the producer organisations to organise themselves in the management of their collective marketing activities. With the grant, the group started new activities and needed to define (or refine) internal rules about pricing, quality control and payment systems. The researchers developed a tool for assessing how well these producer organisations performed in striking this balance between the interests of the group and the interests of the members. The tool captures qualitative information on ten common 'tensions' in collective marketing (each group developed specific solutions to contain these tensions), and explores if these have changed as a result of the new business. The tool made it possible to rank organisations and to benchmark them on their organisational performance (Ton et al., 2014a).The research documented practical experiences from which farmer organisations can learn from one another. Organisations that devise and implement simple and cost-effective rules and regulations are more resilient and have less internal tensions.

3 Research for advocacy

The Empowering Smallholder Farmers in Markets programme (ESFIM) supported the advocacy capacities of national farmer organisations (NFOs) to create a more favourable policy environment for farmer-firm relations that improve smallholder market access. The programme, led by LEI and implemented with the Natural Resources Institute (NRI) and the Centre de coopération international en recherché agronomique pour le développement

(CIRAD), was co-financed by the European Commission, the research programme on Global Food Security and other donors. It gave NFOs in 11 developing countries the opportunity to contract local experts to strengthen the evidence-base of their advocacy proposals. In a highly participative process, each NFO analysed key advocacy issues for which research support was most needed. This resulted in a diversity of themes and advocacy processes, for example, research and advocacy on the role of cooperatives in Uruguayan innovation policies, a simulation game on market dynamics in a commodity exchange in the Philippines, a review of various seed multiplication programmes in Malawi, and legal and administrative hurdles preventing smallholders from selling to government procurement programmes in Peru and Bolivia (Ton and Proctor 2013).

To assess the impact of these research support activities on the advocacy capacity of the NFOs, the researchers used a self-evaluation technique, in which board members considered a list of statements covering five capacities that are deemed necessary for effective advocacy. The information obtained was used to reflect with the board on ways to improve their capacities in the future.

Moving forward in farmer-firm relations

The research (see Ton et al., 2014b) served to inform policy- and decision-makers in the government and development sector about the effectiveness and replicability of instruments used in markets and value chains aimed at improving the livelihoods of smallholders. The three tools to facilitate and assess development impacts in farmer-firm relations laid the basis for methodological approaches in other areas. For example, in a multi-year programme, Pioneering Real-time Monitoring and Evaluation (PRIME), which is examining the effects of export promotion and management training by the Centre for the Promotion of Imports from Developing Countries (CBI) and the Netherlands Senior Experts (PUM), and in projects that assess the impacts of certification schemes like Utz Certified and Rainforest Alliance.

Contributors
Giel Ton *giel.ton@wur.nl*
Ted Schrader

Driving innovations in the agri-food system

In many developing countries, targeted action will be needed to develop the existing agri-food system in order to meet the challenge of expanding the supply of sufficient, healthy, and nutritious food in a sustainable and efficient manner. Based on practical experience in the field, researchers from Wageningen UR have gained some insight into the innovation processes within the agri-food system. They have identified general patterns in the development of this system, and propose a generic model and a set of interventions for action towards speeding and scaling up a process of change within value chains.

As many as ten cases in different agricultural sub-sectors and stages of development are being studied, including vegetable and root crops, poultry farming, and high-end food chains for fresh dairy and meat products. Study sites are located in Ethiopia, Ghana, Kenya, Mexico, South Africa and Vietnam.

Description of the agri-food system development model

The agri-food system development (AFSD) model is used as a kind of map to help guide the process of driving innovations. Four stages of value chain development can be distinguished (Figure 1): *Informal*: subsistence or smallholder farmers marketing surplus to local fresh markets; *Local chain*: emerging farmers marketing to wholesale markets; *Formal chain*: emerging or commercial farmers marketing to wholesale, retail or out-of-home consumption markets; *High-end chain*: commercial or industrial farmers selling to retail or specialised markets. It assumes that agri-food value chains behave in a way typically associated with complex adaptive systems. There are three major phases of transition hypothesised in the AFSD model and they form a sort of barrier between the different stages. In developing and emerging market economies, the transaction costs involved in moving up the ladder towards more advanced value chains can be rather high as new production-marketing mechanisms and systems have to be developed when markets are functioning poorly or are non-existent

To examine the wide range of agri-food value chains and their differentiation, they are plotted in the model on the basis of a) their level of product and production sophistication, and b) the level of

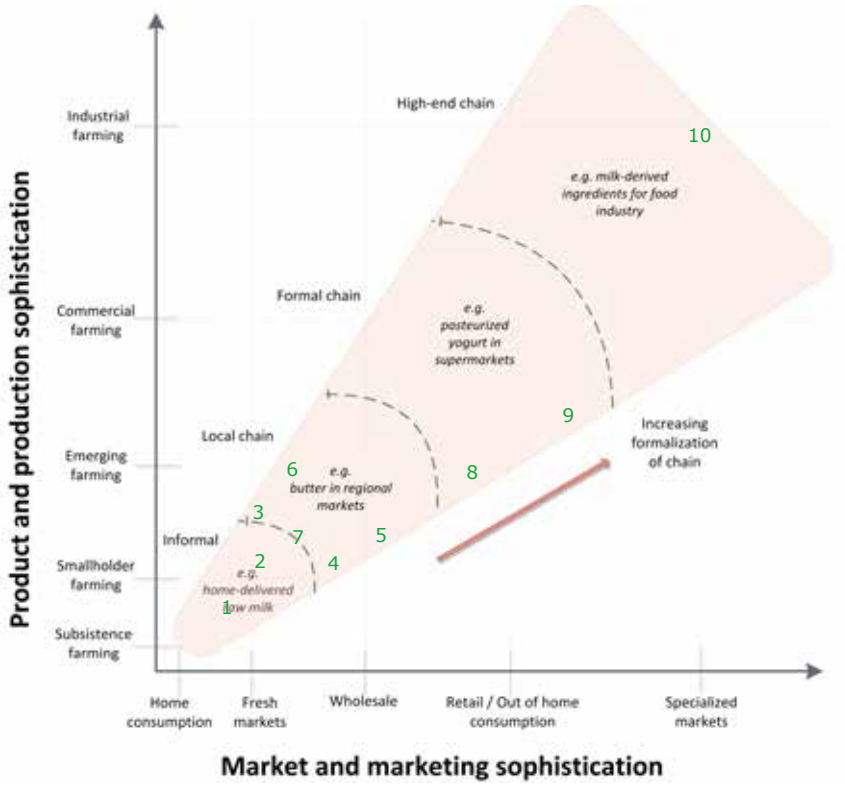


Figure 1 AFSD model showing pathways for value chain development

market and marketing sophistication. The cone-shaped area in the diagram represents the area where cases can be positioned. It shows that higher up in the scales the options for differentiation increase. The location of the barriers where the hypothesised phase transitions are likely to take place is drawn into the diagram as well. These are frontiers or tipping points where, once passed, a return to the original state is impossible. In the model this transpires when, viewed from an original position, a new product(ion) *and* new market(ing) position in the diagram has been obtained in a different phase. The cases presented in Table 1 have been plotted in the ADFS model (Figure 1).

