SCIENCE FOR AGRICULTURE AND RURAL DEVELOPMENT IN LOW-INCOME COUNTRIES

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PREFACE

It has become a habit that following completion of a research programme, a review or assessment is performed. Partly to justify the money and efforts that went into the programme and partly to identify novel directions for new programmes. Following this tradition, the sponsor of the International Cooperation research programme (DLO-IC), the Dutch Ministry of Agriculture, Nature and Food Quality (LNV), asked a small group of scientists to draw lessons from its recently completed North-South programme. The task group was asked to focus on the research theme 'rural development and sustainable agriculture' (RDSA) to contribute to future thinking about issues related to poverty alleviation, food security improvement and natural resources conservation, a tall order for anyone.

By 2005, of the total of 70 North-South collaborative projects, some 35 were related to RDSA. In addition to all science groups at Wageningen University and Research centre (Wageningen UR), the projects involved many local and international research institutes. Any attempt at comprehensively capturing the efforts of such a large number of scientists from different disciplines over an 8-year period, and their results, will inevitably have shortcomings. This book forms no exception. However, in addition to being a challenge, too interesting to pass, we think that the successes of and insights emerging from the programme are worthwhile to share with a larger audience. Agricultural research in 'Wageningen' has been at the forefront of shaping innovation in research, development, and agricultural practice for decades. The research efforts presented here, follow this tradition and reflect the wide spectrum and recent progress made in research on rural development and sustainable agriculture.

In this book, we have tried to deal with past, present and future research directed at rural development and sustainable agriculture in low-income countries. First, we sketch the current challenges, next we give an historical overview, and then present the state-of-the-art with respect to the most important issues in RDSA. Finally, we capture the most important lessons drawn from the programme, as a stepping stone for an outline of the ways ahead to shape rural development and sustainable agriculture.

Agricultural development during the last 50 years was shaped by three forces: people, technology and globalization. Globalization has increasingly shifted the focus from local to global threats and opportunities, with world markets becoming more accessible and thus exerting growing influence. Changing technologies improved the production possibilities and efficiencies, to better tailor deliveries to consumer needs and desires. People, the main driving force, are exerting their influence via their numbers, and their preferences as consumers or custodians of the environment in which food and fibre products are produced. Changes in these forces and their implications for research are discussed in Chapter 2. In Chapter 3, the role of agriculture in achieving food security in the light of ongoing population growth, accelerating urbanization and changing diets is discussed. The disparities between the Asian and African continent are highlighted. Research aimed at increasing resource use efficiencies and breaking the yield barrier remains important. Chapter 4 deals with environmental issues. In the chapter, the contribution of the programme to confronting the environmental threats to sustainable development, particularly soil and land degradation, chemical pollution of soil and water, impact on biodiversity and climate change are discussed. The importance of agriculture in realizing development goals is obvious, when realizing that the majority of the poor are located in the rural areas of low-income countries. Rural households therefore play a key role in poverty reduction policies. Understanding how and which decisions are made at this level, is dealt with in Chapter 5.

We have focused on a selected number of aspects of a very wide research programme, by placing its findings in a broader perspective. Insight into the contribution of agriculture to rural development can only be gained if we understand how it interacts with other sectors and non-agricultural development priorities. Understanding the larger picture remains a priority for future research efforts. For research to continue to have an impact and contribute to rural development and sustainable agriculture, research should focus on the three specific roles of agriculture in rural development strategies: (i) basis for changing livelihoods, (ii) provider of high quality affordable food, and (iii) provider of environmental services.

This book would not have materialized without the contributions of a large number of colleagues, policymakers and other stakeholders from the Netherlands and its partner countries – and we are very grateful. Some of those, however, deserve special mention: We thank André de Jager (LEI, The Hague) and Frank van Tongeren (OECD, Paris) for their support in setting up this project, and for their contributions to Chapters 1, 4 and 6. Marcel Vernooij, Désiree Hagenaars, Gerrit Meester and Hayo Haanstra of LNV (The Hague) for intensive discussions and for their guidance in keeping us on track. Our Wageningen colleagues Marianne van Dorp, Huib Hengsdijk and Joost Wolf for their contributions to draft Chapter 3. Henk Wösten, Gerdien Meijerink and Derek Eaton for their participation in elaborating Chapters 4, 5 and 6. Special thanks to the following DLO-IC project leaders who's contributions provided substantial input to Chapter 6 and constitute the core of Chapter 7: Rik van den Bosch, Paul van den Brink, Coen Ritsema, Simone Verzandvoort-van Dijck, Kees van Diepen, Ben Kamphuis, Siebe van Wijk, Derek Eaton and André de Jager. At Soil Science Center, Anne Zaal and Linda van Kleef are acknowledged for secretarial support, and Klaas Oostindie for polishing several figures. We are thankful to Rudy Rabbinge (Chair, CG Science Council) and Hans Herren (MI, Arlington) for providing valuable comments on the executive summary, and to Ewald Wermuth of the Royal Dutch Embassy (to UN in Rome) and Bram Huijsman (Wageningen International) for the opportunity to present our findings at a side-event to the 131st session of the FAO Council at Rome, 20-25 November 2006.

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Wageningen, June 2007

EXECUTIVE SUMMARY[1]

INTRODUCTION

Since 1998, the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) promotes development-orientated agricultural and environmental research and strengthening of North-South partnerships through its International Cooperation (DLO-IC) research programme. By 2005, some 70 collaborative North-South projects had been carried out. All science groups of Wageningen University and Research centre (Wageningen UR) were involved in the implementation of the programme and at least half the projects and activities undertaken were directly related to rural development and sustainable agriculture.