From analysis to a strategic action plan

Case number 8 on the marketing of milk through dairy business hubs in Kenya is a good example where intervention has helped the sector move from a local to a formal chain. An interventionist approach to agri-food system development is useful in order to avoid 'lock-in' and to keep the system moving towards meaningful change within the context of food security.

Box 1 What happens in agri-food value chains when a collective innovation process is put in motion

Reduced transaction costs in production processes can be to the benefit of producers (higher margins) or consumers (lower prices or better products) or both, depending on the nature of competition. When cost reduction is at least partly passed on to consumers, it may create additional demand from existing and possibly new consumers, particularly for the food products that are part of richer diets such as livestock products or processed foods. The expanded demand may result in higher farmgate prices and a higher income for producers, which can contribute to an upward spiral of the local economy. To keep the process in motion, it is critical that at least part of the cost reduction is used to beef up producer margins and invested into productive assets, to deliver the necessary output expansion and stimulate entry of new producers. Once this is achieved, the next challenge in the AFSD model is to ensure continued innovation and transition in the agri-food system. Innovation platforms can play a pivotal role in ensuring that the process is continued.
Note: the AFSD model uses the 'asset pentagon' of the Sustainable Livelihood Approach (SLA) to analyse the transition process from smallholder producer and/or micro entrepreneur to emerging producer and/or small to medium-sized entrepreneur.

The researchers apply approaches such as the Chain-wide learning (CWL) to kick-start an innovation process. This methodology was originally developed to link smallholders to modern markets (Vermeulen et al., 2008) and has been adapted in such a way that it results in the development of a strategic action plan that aims at substantially reducing the level of transaction costs in the agri-food value chain. Transaction costs are key to whether a business can operate profitably within the agri-food system and have to do with the costs involved when participating in the market. At the same time, as part of a strategic action plan, the groundwork is being laid to enhance the particular agri-food value chain case in a new period. For example, when an agri-food value chain develops, a new marketing model may need to be initiated. The strategic plan may anticipate this next period situation.

A set of interventions for moving value chains up the development ladder

Seven types of interventions are available to drive the innovation process further. Strong supportive evidence from the cases shows that these interventions are most effective at a particular stage, and hence are connected with the starting position of the specific case. To transit from stage 1 to 2, typically Rural Peoples' Organisations (RPOs) and Agribusiness Development (ABD) seem to be most effective; to transit from stage 2 to 3, these are Public-Private Partnerships (PPPs) and Corporate Social Responsibility Initiatives (CSRI); and to transit from stage 3 to 4, these are Supply Chain Management (SCM) and Metropolitan Food Clusters (MFCs). The CWL methodology can be used in all phases. The intervention types take advantage of the income and multiplier effects and help agri-food value chains develop their product(ion) and/or market(ing) sophistication.

The intended result of each particular intervention is an expansion of the volume or quality of output in response to demand, which may result in rising income opportunities throughout the value chain and subsequent multiplier effects in the economy (Box 1). Along the pathway of the innovative change of the agri-food system, the innovation process can be further promoted by institutions like innovation platforms, communities-of-practice, agribusiness clusters, business-hub networks, rural transformation centres, etc.

Drawing on the example of the dairy sector in Kenya, dairy business hubs have been springing up around the country, currently providing services to some 25% of smallholder farmers. This case shows how the innovation process driven by PPP interventions has led to scaling up within the sector – larger numbers of smallholder dairy farmers have come together to supply their milk through hubs and this in turn has created momentum for the sector to transition to the formal value chain.

Box 2 Next period scenarios: Coping with uncertain futures

Building on the illustration in Box 1, it can be expected that all chain actors will, to some extent, convert the temporary extra income gained into productive assets. This expectation is based on the assumption that chain actors would like to earn the extra income on a more permanent basis. Principally, this will lead to a structurally higher output of the agri-food value chain. If the extra output is not being absorbed by extra demand, the development of the agri-food value chain comes to a halt and income effects peter out. The interventionist approach in the AFSD model will accommodate for new futures by including the creation of extra market demand into the intervention.

Incorporating various future development pathways in planning interventions

The AFSD model incorporates an innovative 'next period scenario' concept. By integrating scenario analysis into the planning process of an intervention, the planning can accommodate for the next-period situation. This is a way to cope with uncertain futures of adaptive, complex systems (Box 2). Case number 9 is a good example where future scenarios have been applied to the intervention of connecting small farmers to a retailer of a packaging centre. The AFSD model indicated that problems might occur in meeting the retailer's requirements because the farming systems have not yet adapted to new market demands.

To test the validity of the AFSD model as well as to refine it further, a number of cases are being described and researched, mainly focusing on agri-food value chains (Table 1). This evidence base of the Designing Innovative Pathways for Agri-food Systems (DIPAS) project is the source of empirical and supporting data. The project owners have been collaborating with an extensive network of researchers and research institutes, especially in Ethiopia, Kenya, South Africa and Ghana. For more information on the specific cases, the case 'owner' can be contacted directly.

Table 1 Overview of cases

	Case	Location, Country	Sub-sector	Phase	Action	Owner	Collaborators
1	Straw mushroom value chain	Vietnam	Upland crops	Smallholder/ fresh market	CWL	Helder	IAS, CTU
2	Locally traded and processed cassava	Kumasi, Ghana	Roots, tubers	Smallholder/- entrepreneur	CWL	Helder	BIRD/KNUST
3	Locally traded and processed tomatoes	Nakuru, Kenya	Fresh produce vegetables	Small-emergent/ fresh market	CWL	Helder	Egerton University
4	Vuselela sugar smallholder production scheme	KZN, South Africa	Sugarcane	Smallholder/ processing-wholesale	CSR	Helder	Tongaat Hulett Natal
5	Ware potato value chain	Harar, Ethiopia	Roots & tubers	Smallholder/ fresh market	CWL	Helder	Haramaya Univ, CASCAPE project
6	Commercial poultry production for urban markets	Ethiopia	Poultry	Emergent/fresh market	CWL, ABD	Vernooij	HAPP, EPPA
7	Local milk marketing	Asella, Ethiopia	Dairy	Smallholder/local market, processing		Van der Lee	Haramaya University
8	Marketing of milk through dairy business hubs	Kenya	Dairy	Smallholder/ processing-wholesale	ABD, PPP	Van der Lee	SNV
9	Direct farm pilot evaluation	Limpopo, South Africa	Fresh produce vegetables	Smallholder - wholesale	SCM	Groot	TechnoServe, Massmart
10	Agropark development	Mexico	Dairy, poultry, meat, fruits, vegetables	Industrial for high-end	MFC	Groot	FOCIR, SAGARPA

N.B. Cases with Friesland Campina in Vietnam and Indonesia are being considered, pending start-up of projects there.
Key: BIRD/KNUST-Bureau of Integrated Rural Development-Kwame Nkrumah University of Science and Technology; CASCAPE-Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia; CTU-Can Tho University; EPPA-Ethiopian Poultry Producer Association; FOCIR-The Capitalization and Investment Fund for the Rural Sector in Mexico; HAPP-Holland-Africa Poultry Partners; IAS-Institute of Agricultural Sciences (of South Vietnam) SAGARPA-Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food in Mexico; SNV-Netherlands Development Organisation.

Contributors
Jan van der Lee *jan.vanderlee@wur.nl*
Jan Helder
Jim Groot

Scaling innovations: Do we know what makes contexts conducive?

Many policy makers, business partners and researchers often think about innovations related to food security as the natural outcome of best practices and that scaling can be easily done once it becomes the responsibility of some manager or engineer. However, work done by researchers from Wageningen UR found that the scaling of innovations has tended to be an unpredictable, complex process, depending on the interaction between the 'DNA' of the innovation and the context within which it is taking place.

Governments, donor agencies and some private companies are often strapped for funds to invest in agricultural technical or organisational innovation processes, so it is important for them to know whether a particular innovation will have the desired impact on the lives of people, especially the rural poor, and result in better access to food grown in a sustainable way. For innovations to come to scale, it is important to understand how an innovation takes hold. The central issue therefore, is not whether it works, but whether an innovation will scale, how it works, for whom it works and the context – under what conditions is the innovation likely to achieve scale? To analyse the scalability of innovations, a group of researchers led by Jolanda van den Berg, a development expert at LEI Wageningen UR, drew on the 'realist' methodological framework for inspiration. They adapted and developed it, under the KB1 'Innovation systems and scaling in practice' project, to help them identify the processes triggered by a programme or innovation, taking into consideration that the context has a bearing on outcomes (Figure 1). Cases in three countries made use of this methodology: Benin (Integrated Soil Fertility Management), Kenya (Dairy Business Hubs), and a case from Denmark on integrated pest management, illustrating the wide-scale applicability of the framework, in very different agricultural and innovation settings in providing insights into the innovation process.

Research on Integrated Soil Fertility Management in Benin showed that with innovation, new and increased levels of transaction came about and that the accompanying feedback mechanisms triggered interactions between different innovations at the local level. The emerging combination of technical and organisational changes, as well as the growing involvement of different players in the selection of options, encouraged the spread of an integrated approach to managing soil fertility. The level of cooperation between farmers in Ifangni, South East Benin, in growing yellow maize and regional chicken farmers who buy it for feed, is a good example of this. Yellow maize was introduced to

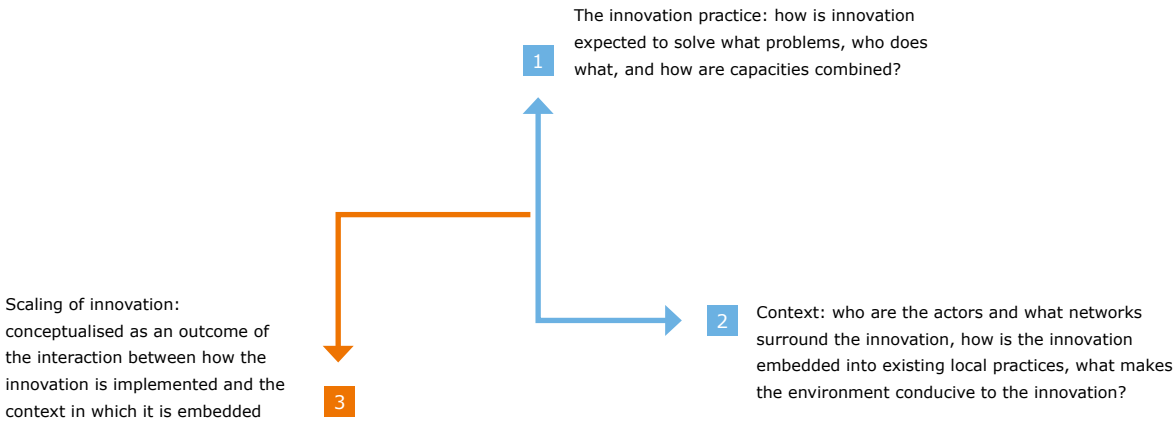


Figure 1 Scalability as an outcome of an interplay between innovation and context
Adapted from Pawson and Tilley (1997)

farmers to produce chicken feed and assistance was given to develop local small-scale chicken farms. The resulting chicken manure is then sold back to the maize farmers as fertiliser. The growing interdependencies between buyers and sellers, who previously did not interact, triggered an evolving process of selection, improvisation and technical change altering soil management in a larger area.

The case study in Kenya on the scaling of Dairy Business Hubs (DBH), an input and service provision model that led to the strengthening of linkages between input supply and milk marketing around milk collection centres, showed the interaction of the DBHs along with several contextual factors were key to the success of scaling. These factors included: a robust, urban demand for quality dairy products; availability of sufficient feed and fodder to meet that demand cost-effectively; the presence of farmers and entrepreneurs with the management capability to gradually expand the set of services offered by DBH in line with smallholder farmer demand for inputs and services; and a business climate that facilitates stronger linkages between value chain actors, in which development organisations play an important role in facilitating investments in hardware and capacity building. These factors resulted in stimulating the rapid expansion of DBHs throughout in Kenya. For example, over the course of a decade, 35 DBHs sprung up, providing tailored services to some 25 percent of the 800,000 Kenyan dairy farmers.
In Denmark, the Integrated Pest Management (IPM) case provides an added perspective to scaling. Although IPM solutions were being tested in the field, it was the very process of advisors supporting farmers to analyse future problems, experimenting with possible solutions that set the scene for innovation and IPM. Three so called scaling forces are identified:

1 broadening the time horizon and directions of search,
2 stimulating farmers to take the lead and experiment with solutions,
3 the changing role of advisors from solution supplier to becoming the sparring partner of farmers.

It is these scaling forces that might have a more sustainable effect on the reduction of pesticide risks than the scaling of a specific IPM technology. So, besides asking how a certain technology can be scaled, perhaps the thought process should be reversed, to start from the intended impact, 'backcasting' (a way of describing how you would want the future situation to be), to determine which scaling processes are needed to achieve the desired outcome.

Innovations unfold in unexpected ways

The cases highlight how useful the framework has been in understanding innovation processes. Further, they show how innovation is a continually evolving bundle of technological, organisational and institutional processes, involving networks of multiple actors whose ideas and knowledge lead to adjustments and improvements to innovations along the way. There is also the suggestion that scaling can be engineered if the innovation already has clear boundaries and a strong functionality for managing supply of inputs and outputs. The cases in Benin and Kenya indicate that scaling seems to be less easy to steer in settings where the innovation is more open, where different actors seek to combine or select bundles of technical and organisational options.

Advisors and farmers interacting with each other in the field

Technologies are often seen as central to innovation, transferable from one context to another, but in practice, technologies are shaped by people using them within their social, economic and institutional context. Social and institutional changes are always needed so that new technologies can be fully integrated into local practice. Scaling then becomes more dependent on a selection of 'recipes' and on how induced interventions find a fit with established processes of problem-solving and handling risks. Hence, whether a technical or organisational innovation achieves scale is hard to predict or plan. Some of the cases also showed that innovations are more likely to scale if rigid pre-planned prescriptions about what to do are avoided and if these innovation processes are supported over a long time in a flexible way adapted to the specific context and the evolving opportunities. The scaling of innovation therefore centres on building the capacity of institutions to interact closely on the ground with diverse stakeholders and to acquire the skills needed to support making the fit between intervention and context conducive to scaling.