In recent years there has been a search for more sustainable development strategies. This has direct implications for agriculture, given its relations with the natural resource base and its prime economic importance in low-income countries. We identify three areas where agriculture can make a critical contribution: alleviating poverty, protecting natural resources and increasing food security. These areas are directly related to two Millennium Development Goals (MDGs): eradicating extreme poverty and hunger (MDG 1) and ensuring environmental sustainability (MDG 7).

Our aim is to draw lessons from the DLO-IC projects to contribute to future thinking about issues of poverty alleviation, increasing food security and natural resources conservation. Our conclusions stress the strategic role of agriculture in development processes, in which we have identified three different functions:

- *provide a stable basis for changing livelihoods* facilitating the gradual transition out of agriculture into other sectors of the economy;
- *deliver essential environmental services*;
- *provide sufficient affordable food* of the quality needed to sustain a growing world population.

The relative significance of these three functions is, of necessity, location-specific. These three roles are neither mutually exclusive nor necessarily in conflict with each other. It is, however, essential that the role of agriculture in a specific setting is identified, so research can be tailored accordingly.

This *Summary* is divided in five parts. First, the changing role of agriculture is placed in a *Historical perspective*. Guaranteeing the production of sufficient food to meet the needs of a growing population has long been the focus of agricultural research. In the chapter on *Food security* we acknowledge this role as a continuing and major concern. At the same time, however, increasing agricultural production often has had serious environmental repercussions.

In the chapter *Agriculture and environment*, a short review of DLO-IC projects, and how production decisions by rural households affect both the environment and the way natural resources are managed, is given. As such, they play a significant

[1] This summary has been published as a brochure in 2006, and is available from the secretariat of the Soil Science Centre, Alterra, Wageningen UR.

role in determining the extent to which policy objectives can be achieved. Decisions taken at household level not only determine actual levels of agricultural production (food security objectives), they also affect the long-term quality of local natural resources and their capacity to support livelihoods (sustainability objectives).

The majority of the world's poor live in the rural areas of developing countries. Rural households are, therefore, a major target group in poverty reduction policies. In the *Rural livelihoods* section, it is argued that non-agricultural activities are an essential part of community and household activities and livelihoods. We conclude that analysing and interpreting the interactions between agricultural and non-agricultural activities is a particularly fruitful line of future research.

In *Lessons learned*, the issues raised are integrated and we reflect on the role that agriculture may play in the future.

THE HISTORICAL CONTEXT OF AGRICULTURAL DEVELOPMENT

The history of agricultural and rural development since the end of *World War II* in 1945 is characterized by changing priorities and concerns. Immediately after this war and the widespread experience of serious malnutrition, there was a determined effort to increase food production in the *developed world*. Technological innovation became the keystone of agricultural research and development (R&D) and resulted in increased use of chemical inputs (fertilizers and biocides) to intensify production. Yields of key crops rose substantially, labour productivity increased and, within rural society, there was a strong reduction in the demand for agricultural labour.

As agricultural productivity increased, emphasis on food production declined. The focus shifted to the economic context of food production as well as to the issue of ensuring parity between the incomes of farmers and other occupational groups. In many developed countries, policy measures (price support, export subsidies and import levies) were introduced to guarantee farm incomes. In the long term this would lead to overproduction and the distortion of world markets for agricultural products.

It was against this background that concerns about the environmental impact of new agricultural technologies began to grow. Rachel Carson's book *Silent Spring* was amongst the first to draw attention to the devastating effect of biocides on fauna. Subsequent studies demonstrated the negative effects of nutrient surpluses on water quality, soil and flora. The resulting increased environmental concerns led to the Stockholm Conference on Environment in 1972. Gradually, agricultural research came to focus on so-called integrated production systems, emphasizing the need to maintain the economic viability of agricultural holdings, while reducing the negative environmental impacts of farming practices. It took time for decision makers to respond to environmental concerns, but gradually legislation was introduced to regulate production levels and the use of inputs. Most recently, pressure from civil society to reduce production subsidies and address environmental concerns has been formalized in agreements, protocols and treaties in WTO and other international organizations. These measures are, in part, an expression of the growing awareness that product subsidies and distortions in world markets seriously disadvantage producers in developing countries.

The colonial economies of Asia and Africa were oriented to the production of raw materials for the developed world and relatively little attention was given to food production. Following independence of these countries in the 1950s and 1960s, there was a growing concern for food security. Improved medical facilities had led to rapid population growth in most countries, raising the demand for food substantially.

The *Green Revolution* that led to increased cereal production, was made possible through major investments in agricultural research. It was based on the transformation of agricultural practice and reliance on 'high-yielding' crop (wheat, rice and maize) varieties that responded well to external inputs, in particular (nitrogen) fertilizer, irrigation water and crop protection agents. Policy measures were enacted to make external inputs economically attractive to farmers and – in the better endowed regions of the developing world in particular – food production increased dramatically, the fear of structural famines disappeared and food prices could be maintained at a relatively low level.

Enthusiasm for *Green Revolution* technology was accompanied, however, by growing scepticism. On the one hand because farmers in less-favoured areas were unable to afford the required inputs and on the other because over time, it became clear that the (excessive) use of agro-chemicals had negative environmental effects.

In response to this criticism, the *Consultative Group on International Agricultural Research* (CGIAR) began to shift its attention from the mere agro-technical aspects of agriculture towards (socio)-economic issues. As a result *Farming Systems Research (and Development and Extension)* started to appear on research agendas in many different forms. However, despite its initial promise, it proved to be a methodology that failed to live up to expectations.

Gradually, via the eco-regional approach that focused on region-specific potentials and constraints, *Farming Systems Research* developed into *Integrated Natural Resource Management* (INRM). Here, the focus was agricultural production and the effects of production (technologies) on the quality of natural resources (land, water and air). The movement towards the *INRM* approach was heavily influenced by the emergence of the sustainability paradigm following the publication of the influential *Brundtland Commission* report '*Our Common Future'*.