Figuur 2 Dairy business hub associated services in Kenya

Contributors
Jolanda van den Berg *jolanda.vandenberg@wur.nl*
Jorieke Potters
Jan van der Lee
Sietze Vellema
Pieter de Wolf

Towards solving the food puzzle

For a food secure future, transformative changes in the world's food systems are needed in order to deliver sufficient nutritious food at affordable prices to the consumer, with less pressure on natural resources. In the process, agriculture will have to continue to support the livelihood of hundreds of millions of families. The research programme Global Food Security: Scarcity and Transition has been contributing to this challenge by helping to increase the understanding of processes underlying food insecurity and by providing tools and knowledge that are being used to underpin policy and action on agricultural development and food and nutrition security.

Putting the pieces together

Broadly speaking, two major areas of effort to improve food and nutrition security have been identified: (1) improving livelihood opportunities by breaking the vicious circle of living in poverty, the lack of command over the food resources that prevent hunger and malnutrition and support health, and the inability to escape a vulnerable subsistence; (2) achieving a sustainable growth path for the world's food systems, by accelerating agricultural productivity growth and by mitigating expected instability on global and local food markets (emanating from, for example, climate change, policy, or conflict).

The recurring food price hikes in recent years, persistent hunger and malnutrition, continued depletion of natural resources and stagnating levels of productivity growth in agriculture have become a global priority. A common effort is therefore required to develop a sustainable and resilient agriculture for food systems that provide affordable nutritious food for all.

Towards a prioritised research and knowledge agenda

The solutions for food insecurity, hunger and malnutrition are embedded in long-term strategies aimed at improving livelihoods and health, strengthening the management of natural resources via growth and innovation, while at the same time addressing specific concerns such as security, equity, gender and cultural diversity. Informing policy- and decision-makers at all levels in the supply chain and governing institutions on plausible options and directions for innovation and investment in the coming years is imperative in order to support beneficial directions for change. During the course of the research programme, several stakeholder consultations were organised around these priorities, the results of which are now being used in the definition of a future research and knowledge agenda for Wageningen UR.

Views on knowledge contributions

Stakeholders have voiced their appeal for coherent visions on the pathways and options that sustain people's access to healthy food with high nutritional value and the sustainability of agricultural production. A key issue to understand is if and how a diverse agricultural production system contributes to a healthy diet, and how specialization and diversification create synergy or trade-off through their impact on gender balance in food consumption, resilience to withstand crises and other mechanisms that drive food and nutrition security. Although the coherent view is not complete, several elements that will contribute to

reaching this more integrated view are apparent. Some suggestions for elaborating on the research agenda relate to:

- *Fisheries:* There is limited insight into the tension between the diversity of local production systems in relation to innovation, supply chain development, consolidation and power. The role of fisheries and biomass from oceans deserves more attention in the integrated food-energy-water issues.
- *Agricultural practices:* Clarity is needed regarding the uncertainties and trade-offs related to agricultural practices – not only in regions where management practices are characterised by low skills and incomplete information (particularly in low-income countries), but also in regions and countries transitioning to high output agriculture, for example, areas undergoing urbanisation and middle-income countries. Safeguarding food safety and the prevention of food losses requires solutions across the entire supply chain.
- *Food insecurity in fragile states:* Some of the hotspots of food insecurity have weak institutional environments and are afflicted by conflict – there is a need to assess solutions to food insecurity in these fragile states.
- *Managing risk and instability in the food system:* The integration of agricultural markets is key to connect supply surpluses and deficits, yet it also advances the potential transboundary impact of shocks in the global food system. Information and communication technologies such as mobile phones and data networks and technology in changing the optimal practices and managing or preventing risk and instability can play a vital role here.
- *Meeting the increasing demand for fresh and nutritious food:* The increasing demand for high-quality and safe food by more affluent consumers in low- and middle-income countries is creating dramatic change in the organization of food processing and retail. Upgrading of agricultural value chains for crops, livestock, fish could benefit welfare and stability in the long run provided that enabling policies and checks and balances are in place.

Working towards solutions

Key knowledge challenges emerging from the domain of food and nutrition security lie in the integration of perspectives on sustainable consumption (access) and production (supply) within the framework of resilient food systems. There is a long record of separate interventions motivated by considerations of either agriculture/food, or nutrition/health. Although advances have been made in this type of research, working in silos has failed to produce the integrated, cross-cutting perspectives and solutions that are needed to overcome the challenges at hand. The integration is needed across three mutually related outcomes:

Sustainable agricultural development pathways

Production systems for crops, livestock, forestry and fisheries face major constraints for efficiently increasing (land, water and labour) productivity in settings of scarce natural resources, and large climatic variability and diverse institutional arrangements. The options for sustainable intensification of resource use should be considered along with conservation needs and the need to reverse degradation of the ecosystem – which calls for an integrated, yet differentiated analysis. Thresholds for improving input efficiency and output productivity within the context of fragile and vulnerable regions need to consider principles of adaptation, resilience and flexibility. Reducing yield gaps and crop losses and raising productivity and environmental protection in livestock farming therefore require simultaneous interventions at the level of biophysical constraints (input availability), knowledge (input use, skills levels, young farmers) and economic incentives (credit and assured land rights that favour adoption). With respect to the intensification and/or integration of mixed cropping and agroforestry systems and the transformation of transhumant animal systems and design of innovative terrestrial and acquatic systems special attention needs to be paid to spillovers and internal synergies, as well as risk management (and sometimes reputation) motives.
In marginal areas already under environmental or other stresses, or in high input systems, extensification towards more appropriate and sustainable production systems may be the solution. Finding the right balance between societal and environmental realities is key in the development of production systems.

Value chains and markets support dietary transitions

Undernutrition in energy terms remains widespread in settings of conflict and (chronic) crisis. Micronutrient deficiencies are much broader phenomena, which occur alongside overconsumption. Climate change contributes to health risk and livelihood vulnerability in remote areas. In the newly urbanizing and rapidly growing metropolitan settings, access to safe and nutritious food and healthy diets is needed to prevent huge concentrations of health risk.

The bulk of the world's food never reaches a formal market place. Food prices and their fluctuations

around a trend are to a large extent determined on local markets. Nonetheless, the ways of organizing food value chains and markets has a huge (potential) impact on the access to nutritious food and the stability of nutrient intake. Deeper insight is needed, therefore, in the options for intervention within supply chains and markets for more favourable FNS outcomes, and how these complement safety nets to safeguard the livelihoods of the vulnerable members of society.

Particular attention should be paid to gender differences in income-generating activities and in supply chain transactions that perpetuate nutrition deficiencies at the intergenerational level. Access to food that is of acceptable quality and safe is also related to prevailing health, education, water and sanitation regimes and on/off-farm business cases for agricultural intensification and labour opportunities at the small and larger scale.