Programmes in the CGIAR shifted from science-driven single issue research, dealing with such issues as soil degradation, erosion and pesticide use to demand-driven, complex, rural development research in which the interrelationships between factors affecting natural resource availability and the economic and socio-cultural conditions determining production and environmental impacts were central.

The DLO-IC programme followed a similar development in its research approaches, Increasingly, it addressed all the three agriculture-related pillars of sustainable development, namely, economically-viable, environmentally-sound and socially-acceptable agricultural systems and practices.

FOOD SECURITY

Despite the impressive achievements of recent decades, the annual FAO reports on the world food situation – the state of World Food Insecurity – continue to show that 800 million people, mainly in developing countries, live in hunger. In 2005, following MDG 1, the UN Task Force on Hunger set out the interventions needed to halve the number of people living in hunger by 2015. It is clear that reaching this goal and ensuring affordable and nutritious food for the world's population remains a major challenge. Although theoretically there is sufficient food to feed the entire world population, challenges related to sustainable production remain.

Food insecurity is strongly linked to poverty, preventing people from obtaining the food they require to lead healthy and productive lives. While it is true that no one would go hungry if all food were equally distributed, such redistribution seems not feasible. Strategies to reduce poverty and hunger must be based on approaches that take local and regional biophysical, economic and socio-cultural factors into consideration. The rapid transformation of diets and changes in food systems at production, processing, distribution and retail levels also pose important challenges for food security, good nutrition and health. These developments also instigate efforts to develop effective rural livelihood strategies and environmental policies.

Challenges abound: The majority of those suffering from chronic or acute hunger live in Asia and Africa. The figures tell a grim tale with India (220 million), China (142 million) and Sub-Saharan Africa (204 million) having particularly large numbers of hungry and malnourished people. Although in absolute terms the number of hungry people in Asia is high, the proportion exposed to food insecurity has declined in recent years. In Africa, by contrast, the proportion and number of undernourished adults and children continue to rise.

In general, the total demand for food worldwide is expected to double in the next 50 years, with the highest increase coming from developing countries. In addition, changes are taking place both in the pattern of demand and the type of food – more meat, dairy products and fish – being consumed. Increasingly, this food needs to be produced in an environmentally and socially sustainable manner in order to comply with higher food safety standards, environmental regulations and consumer preferences. As competition for scarce natural resources intensifies, agriculture has to find ways of making more efficient use of resources, land and water in particular, to provide high quality affordable food. In less-endowed regions, improved agricultural practices must be tailored to local bio-physical and socio-economic conditions, to provide a solid base for poor farm households' livelihoods, if they are to have a positive impact. Resource use efficiency gains in well-endowed regions will help increase production at lower input costs, but result in lower product prices. Beneficiaries will, in first instance, be urban consumers and environmental quality – and to a lesser extent rural households.

Meeting these challenges implies that the agricultural sector must become more productive (e.g., through improved technologies, improved institutions, etc.). Scientific research will need to contribute to generating knowledge on how to:

- Feed the growing world population, and meet consumer needs;
- Enhance rural livelihoods (by increasing or stabilizing income); and
- Safeguard the environment (maintain resource quality and protect biodiversity).

Clearly, scientific and technical solutions are not 'magic bullets'. In isolation they cannot resolve the complex problem of food insecurity which is closely related to poverty. Poor people do not have access to food and health services, and often lack of education, poverty and hunger seriously limit economic growth. However, it should be recognized that economic growth in itself is not a remedy for hunger. It cannot guarantee equitable access to food and it does not ensure that people can claim their rights. More insights and knowledge are needed on this topic in which multi-disciplinary research can play a role. To have impact, higher investments are needed to escape the poverty trap.

A global assessment of food supply and demand gives insufficient insight into the nature and urgency of poverty, hunger and malnourishment in developing countries and regions. This is especially true for large parts of Sub-Saharan Africa. Different drivers require a regionally differentiated view of food security and related issues to identify research challenges and opportunities.

East and South-east Asia

Stagnating cereal yields in very intensive agricultural systems are a major constraint to increasing food supply in Asia. Additional research is needed into the underlying causes of phenomena such as 'soil fatigue' and the processes associated with long-term and continuous mono-cropping in order to deal with the problem. At the same time, research into new crop varieties that have greater resistance to multiple stresses and the capacity to break yield barriers must be continued. These efforts should take place within a research framework that addresses the need for targeted management packages and takes into consideration the challenge that climate change, food quality and safety legislation presents to crop and livestock breeding. This also means a continued effort to support the activities of farmers to manage local varieties and genetic diversity in a way that is also economically viable (e.g., through marketing), as DLO-IC research has shown to be possible.

There is considerable potential for improving resource use efficiency in Asian agriculture. Analyses, using the Wageningen QUEFTS model for soil fertility in conjunction with rice experiments set up across Asia, have shown conclusively that nutrient use efficiencies in cropping systems were far below what could be achieved if agricultural practices were improved. Rice cultivation in particular offers considerable scope for improving current low nitrogen use efficiencies, and appropriate crop and soil management techniques can lead to significant yield increases. Lack of knowledge, the absence of economic incentives and policies to support sustainable management practices, as well as a shortage of labour are among the factors that obstruct the realization of this potential increase in resource use efficiency.

The intensification of agricultural production, especially animal production, has increased nitrogen emissions to the environment. Human health and ecosystem quality have also been negatively affected by the excessive use (and loss) of agro-chemicals in vegetable production systems. In many Asian communities, dietary change as a result of economic development, is posing new challenges to human health as the increased incidence of nutritional diseases such as obesity and diabetes in Thailand and the Philippines show. At local and regional levels, this nutrition transition threatens food security and human health in different ways. The influence that cultural factors exert over food security must also be taken into account. Within Asian communities in India, Bangladesh and Pakistan, for example, the position of women, traditional customs and the intra-household distribution of food have a strong influence on the incidence of malnutrition.