Upgrading of agricultural value chains (crops, livestock, fish) has the potential to strengthen livelihoods and contributes to an expanding supply base that could accompany dietary transitions through concerted efforts of agents in the chain, including retail and corporations, policy-makers and regulators. Upgrading entails strengthened food trading systems (including storage, transport and reduced post-harvest losses and waste e.g. through agrologistics, producer organizations) and better integrated markets for farm inputs, financial services and risk management practices (insurance) and outputs. The scope for more integrated local and regional markets to permit a more equitable distribution of food and reduces risks of food inequality – provided that safety nets are in place – remains elusive. Adequate incentives for addressing these challenges also include governance regimes that enhance trust and increase reliability of food supply.

Stable and resilient food systems as international public goods

Food and nutrition security has a public good character, considering its fundamental role in economic development and (geographic and system-wide) transboundary effects that may arise from the collapse of food and commodity supply, particularly in (post)conflict regions. To support resilient food systems insights on the role of agricultural policies for reducing emerging risks (early crop failure warning; animal diseases including threats to humans, food scares), strengthening local governance and interregional trade, and enhancing trust and loyalty between supply chain stakeholders are required.

In several post-conflict areas, food production systems and the enabling environment need to be developed from practical non-existence. Climate change has the potential to drive the emergence of new sources of socio-political, environmental and economic risk in the food system and the trade relations with developed countries, where early detection of compromised food safety, animal or plant health is necessary for maintaining trust. The quality and safety control in sourcing regions needs strengthening even where public institutions alone face difficulties to monitor and enforce.

Public policy responses to the challenges differ widely across regions, and are struggling with coherence across domains such as agriculture, fishery, health and security. Ongoing market integration and ever more stringent food safety and quality standards - further reinforced through bilateral and multilateral trade agreements (e.g. the Transatlantic Trade and Investment Partnership, the Economic Partnership Agreements) - ask for more institutional coordination even if the current system of rules brings little push towards more sustainability and equity. The private sector, alarmed by looming difficulties in commodity sourcing and triggered by expanding global consumer markets, drives long-term agendas for transformation (particularly on sustainability) that require checks and balance through alignment with civil society, government and science.

Partnerships for solving the food puzzle and realising change

Wageningen UR's contribution to the Zero Hunger Challenge (proposed by the United Nations Secretary-General Ban-Ki-moon) will be achieved by engaging with stakeholders and decision-makers at different scales in a variety of spheres. Strategic partnerships for food and nutrition security research are in place with a range of actors including the government, private sector, civil society and knowledge partners in the Triple helix in the Netherlands and the low and middle income countries (particularly in partner countries of the Dutch food security strategy). Partnerships with industry include foreign branches of Dutch companies in emerging or developing countries, but also partnerships with local industries have been established. Some of the flagship programmes include industrial partnerships (through IDH Sustainable Trade Initiative, the Seas of Change community of practice, Global Agricultural Information Network and bilaterally), the Consultative Group for International Agricultural Research, the Bill and Melinda Gates foundation (which, for example, funds a programme on global yield gap analysis), the Ministry of Economic Affairs

(programme funding and public-private partnerships) and the European Commission (e.g. FOODSECURE, EAU4FOOD, SAFEFOOD). The research programmes at Wageningen UR are more and more collaborative in nature with other countries, for example, through the European facilities (Horizon 2020, ERA nets and Joint programming initiatives) and global initiatives such as the Agricultural model intercomparison network (AgMIP); the alliance for Climate Smart Agriculture, the Global Research Alliance on Agricultural Greenhouse Gases, the Livestock Dialogue, Exploration of the Oceans, Seas of Change and the Network of Excellence Postharvest Losses.

The extensive network that Wageningen UR has, especially its strong links to governments, industries, civil society and practitioners and its central role in the knowledge system around agriculture and food, makes it well placed to translate knowledge into practice. Whether it is through action-oriented partnership programs or cooperation for scientific excellence, Wageningen UR commits to contribute towards solving the food puzzle and eliminate hunger.

Contributors
Thom Achterbosch *thom.achterbosch@wur.nl*
Marianne van Dorp
Wim van Driel
Jim Groot
Jan van der Lee
Jan Verhagen
Ruerd Ruben

References and further reading materials

1 Geopolitical dynamics of scarce resources

Global trade or regional cooperation: a perspective from the Nile

Kummu, M., Gerten, D., Heinke, J., Konzmann, M., Varis, O., 2014. Climate-driven interannual variability of water scarcity in food production potential: a global analysis. Hydrology and Earth System Sciences 18, 447-461. www.hcss.nl/reports/the-emerging-geopolitics-of-food/121/

Suweis, S., Konar, M., Dalin, C., Hanasaki, N., Rinaldo, A., Rodriguez-Iturbe, I., 2011. Structure and controls of the global virtual water trade network. Geophys. Res. Lett. 38, L10403.

Martine Rutten, Lindsay Shutes, and Gerdien Meijerink, 'Sit down at the Ball Game: How Trade Barriers Make the World Less Food Secure', Food Policy 38, no. 0 (February 2013): 1-10, doi:10.1016/j.foodpol.2012.09.002.

Jean-Christophe Bureau and Sébastien Jean, *International Agricultural Trade and Negotiations: Coping with a New Landscape*, FOODSECURE Working Paper No. 8 (The Hague: LEI Wageningen UR, 2013), http://www.foodsecure.eu/PublicationDetail.aspx?id=22.

The balance between short-sightedness and utopian thinking

Sattari, S., Bouwman, L., Giller, K., Van Ittersum, (2012). Residual soil phosphorus as the missing piece in the global phosphorus crisis. M. PNAS 109, 6348-6353.9 www.pnas.org/content/109/16/6348

Yield gap analysis with local to global relevance – a review. Field Crops Research, in press. (2013). Van Ittersum, M.K., Cassman, K. G., Grassini, P., Wolf, J., Tittonell, P., Hochman, Z. www.sciencedirect.com/science/article/pii/S037842901200295X

Future harvest – the fine line between myopia and utopia (2011). Inaugural lecture, Wageningen University. Van Ittersum, M. K., 2011. http://edepot.wur.nl/169680

Innovative cropping systems paving new opportunities for smallholder farmers Vegetable production in Vietnam and Tanzania *(DL 4.1)*

Everaarts, A. P., de Putter, H. and Amon, W. (2011) A survey of field vegetable production in Tanzania. Applied Plant Research, Wageningen UR, Lelystad. iv+66 pp. http://edepot.wur.nl/195026 (accessed 2 February 2014)

Huong, P. T. T., Everaarts, A. P., Neeteson J. J., Struik P.C (2012) Developing permanent vegetable production systems for the Red River Delta, Vietnam. Act Horticulture 958: 53-58.

Huong, P. T. T., Everaarts, A. P., Neeteson J. J., Struik P.C. (2013) Vegetable production in the Red River Delta of Vietnam. I. Opportunities and constraints. NJAS – Wageningen Journal of Life Sciences 67: 27-36

Huong, P. T. T, Everaarts, A. P., Neeteson J. J., Struik P.C. (2013) Vegetable production in the Red River Delta of Vietnam. II. Profitability, labour requirement and pesticide use. NJAS – Wageningen Journal of Life Sciences 67: 37-46

A global spatial framework for agricultural productivity

Conijn, J. G.; Wolf, J.; Hengsdijk, H.; Descheemaeker, K.; Bindraban, P.S. (2013a) A generic methodology for calculating water and nutrient requirements for attaining target crop yields. First International Conference on Global Food Security, 29 September-2 October 2013, Noordwijkerhout, The Netherlands.

Conijn, J.G.; Bai, Z.G.; Bindraban, P.S.; Rutgers, B. (2013b) Global changes of net primary productivity, affected by climate and abrupt land use changes since 1981. Towards mapping global soil degradation. ISRIC Report 2013/01, ISRIC – World Soil Information, Wageningen, The Netherlands. http://www.isric.org/sites/default/files/Report%202013_01_total_SEC.pdf

Conijn, J.G.; Querner, E.P.; Rau, M.L.; Hengsdijk, H.; Kuhlman, J.W.; Meijerink, G.W.; Rutgers, B.; Bindraban, P.S., 2011. Agricultural resource scarcity and distribution: a case study of crop production in Africa. Wageningen: Plant Research International, (Report / Plant Research International 380) – 85p. edepot.wur.nl/165556.

Evert, F.K. van; Ruijter, F.J. de; Conijn, J.G.; Rutgers, B.; Haverkort, A.J. (2013) Worldwide sustainability hotspots in potato cultivation. 2. Areas with improvement opportunities. *Potato Research* 56 (4): 355-68. edepot.wur.nl/295752.

Haverkort, A.J.; Ruijter, F.J. de; Evert, F.K. van; Conijn, J.G.; Rutgers, B. (2013) Worldwide sustainability hotspots in potato cultivation. 1. Identification and mapping. *Potato Research* 56 (4): 343-53. edepot.wur.nl/295751.

Hengsdijk, H., Smit, A.A.M.F.R., Conijn, J.G., Rutgers, B., Biemans, H. (2014) Agricultural crop potentials and water use in East-Africa. Wageningen: Plant Research International, Business Unit Agrosysteemkunde. Rapport/Plant Research International report 555.

Jing, Q.; Conijn, J.G.; Jongschaap, R.E.E.; Bindraban, P.S. (2012) Modeling the productivity of energy crops in different agro-ecological environments. *Biomass and Bioenergy* (46) 618-33. edepot.wur.nl/238506.

Meijerink, G.W.; Conijn, S.; Hengsdijk, H.; Shutes, K.; Asseldonk, M.A.P.M. van; Dijk, M. van (2012) Mapping weather index-based insurance in Mali using spatial data analysis. In: *Research Conference on Microinsurance*, 2012, 2012-04-11/ 2012-04-13 – p. 29. edepot.wur.nl/245105.

Ray DK, Mueller ND, West PC, Foley JA (2013). Yield trends are insufficient to double global crop production by 2050. PLoS ONE 8(6): e66428. doi:10.1371/journal.pone.0066428. www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0066428.

Market development and trade as drivers of food security: The case of India

Brouwer, F. M. and Joshi, P. K. (eds) (forthcoming) International Trade and Food Security; the Future of Indian Agriculture. CABI, Wallingford

Gulati, A., Brouwer, F. and Ganguly, K. (2012) Indian agriculture: Unfolding structural changes and their relevance to the EU. EuroChoices, 11(1), pp. 19-25. doi: 10.1111/j.1746-692X.2012.00220.x

Climate change and global water resources: Adaptation strategies for the agricultural sector

Biemans, H. (2012) Water constraints on future food production. Wageningen University, 168 pp. Wageningen, the Netherlands.

Biemans, H., Haddeland, I., Kabat, P., Ludwig, F., Hutjes, R. W. A., Heinke, J., Bloh, W. von and Gerten, D. (2011) Impact of reservoirs on river discharge and irrigation water supply during the 20th century, *Water Resources Research*, 47(3).

Biemans, H., Speelman, L., Ludwig, F., Moors, E., Wiltshire, A. J., Kumar, P., Gerten, D. and Kabat, P. (2013) Future water resources for food production in five South Indian basins and potential for adaptation – A modelling study, *Science of the Total Environment*, 468-469, Supplement, S117-S131.

Fischer, G., Shah, M., Tubiello,F. N. and Velhuizen, H. van (2005) Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990-2080, *Philosophical Transactions of the Royal Society B-Biological Sciences*, *360* (1463), 2067-2083.

Rost, S., Gerten, D., Bondeau, A., Lucht, W., Rohwer, J., and Schaphoff, S. (2008) Agricultural green and blue water consumption and its influence on the global water system, *Water Resources Research*, 44 (9).

World Commision on Dams (2000), Dams and development: A new framework for decision-making. The report of the World Commission on Dams. Earthscan Publications Ltd, London and Sterling, VA. *www.internationalrivers.org/files/attached-files/world_commission_on_dams_final_report.pdf*

A review of food security scenario studies: Gaps and ways forward

Dijk van, M., Meijerink, G., 2014. A review of global food security scenario and assessment studies: results, gaps and research priorities. (FOODSECURE Working Paper No. 20). LEI Wageningen UR, The Hague.

FAO (2013) Food Outlook: Biannual Report on Global Food Markets: www.fao.org/docrep/019/i3473e/i3473e.pdf (accessed 27 February 2014).

2 Global food security 2050: Exploring future scenarios

Adaptive delta management

Bergh, D. van den, Bucx,T., Guchte, C. van de (2012) Assessments for investments – Dutch business case for adaptation with focus on the case of Bangladesh. Results from the sessions at the Amsterdam IWW/Aquaterra conference 2011. Delta Alliance report number 5. Delta Alliance International, Delft – Wageningen, The Netherlands.

Bucx, T., Marchand, M., Makaske, A, Guchte, C. van de (2010) Comparative assessment of the vulnerability and resilience of 10 deltas – Synthesis report. Delta Alliance report number 1. Delta Alliance International, Delft – Wageningen, The Netherlands.

Haasnoot, M. (2013) Anticipating change – Sustainable water policy pathways for an uncertain future. PhD thesis, Utrecht University, Utrecht.

Marchand, M. and Ruigh-van der Ploeg, T. (2009) Reframing integrated water management for urbanizing deltas: a combined approach of spatial planning and governance to analysis and design. Paper presented at the Conference People and the Sea (V) on 'Living with uncertainty and adapting to change', 9-11 July 2009. Amsterdam, The Netherlands.

Marchand, M., Bucx, T., Makaske, B., Guchte, C. van de and Driel, W. van (2012) Enabling Delta Life – What makes managing land and water in deltas different? Discussion paper. Delta Alliance and GWP.

OECD (1993) OECD core set of indicators for environmental performances reviews: A synthesis report. Environment Monographs No. 83. Group on the State of the Environment. Organisation for Economic Co-operation and Development OECD, Paris, France. http://enrin.grida.no/htmls/armenia/soe2000/eng/oecdind.pdf (accessed 10 April 2014)

Syvitski J. P. M., Kettner, A. J., Overeem, I., Hutton, E. W. H., Hannon, M. T., Brakenridge, G. R., Day, J., Vörösmarty, C, Saito, Y., Giosan, L., and Nicholls, R. J. (2009) Sinking deltas due to human activities. Nature Geoscience Volume 2, No. 10, 681-86. http://www.deltas2010.com/SinkingDeltas-NatureGeo9-20-09.pdf (accessed 10 April 2014)

Determining sustainable production limits for Green Growth

Alterra Wageningen UR (n.d.) *Green Economic Growth*. See: www.wageningenur.nl/greeneconomicgrowth

Bogardi, J. J., Fekete, B. M., & Vorosmarty, C. J. (2013). Planetary boundaries revisited: a view through the 'water lens'. *Current Opinion in Environmental Sustainability,* 5(6), 581-589.