In many parts of Asia, clean and safe water is a scarce resource and competition for available water resources is intense. This indicates the need for research into water-saving technologies and improved water use efficiency in agriculture. Another challenge to food production is the increasing tendency to use fertile agricultural land for non-agricultural purposes. The growing income disparity between rural and urban areas continues to precipitate the migration of young men to urban and peri-urban centres with far-reaching consequences for agricultural labour. As a result, in many households women have been left to cope with the day-to-day management of the farm.

In recent years, deforestation and climate change have been identified as responsible for the increased incidence of flooding. In addition to floods, climate change has increased the risk of high temperatures and the frequency of drought. Together these factors have had a severe and negative impact on crop yields and pose a serious threat to food security.

The growing importance of globalization and the increasing integration of farm and non-farm activities pose new research challenges. Globalization means that farmers are more exposed to the demands and influences of world markets. On the one hand, there are questions pertaining to market access, adhering to high quality standards (e.g., Eurepgap), and on the other hand, questions pertaining to the management of local or traditional varieties, and the self-reliance of farmers vis-à-vis multinational corporations (from seed companies, logging firms to the pesticide industry). Institutional issues such as access to (world) markets, and natural resources and (intellectual property) rights over natural resources are important topics in this respect.

Research continues to be necessary in plant breeding, agronomy, farm management, human nutrition and rural sociology in order to work jointly with communities to attain the knowledge and technologies necessary to adapt to environmental change, limit yield losses and identify the best land use options in the given local biophysical and socio-economic settings.

Sub-Saharan Africa

In addition to global issues such as climate change and economic integration, there are issues specific to Sub-Saharan Africa. In many parts, low yields, low land productivity and low labour productivity are common. This is because of poor soils, low and erratic rainfall and the poverty that undermines the purchasing power of many potential consumers.

Low and declining soil fertility is one of the major causes of poor yields and the loss of fertile topsoil as a result of erosion and desertification has seriously reduced the production potential of previously fertile lands. Opportunities to raise yields and increase land and labour productivity through improved soil management and water conservation rely heavily on the use of external (yield-increasing) inputs.

Climate change in recent years has increased the severity and frequency of drought and this – in combination with the devastating impact of HIV/AIDS – has significantly reduced the capacity of the rural labour force to maintain adequate and nutritious food supplies, and many old people and children are left to fend for themselves. Non-farm employment is an important source of income for many rural households. Especially in remote and marginal areas, non-farm income derived from migratory work often represents a crucial source of income.

In Sub-Saharan Africa, agricultural research needs to continue to address problems such as the need to replenish soil nutrients and improve soil health. Research into drought-resistant crops, the nutritional requirements of individual household members and the availability of local resources such as micro-nutrient rich plant species continue to be necessary to reduce malnutrition, secure food resources and increase agricultural productivity. Research is also needed into crop and farm management to enable farmers to adjust their agricultural practices to the exigencies of environmental change. Besides a continued need for research in these areas, the DLO-IC research programme has shown that there is also a need for research into institutional barriers that rural communities in Africa face, such as a lack of markets or market access, or access to or rights over natural resources. In this context, the question of how such institutional barriers can be overcome within different governance systems, is an important, if unanswered one.

AGRICULTURE AND ENVIRONMENT

Agriculture utilizes natural processes to produce the goods – both food and non-food – needed to meet the demands of the growing world population. Agriculture contributes to economic development by generating income and employment. Paradoxically, however, economic growth and poverty reduction have led to a decline in the relative importance of the agricultural sector.

In most developing countries, agriculture is still the main economic activity and traditionally the key livelihood strategy in rural communities. It has also been identified as being of prime importance in achieving development goals at national and international levels. Agriculture is, therefore, at the forefront of shaping the concept of sustainable development.

Agricultural land use may lead to damage to or destruction of the natural resource base, undermining future production capacity and development options. For various reasons, agricultural activities may result in environmental degradation. The solution to the problems associated with these negative impacts lies not only in inducing changes in consumer diet and life style towards natural resource- and material input-saving products, but also in ensuring that the agricultural sector takes responsibility for finding ways to reduce the environmentally destructive impact of its activities.

Here we address some of the most pressing environmental issues related to agricultural land use and discuss how these are linked to rural development:

- Soil and land degradation;
- Chemical pollution of soil and water;
- Impact on biodiversity; and
- Climate change.

As might be expected, these issues are interrelated and share common causes, as well as solution pathways. Some of these problems are well recognized and local, national and international action is being taken to deal with them.

Knowledge plays a crucial role in signalling problems and identifying the pathways. Lack of knowledge, insight or awareness at all decision-making scales from international to the farm household, can lead to inappropriate action or no action at all. At the farm household scale, decisions are translated into actions that have a direct impact on the biophysical and socio-cultural environment.

Environmental issues were strongly embedded in research activities implemented under the DLO-IC programme. The programme's African soil fertility research projects provide a particularly clear example of the approach. The initial observation that declining soil fertility undermines the productive capacity of the land was developed further and linked to the problem of food insecurity. As the projects evolved, participatory on-farm research through farmer field schools provided input for the development of integrated nutrient management strategies taking full account of (macro-) economic aspects. A similar process can be identified in research carried out in Asia into the effects of the inappropriate use of agro-chemicals on soil and water quality. These two examples not only reveal the causal complexity of the problems facing agriculture in developing countries, but also make clear that possible solution pathways are not only complex, but are scale- and location-specific.

Agriculture is regularly criticized for having adverse effects on biological diversity. The largest losses of wild biodiversity occur in situations where habitats are destroyed and fragmented as a result of agricultural activities. Biodiversity is also negatively affected by the environmental degradation caused by the physical, chemical and biological impacts of intensive agricultural practices. These negative impacts can be addressed by increasing agricultural resource use efficiencies and land and labour productivity, leading to increased food supply without the need for expansion of agricultural land.