Brisbane Declaration (2007) www.eflownet.org/download_documents/brisbane-declaration-english.pdf

FAO (n.d.) *AquaCrop* www.fao.org/nr/water/aquacrop.html

Hellegers, J. G. J., Jansen, H. C., Bastiaanssen, W. G. M. (2012) An interactive water indicator assessment tool to support land use planning. *Irrigation and Drainage*, 61:2, 143-54

Janssen, B.H., Guiking, F.C.T., Eijk, D. van der, Smaling, E.M.A., Wolf, J. and Reuler, H. van (1990) A system for quantitative evaluation of the fertility of tropical soils (QUEFTS). *Geoderma* 46: 299-318

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington DC.

Querner, E.P., Morábito, J.A. and Tozzi, D. (2008) SIMGRO, a GIS-supported regional hydrological model in irrigated areas: Case study in Mendoza, Argentina. *Journal of Irrigation and Drainage Engineering* 134:1, 43-48

Rockstrom, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., Lambin, E., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., et al. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. Ecology and Society, 14(2).

Querner, E. P., Herder, C., Fissahaye, D., & Froebrich, J. (2014). *Modelling crop production in water-scarce basins with SWAT - case studies of the Limpopo River basin and in Ethiopia* (No. Alterra report 2534). Wageningen: Alterra.

Supit, I., Diepen, C.A. van, Wit, A.J.W. de, Wolf, J., Kabata, P., Baruth, B., Ludwig, F. (2012) Assessing climate change effects on European crop yields using the Crop Growth Monitoring System and a weather generator. *Agricultural and Forest Meteorology*, 164: 96–111

Woltjer, G., Kuiper, M., Meijl H. van (2011) MAGNET. In: Woltjer, G., Bezlepkina, I., Leeuwen, M. van, Helming, J., Bunte, F., Buisman, E., Luesink, H., Kruserman, G., Polman, N., Veen, H. van der, Verwaart, T. (eds.). *The Agricultural World in Equations: An Overview of the Main Models Used at LEI.* LEI, The Hague. edepot.wur.nl/202770

Evaluating the Impact of Policy on Food Security Outcomes at the Household Level

Dijk, M. van and Meijerink, G. (forthcoming) A review of global food security scenario and assessment studies: results, gaps and research priorities. Global Food Security

FAO (2001) *Food Balance Sheets: A Handbook.* FAO, Rome, Italy. www.fao.org/economic/ess/ess-fs/fs-methods/ess-fbs02/en/

Foster, F., Greer, J. and Thorbecke, E. (1984) A class of decomposable poverty measures. *Econometrica* 52 (3): 761-66.

Kuiper, M. and Shutes, L (forthcoming), Expanding the household coverage of global simulation models: an application to Ghana, FoodSecure Technical Paper.

Minor, P. and Walmsley, T. (2013) MyGTAP: A Program for Customizing and Extending the GTAP Database for Multiple Households, Split Factors, Remittances, Foreign Aid and Transfers. GTAP Working Paper No. 79, Center for Global Trade Analysis, Purdue University. https://www.gtap.agecon.purdue.edu/resources/download/6660.pdf

Pangaribowo, E.H., Gerber N., and Torero, M. (2013), Food and nutrition security indicators: A review, ZEF, Working Paper 108, Bonn, February 2013.

Rutten, M., Tabeau A. and Godeschalk, F. (2013) A New Methodology for Incorporating Nutrition Indicators in Economy-wide Scenario Analyses. FOODSECURE Technical Paper No 1. www3.lei.wur.nl/FoodSecurePublications/TechPap01_FoodSecure%20Paper%20Nutrition%20Module%20MAGNET.pdf.

Walmsley, T. and Minor, P. (2013) Walmsley, T. and Minor,P. (2013) MyGTAP Model: A Model for Employing Data from the MyGTAP Data Application, Multiple Households, Split Factors, Remittances, Foreign Aid and Transfers. GTAP Working Paper 78. Center for Global Trade Analysis, Purdue University. www.gtap.agecon.purdue.edu/resources/download/6659.pdf

WHO (2004) Global Strategy on Diet, Health and Physical Activity. Strategy Document No. WHA57.17. World Health Organization, Geneva. http://www.who.int/dietphysicalactivity/strategy/eb11344/strategy_english_web.pdf (accessed 4 March 2014)

Woltjer, G., Rutten, M. and Kuiper, M. (2013a) Working with MAGNET: User guide. Internal document, LEI Wageningen UR, The Hague.

Woltjer, G., Kuiper, M. and Kavallari, A., van Meijl, H., Powell, J., Rutten, M., Shutes, L., and Tabeau, A. (2013b) The MAGNET model: Module description. Internal document, LEI Wageningen UR, The Hague.

Stakeholder engagement in developing scenarios on future food security and climate change adaptation

Alcamo, J. (2008) The SAS approach: Combining qualitative and quantitative knowledge in environmental scenarios. In: Alcamo, J. (ed.), Environmental Futures: The Practice of Environmental Scenario Analysis. Elsevier, Amsterdam.

Alcamo, J., Henrichs, T. (2008) Towards guidelines for environmental scenario analysis. In: Alcamo, J. (ed.), Environmental Futures: The Practice of Environmental Scenario Analysis. Elsevier, Amsterdam, pp. 13-35.

Carpenter, S.R., Pingali, P.L., Bennett, E.M., Zurek, M. (eds.) (2005) Ecosystems and human well-being: Scenarios, Vol. 2. Island Press, Washington, DC.

Chiwaka, E. and Yates, R. (2005). Participatory Vulnerability Analysis (PVA): A step-by-step guide for field staff. Action Aid International, London, pp 3-35.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grubler, A., Jung, T.Y., Kram, T. (2000) Special report on emissions scenarios: A special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Riel, K. van (2013) Vulnerability and capacity of fisheries and fishery dependent communities to climate variability and change in Kerala state, South India. MSc thesis, Integrated Water Management, Wageningen University, The Netherlands, 100 pp.

Smit, B., Wandel, J. (2006) Adaptation, adaptive capacity and vulnerability. Global Environmental Change, 16: 282-92

UNEP (2012) GEO 5 Global environmental outlook: Environment for the future we want. United Nations Environment Programme, Valletta, Malta.

3 Governance towards sustainable action

From Product to Place: Towards a Landscape Approach to Agro-Food systems

Bodegom, A. J. van (2013) Optimization of land use for soy, palm oil and sugarcane. Can we deal with deforestation and land tenure issues? Wageningen UR Centre for Development Innovation, Wageningen, Netherlands.

Brascamp, F. (2013) Landscape restoration through innovative landscape governance. A case study of coal mining in East Kalimantan, Indonesia. Wageningen UR Forest and Nature Conservation Policy Group.

Brassett, J., Richardson, B. and Smith, W. (2011) Experiments in global governance: Sustainability round tables and the politics of deliberation. Political Studies Association, 2011, 1-32.

Dries, B. van den (2013) The landscape governance process for conserving The Sungai Wain Protection Forest. Wageningen UR Forest and Nature Conservation Policy Group.

Hennemann, I. (2012) Looking beyond the forest: exploring the significance of alignment between politics and practices in landscape governance. A case study of the corridor in Gunung Halimun Salak National Park in West Java, Indonesia. Wageningen UR Environmental Policy Group.

Imbrechts, L. (2011) Protection forest governance: Inside-out. Exploring the gaps between discourse and reality. Master Thesis, Katholieke Universiteit Leuven. Faculty of Social Sciences Master of Cultures and Development Studies. www.scriptiebank.be/sites/default/files/88905cfc8ad8961e011ab5c400254450.pdf

Koning, J. de and Cleaver, F. (2012) Institutional bricolage in community forestry: An agenda for future research. In: Forest-people interactions: understanding community forestry and biocultural diversity, Arts, B, van Bommel, S., Ros-Tonen, M. and Verschoor, G. (eds.), Wageningen Academic Publishers, pp. 277-290.

Oosten, C.J. van, (2013) Restoring landscapes governing place: a learning approach to forest landscape restoration. Journal of Sustainable Forestry, 32:7, pp. 659-676.

Zakaria, A., Wakker, E. and Theile, C. (2009) Failing governance – Avoiding respnsibilities. European biofuel policies and oil palm plantation expansion in Ketapang District, Werst Kalimantan (Indonesia). Amsterdam: Friends of the earth Netherlands (Milieudefensie) and WALHI Kalimantan Barat. www.wageningenur.nl/nl/Publicatie-details.htm?publicationId=publication-way-343433363531

Going Beyond the Buy – The Business of Investing in Smallholders

Lundy, M., Becx, G., Zamierowski, N., Amrein, A., Hurtado, J. J., Mosquera, E. E., Rodríguez, F. (2012) LINK methodology: A participatory guide to business models that link smallholders to markets. Centro Internacional de Agricultura Tropical (CIAT), CIAT Publication No. 380, 171pp. CIAT, Cali, Columbia. http://dapa.ciat.cgiar.org/wp-content/uploads/big-files/2012/LINK_Methodology.pdf (accessed 18 February 2014)

Sopov, M., Saavedra, Y., Sertse, Y., Wellema, W. (forthcoming) Is Inclusive Business for You? Managing and upscaling your company: Lessons from the field. Wageningen UR Centre for Development Innovation. Wageningen, the Netherlands

Woodhill, J., Guijt, J., Wegner, L. and Sopov, M. (2012) Seas of Change: From islands of success to a report on scaling inclusive agri-food markets. Centre for Development Innovation, Wageningen UR, 2012. seasofchange.net/file/2012/10/SOC2012report.pdf

4 Adapting agriculture and innovating supply chains in developing countries

Climate-smart agriculture as a guiding principle for agricultural transformation

Birch, P. R. J., Bryan, G., Fenton, B., Gilroy, E. M., Hein, I., Jones, J. T., et al. (2012) Crops that feed the world 8: Potato: are the trends of increased global production sustainable? *Food Security, 4*(4), 477-508. doi:10.1007/s12571-012-0220-1

FAO. (2013) *Climate-Smart Agriculture Sourcebook*, 1-570.

Hengsdijk, H. and Verhagen, J. (2013). Linking Climate Smart Agriculture and Good Agricultural Practices: Case studies on consumption potatoes in South Africa, the Netherlands and Ethiopia (pp. 1-38).

Neufeldt, H., Jahn, M., Campbell, B. M., Beddington, J. R., DeClerck, F., De Pinto, A., et al. (2013) Beyond climate-smart agriculture: toward safe operating spaces for global food systems, 2(1), 1-1. doi:10.1186/2048-7010-2-12

Verhagen, J., Hengsdijk, H., Bezlepkina, I., Groenestein, K., Jansen, H. G. P., & van t Klooster, K. (2013) Linking good agricultural practices and climate smart agriculture, 1-46

Strengthening farm-firm relations in the food chain

Schrader, T., Groot Komerlinck, A. and Janssen, I. (2012) Firm-farmer relations: Taking market linkages to the next level. Analysing farm-firm business cases with the tool 'it takes two to tango'. Wageningen, WUR-CDI – KIT – Agri-ProFocus.

Ton, G., Flores, L., Monasterios, R. and Yana, E. (2014a) Capabilities and performance in collective marketing: The importance of learning to cope with agency dilemmas. In: Innovative Institutions, Public Policies and Private Strategies for Agro-Enterprise Development. Christy, R., da Silva, C. A., Mhlanga, N., Mabaya, E. and Tihanyo, K., (eds). World Scientific Publishing Co. Inc.

Ton, G., de Grip, K., Lançon, F., Onumah, G.E., and F. Proctor (2014b). Empowering smallholder farmers in markets: Strengthening the advocacy capacities of national farmer organisations through collaborative research. Food Security 6(2): 261-73.

Ton, G. and F. Proctor (2013). Empowering Smallholder Farmers in Markets: Experiences with farmer-led research for advocacy. Wageningen, CTA-AGRINATURA-LEI Wageningen UR.

Driving Innovations in Agrifood Systems

Vermeulen, S., Woodhill, J., Proctor, F. and Delnoye, R. (2008) Chain-wide learning for inclusive agrifood market development: a guide to multi-stakeholder processes for linking small-scale producers to modern markets. Wageningen, International Institute for Environmental and Development

Scaling innovations: do we know what makes contexts conducive?

Pawson, R. and Tilley, N. (1997) Realistic evaluation, SAGE, London

Colophon

The Food Puzzle
Pathways to securing food for all

Publisher
Wageningen UR

Editors
Thom Achterbosch
Marianne van Dorp
Wim van Driel
Jim Groot
Jan van der Lee
Jan Verhagen
Irina Bezlepkina

Text
Karen Batjes (kb consulting)
With a contribution from Harry van Dooren and Jos van der Schot (Text and context) for: The balance between short-sightedness and utopian thinking.

Project and production management
Communication Services, Wageningen UR

Graphic design and photo research
Communication Services, Wageningen UR

Printing
MediaCenter, Rotterdam

Photography
Marc Ryckaert © Nile Barge | under license CC3.0 | commons.wikimedia.org/wiki/File:Nile_Barge_R02.jpg (p17), Project1photography/shutterstock.com (p26), McKay Savage (p27), Viet Images/shutterstock.com (p34), Jochen Froebrich (p37), oksana.perkins/Shutterstock.com (p41), jaume/Shutterstock.com (p43), Eddy Moors (p44, 46), Ilse Hennemann (p48, 49), Yeray Saavedra (p51), Henric Verjans (p53), Arij Everaars (p58, 59, 60), Giel Ton (p61, 63), Radiokafka/shutterstock.com (p64), Anne Floquet (p68), shutterstock.com, Wageningen UR

Visuals
Wageningen UR, Wageningen UR Centre for Development Innovation

ISBN 978-94-6257-192-1

Wageningen, November 2014

www.wageningenUR.nl