The contribution of agriculture to biodiversity and its capacity to enrich biological diversity is often overlooked. The crop and livestock species-, variety- and breed-diversity available within agricultural systems provides the genetic base for enhancing productivity. At the same time, however, it is important to realize that the widespread introduction of modern high-yielding varieties has resulted in disappearance of many traditional crop varieties. Farmers are the key to conserving and managing traditional crop and livestock varieties, as well as genetic diversity. Farm households use a variety of traditional crops for a range of purposes (food, medication, etc.). The conservation of diversity can be enhanced when conservation goals are combined with economic goals, such as improved marketing, e.g., through creating niche markets. Across the developing world, integrated participatory approaches are being developed, aiming at strengthening seed systems, restoring and improving local varieties, reducing pesticide and fertilizer use, and creating new market channels for local products. The DLO-IC programme through its participation in the PEDIGREA project has made a major contribution to these approaches by linking these goals with the farmer field school concept as an instrument to increase impact and sustainability of interventions.

Climate change

Global climate change is one of the most pressing problems of our time. The effects of climate change are local and vary among systems, sectors and regions. Climate change affects all aspects of development. There is an urgent need to reduce the emission of greenhouse gases into the atmosphere and, concurrently, agricultural production systems will have to adapt to changing environmental conditions.

Agricultural land use is already affected by ongoing climatic change. Because most crop production systems are adapted to certain ranges in temperature and water availability, their productive capacity is severely curtailed by environmental change. Semi-arid and arid areas in the (sub)tropics are particularly vulnerable to temperature and rainfall change. In addition, changes in climatic conditions can be expected to have direct negative effects on the availability of water and the incidence and severity of pest infestation and diseases – conditions that lead to the further destabilization of crop production.

Global ecosystems and development possibilities are vulnerable to the consequences of climate change which, worldwide, has put the livelihoods of millions in jeopardy. In communities where poverty and hunger are already endemic, rural households have few resources to combat the effects of climate change.

Current agricultural land use, land management and land conversion practices, as well as livestock husbandry contribute to emission of greenhouse gases and therefore contribute to climate change. Future response strategies and sustainable development pathways, therefore, need a two-fold approach: adaptation in response to climate change and mitigation to reduce greenhouse gas emissions.

RURAL LIVELIHOODS

New approaches to understanding the dynamics of rural households have emerged in recent years. The analysis of single production activities has been replaced by the study of the household as a diversified enterprise. The rural household can be seen as a centre of different types of enterprises, including non-farm activities that play an important role in rural livelihood strategies. This holds even in areas traditionally considered to be predominantly subsistence-oriented such as Sub-Saharan Africa.

Non-farm activities have received little attention in agricultural research and rural policy analysis. These activities and the income they generate, however, play a key role in food security and sustainability. Access to non-agricultural income which does not have the seasonal character of agricultural income, can provide farm families with the means to purchase food. Although most non-farm incomes originate from informal and thus insecure employment, they often do not correlate with fluctuations in agricultural income and as such are important in diversifying income risks and securing access to food. The location of non-farm employment also has a direct effect on agricultural activities. If non-farm employment requires temporary or permanent migration, less labour will be available for agricultural production.

Non-farm activities also affect the sustainability of agricultural activities, both, directly and indirectly. The pressure on natural resources, for example, may be reduced when households have access to alternative sources of income. Soil nutrient mining is a key issue in the African context and inorganic fertilizers can be an important source of nutrients. Non-farm cash income can enable farmers to buy fertilizers and increase the sustainability of their farms.

In contrast, in the Asian context, excessive use of fertilizers, pesticides and herbicides is a major concern. Farm households engaged in non-farm activities may not have sufficient labour available for intensive nutrient-efficient management practices, such as site-specific nutrient management. In such situations, non-farm activities may even threaten the sustainability of agricultural practices.

Research on sustainable agriculture and land use within the DLO-IC programme shifted from purely technical studies that focus primarily on soil and water management, to a broader perspective in order to take into account the activities of rural households and their institutional environment. However, so far no explicit attention has been given to the interaction between non-farm and farm activities. Implicitly, the potential role of non-farm activities has been acknowledged by collecting a limited amount of data on non-farm activities in projects aimed at analysing sustainable land use.

These data indicate the necessity for a reorientation of the future research agenda to include the role of non-farm activities in sustainable land use. The access of rural households to non-farm activities depends to a large extent on the proximity of urban centres where most non-agricultural activities take place. The influence of distance is reflected in the relationship between non-farm income and total farm income. Data show, this can range from 12% in remote areas to 35% in peri-urban areas. Data also show that rural household members involved in non-farm activities often no longer take part or invest in agricultural activities.

When analysing the factors that determine an individual's access to non-farm employment we find that, as might be expected, the usual components of household endowments such as land and labour, and personal attributes such as gender and education play a very significant role.

Coming from a large family and having little access to land, for example, increases the likelihood that household members will seek non-farm employment and it is usually the better-educated young males who work off-farm.

The single strongest factors determining the extent to which non-farm employment plays a role in household income, however, is the distance to urban centres. This suggests that policies to combat poverty through (local) non-farm employment may have limited effect in remote areas. In these locations, migration may be the only viable way of engaging in non-farm activities. The absence of young males for extended periods of time has a serious effect on farm communities and the policy and research implications of an increasingly female-dominated agriculture must be explored.

Non-farm activities not only play an important role in combating rural poverty, they may also have a direct effect on agricultural decision-making. Analysing external input use in general, and use of inorganic fertilizer in particular, we do not find non-farm income being correlated with external input use. However, being located nearer to an urban area increasing the scope for non-farm employment, reduces the likelihood of using external inputs in general and inorganic fertilizer in particular. This suggests that the additional income derived from non-farm activities is not used to substitute for the labour withdrawn from agriculture.

In the African context – to which most of our data refer – this furthermore suggests that non-farm income may have a negative impact on nutrient balances. Based on the data available so far, an analysis of the role of non-farm income on the nitrogen balance does not indicate a significant effect. However, it is known that African farm households, including those in the dataset, generally apply insufficient organic and inorganic fertilizers, which makes soil nutrient mining a key issue. Income from non-farm activities, however, does not appear to be invested in agriculture. This finding indicates a possible trade-off between poverty reduction and ecological sustainability concerns.

Our tentative analysis provides us with some initial insights into the relationship between non-farm activities and agricultural production decisions. We conclude that non-farm activities are central to household decision-making and influence future agricultural production potentials. The implication here is that rural development policies should take account of geographical factors that extend beyond agro-ecological characteristics. Factors to be considered include: opportunities for and access to non-agricultural employment, the development of individual capacity (education) and the recognition of trade-offs that may exist between poverty reduction and sustainability objectives.

LESSONS LEARNED

Based on the experiences in the DLO-IC programme we can identify a number of lessons important for future research.

Lesson 1: Disciplinary science provides the basis

Initially, most activities were science-driven with a mono-disciplinary-orientation. This was necessary to increase insight into underlying processes. It provided the basis for the various, improved interdisciplinary research methods and tools needed for and useful in the design and evaluation of higher-scale systems in a considerable number of agro-ecological zones and for (future-oriented) scenario studies. It is important to continue strengthening the bases of disciplinary knowledge while giving special attention to socio-economic research and its links with biophysical and technology-oriented research.

Lesson 2: Solutions and new insights require inter-disciplinary and multi-scale approaches

Inter-disciplinary, multi-scale research and integrated assessments that combine insights and knowledge from different disciplines and scales are needed to deal with the complexity of rural development and to support decision-making processes. This approach allows new insights to be applied in targeted problem-solving and has the potential to deliver solutions acceptable to the end-users. Understanding scale dependencies and linkages is essential for defining successful policy and farm management strategies. Further development of both, up-scaling and down-scaling methodologies in biophysical and socio-economic environments is urgently needed.

Lesson 3: Reinforce focus on resource use efficiency

Substantial resource use efficiency gains are possible, especially for nutrients, water, labour, energy and capital. Efficiency gains have the potential to alleviate pressure on scarce resources, contribute positively to economic development and reduce the environmental impacts of agriculture, including emission profiles and biodiversity. Possible trade-offs should be identified and analysed explicitly – such as the socio-cultural factors that constrain the adoption of new, more resource use efficient technologies.

Lesson 4: Rural development is not equal to agricultural development

The importance of non-farm activities for the rural economy has largely been ignored. Non-farm income-generating activities are, however, key elements in the livelihood strategies of rural dwellers and are strongly linked to food security and the environmental impacts of agriculture. In addition to research on agricultural production, the research agenda for rural development should also consider non-farm activities, institutional arrangements that facilitate rural development and environmental services such as water, carbon and biodiversity.

Lesson 5: Crucial decision level: the farm household

Policies or technologies that are not consistent with the context in which farm households operate will have little impact. Farm households weigh competing claims on their land, labour and capital of different (agricultural and non-agricultural) activities in the light of their household objectives. These objectives and the portfolio of possible household activities need to be taken into account when designing policies or technologies.

Lesson 6: Agriculture and on-farm and off-farm biodiversity are tightly linked

Agronomists and environmentalists need to collaborate in taking local perspectives as the starting point for development of new biodiversity management programmes. Until now, lack of common understanding and of an operational framework have strongly hampered successful implementation of such programmes. Local improvement of germplasm integrates and complements breeding activities in the public sector and contributes to conservation of agro-biodiversity and to rural development.

Lesson 7: Interaction increases impact

In addition to increasing interaction and integration between the different scientific disciplines, attention must also be given to strengthening interaction with stakeholder groups. Over time, participation and multi-disciplinarity, complemented by capacity building, have become leading principles in research projects, reflecting the insight that interaction with relevant stakeholders is an essential element in translating insight into impact. Multi-disciplinary that evolves into inter-disciplinary research, thus, implies building upon the knowledge and experience of the relevant stakeholders (young and old, men and women, rich and poor). This entails a joint learning process, in which the different groups of rural communities such as farmers, researchers, policy makers, traders, NGOs, and other local resource managers learn from and with each other within the context of the research project.

Lesson 8: Invest in involvement of stakeholders

Stakeholders' capacities, involvement and relevance depend on cultural, institutional and financial factors. An accurate identification and involvement of stakeholder groups is essential for effective research and policy implementation. Communication is a key element in this process. The identification and involvement of relevant stakeholders is not always easy, as the same cultural, institutional and financial factors may constrain some groups from actively participating (such as women, landless, minority ethnic or religious groups). Additional care and effort must be put into facilitating the involvement of less vocal and powerful stakeholders.

THE WAY AHEAD

Agriculture has played an important role in rural development processes in the past and will continue to do so in the future. Agriculture, however, does not offer silver bullets for eliminating poverty and promoting sustainable development. The role of agriculture must be seen in its specific local context.

Understanding the larger picture

Agriculture is high on global, regional and local development agendas. It functions in relation to its human and natural environment, determining both its opportunities and limitations. One needs to understand this general setting in which agriculture operates in order to assess how agriculture contributes to sustainable development. Most relevant for agriculture at the present time are the effect of WTO negotiations and the impact of climate change. Guiding international policies are the MDGs that so clearly reflect the principles of sustainable development. These provide the framework for an ambitious global agenda to eradicate extreme poverty and hunger.

By promoting inter-disciplinary research, the DLO-IC programme has made an important contribution to placing agricultural research in this perspective. Research findings indicated the importance of a supportive macro-economic setting, institution building, infrastructure, education and alternative earning opportunities for farm households. The insights gained from this broader perspective indicate that future work should not only continue, but also expand the scope of inter-disciplinary and multi-scale research.

Only a combination of insights from all forms of science seems able to deal with the formidable challenge of identifying the most promising policies for sustainable development.

We argue that agriculture plays three specific roles in future rural development strategies:

- A solid base for changing livelihoods;
- A sector providing high quality affordable food; and
- A provider of environmental services.

Each of these roles has its own specific research requirements. Clearly, the three different roles for agriculture identified here are not mutually exclusive neither are they *per se* in conflict. They do, however, call for a clear identification of the dominant role of agriculture under local biophysical and socio-economic conditions and the tailoring of research to meet these specific requirements.

Agriculture as a solid base for changing livelihoods

Developing countries are typically characterized by large agricultural populations and most of the world's poor live in rural communities in these countries. Agriculture alone is insufficient to lift these communities out of poverty. They need to move from a predominantly agriculture-based economy to one that is more industry- and services-oriented. In the developed world, agriculture played a key role in this process by providing a stable basis from which members of rural households could venture into other sectors of the economy while maintaining the security of their farm base. Supporting developing countries in a structural transformation of their economies requires an understanding of the institutional and social setting, the processes of change and the environmental implications.

In terms of agricultural research one could focus, for example, on ensuring stable production, by providing technologies tailored to female-dominated agricultural households (since males tend to migrate first to urban areas), where possible generating surpluses that allow households to invest in profitable enterprises either within or outside the agricultural sector.

It will also be necessary to look at 'exit strategies' to enable households living in adverse biophysical and socio-economic settings to move out of agriculture. This may involve investments in education and infrastructure, allowing households to access alternative sources of income.

Agriculture as a sector providing high quality affordable food

Against the background of continuing population growth and the changing dietary patterns, agriculture continues to play a key role in ensuring the sustainable supply of safe food at affordable prices. However, many farm households in developing countries are disadvantaged by ongoing globalization, as well as by constraints in the biophysical and socio-economic environment.

Continued investments in agricultural research are needed to overcome these disadvantages. Biophysical improvements, particularly in the field of plant breeding and best agricultural practices, are required in order to increase crop yield potentials, close yield gaps, and increase resource use efficiencies. That should be complemented by farmer-based strategies exploiting local capabilities to increase and diversify production and contribute to environmental sustainability. Land and labour productivity will be increased in this way, creating economic incentives for farm households to produce food in an environmental-friendly way (maintaining resource quality and protecting biodiversity) that is consistent with consumer demands, including local diversity.

Overcoming constraints that emanate from globalization and adverse economic environments requires additional policy research. Research on the scope for agricultural growth needs to be placed in the larger context of increasingly open economies affecting local food markets, the influence of the macro-economic environment as reflected in taxes and relative prices and the impact that the internationalization of agricultural enterprises has on 'rural economic structures'.

Possible implications of expected population growth, dietary changes and climate change for increased food and feed production and associated claims on resources (such as arable land) should be assessed in relation to claims for non-food or non-agricultural use of resources. The provision of biofuels may, for instance, become an important factor leading to fiercer competition for scarce resources in the near future.

Agriculture as provider of environmental services

The multi-functional character of agriculture should enable it to generate more than the traditional benefits of employment, income, food, feed and fibre. It has the capacity to contribute to providing services such as protecting soil and water resources, conserving biodiversity on-farm and off-farm, preserving the landscape and providing an environment for tourism and the well-being of human and animal life.

Most interesting perhaps, are the emerging opportunities to provide clean water and sequester carbon as environmental services through creating markets for such services. These new options go beyond the traditional approaches of conservation and the environmentally sound use of natural resources. Whereas the price of clean water can be negotiated between various stakeholders, specific institutional arrangements, as well as political will, are needed to turn a public good into a private, tradable good – such as in the case of creating a carbon market. Whether and how other services, such as soil protection, the conservation of biodiversity and landscapes and the encouragement of tourism can contribute to sustainable development pathways in different settings requires further investigation. Not much research has been done so far into the topic of which specific institutional arrangements are required to establish markets for environmental services. This also suggests that the scope of research needs to be widened to include important rural development issues, rather than being restricted to agriculture.

LIST OF ABBREVIATIONS

Acronym	**Explanation**
ASAL	Arid and Semi-Arid Lands
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CCD	Community Convention on Desertification
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
DAC	Development Assistance Committee
DC	Developing Countries
DDA	Doha Development Agenda
DLO	Agricultural Research Department of Wageningen UR (in Dutch: Dienst Landbouwkundig Onderzoek)
DLO-IC	DLO – International Cooperation
DSSAT	Decision Support System for Agrotechnology Transfer
EC	European Community
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO-STATistical database
FFS	Farmer Field School
FHM	Farm Household Model
FPR	Farmer Participatory Research
FSR	Farming Systems Research
GAMS	General Algebraic Modeling System
GATS	General Agreement on Trade in Services
GATT	General Agreement on Trade and Tariffs
GMO	Genetically Modified Organism
GNP	Gross National Product
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome
HYV	High-Yielding Variety
IAASTD	International Assessment of Agricultural Science and Technology for Development (led by the World Bank, FAO and IFPRI, 2005-2007) (www.agassessment.org)
IDA	International Development Association
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute (of the CGIAR), Washington D.C.
IMGLP	Interactive Multiple Goal Linear Programming
INRM	Integrated Natural Resource Management
IPCC	Intergovernmental Panel on Climate Change

IPM	Integrated Pest Management
IRMLA	Integrated Resource Management and Land use Analysis in East and South-east Asia
IRRI	International Rice Research Institute (of the CGIAR), Philippines
IVM	Integrated Vector Management
KARI	Kenyan Agricultural Research Institute
LEI	Agricultural Economics Research Institute (in Dutch: Landbouw-Economisch Instituut)
LISEM	LImburg Soil Erosion Model (www.geog.uu.nl/lisem/)
LNV	Ministry of Agriculture, Nature and Food Quality (in Dutch: Ministerie van Landbouw, Natuur en Voedselkwaliteit)
LUPAS	Land Use Planning and Analysis System (developed in SysNet)
MDG	United Nations Millennium Development Goals
NAE	North America and Europe
NAMA	Non-Agriculture Market Access
NARS	National Agricultural Research System
NMR	Natural Resource Management
NUTMON	NUTrient MONitoring system (www.nutmon.org)
ODA	Official Development Assistance
OECD	Organization for Economic Cooperation and Development
PEDIGREA	Participatory Enhancement of Diversity of Genetic Resources in Asia (www.pedigrea.org)
PLAR	Participatory Learning and Action Research
PRSP	Poverty Reduction Strategy Papers
R&D	Research and Development
RDA	Rapid Diagnostic Appraisal
RDSA	Rural Development and Sustainable Agriculture
REPOSA	Research Programme On Sustainability in Agriculture
RESTORPEAT	RESTORation of tropical PEATland
SARP	Simulation and system Approach in Rice Production
SOLUS	Sustainable Options for Land USe (developed in REPOSA)
STRAPEAT	STRAtegies for implementing sustainable management of PEATlands in Bornea
SYSNET	SYStems research NETwork for eco-regional land use planning
TCG	Technical Coefficient Generator
TLU	Tropical Livestock Unit
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
Wageningen UR	Wageningen University and Research centre (WUR)
WEHAB	Water, Energy, Health, Agriculture and Biodiversity
WSSD	World Summit on Sustainable Development (Johannesburg 2002)
WTO	World Trade Organization

CHAPTER 1

AGRICULTURE IN A DYNAMIC WORLD

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Through a combination of technological progress and economic policy convergence, globalization has markedly changed the setting for agriculture during the last decade. Through trade and international agreements, global changes increasingly affect development options for both industrialized and developing economies. At national level, continued population growth, expanding economies and urbanization have, especially in densely-populated areas, led to unprecedented competition for land and water resources between agriculture and other uses such as infrastructure, urban, industry and recreation/nature. This challenges the agricultural sector to produce sufficient, more diverse and safe food, fibre products and feedstocks for biofuel in a sustainable manner. This has to be achieved in an increasingly competitive and globalizing economy. Meeting these challenges requires significant changes in the way agriculture and the value chain are organized.

Some of the major changes affecting agriculture are:

- Globalization of trade, stimulating rapid expansion of the production of high-value agricultural commodities;
- Increasing impact of consumer preferences on agricultural production activities and quality standards;

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- Urbanization processes, industrial development and access to information technology leading to a reduction in cultivated area, especially in the land area for less-remunerative cereal production;
- Impacts of global environmental changes, particularly climate change induced risks on decision making, and the increasing societal concern with respect to the conservation and use of (agro-)biodiversity.

Various studies have addressed the impacts of these changes on agricultural sector development, poverty and food security at the national level in developing countries. However, relatively little is known about the impacts at lower levels. Linking global policy processes such as the WTO[1]-agreements, the World Summit on Sustainable Development (WSSD, Johannesburg 2002), the Kyoto protocol and other international environmental agreements/conventions (CBD, CCD, UNFCCC) to responses at regional and local level is essential for furthering sustainable development. The understanding of the responses to changing political, economic and environmental contexts will determine how successful and sustainable selected development pathways will be.

Research projects executed by Wageningen University and Research centre (Wageningen UR) addressed challenges to sustainable development in various agro-ecosystems and regions in the South. These studies have been supported by the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) through its DLO International Cooperation (DLO-IC) programme. In the course of 2005, LNV developed a new vision on the role of agricultural knowledge and science for development (LNV 2005) to guide its future activities. In the context of this reorientation, a multi-disciplinary group of Wageningen scientists were invited to evaluate and extract lessons learned from past projects in the framework of the DLO-IC programme. This evaluation resulted in the current book.

A common *leitmotiv* in the DLO-IC research programme has been to mobilize and integrate local and international knowledge for reconciling conflicts between the multi-facetted development and land use objectives in rapidly changing rural areas. The extensive networks and research capacity developed over the years in conducting these studies constitute important assets in designing and implementing feasible solutions and have great potential for linking the local-scale options and constraints to the global development agendas.

By 2005, some 70 collaborative North-South projects had been carried out. All science groups of Wageningen UR[2] were involved in the implementation of the programme and at least half the projects and activities undertaken were directly related to the research theme ‘Rural development and sustainable agriculture’[3].

In recent years, there has been a search for more sustainable development strategies. This has direct implications for agriculture, given its relationships with the natural resource base and its prime economic importance in low-income

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[1] A list of acronyms is given in front of the book.
[2] www.wur.nl/UK/research
[3] The other themes covering specific topics on global food chains, agro-biodiversity, nature management, enabling policies, and water.

countries. We identify three areas where agriculture can make a critical contribution: alleviating poverty, protecting natural resources and increasing food security. These areas are directly related to two Millennium Development Goals (MDGs)[4]: eradicating extreme poverty and hunger (MDG 1) and ensuring environmental sustainability (MDG 7).

Major successes of the DLO-IC research programme include scientific work that has resulted in innovative methods to quantify nutrient flows and balances in agro-ecosystems. This work has created scientific and public awareness of the importance of nutrient depletion and has triggered policy reforms in Sub-Saharan Africa (Smaling 1998; Heerink 2005; Koning and Smaling 2005; Gachimbi et al. 2005; De Jager et al. 2005; La Rovere et al. 2005; Giller et al. 2006). Another research line with a significant impact on research capacity building and agro-technology design in Asia resulted in state-of-the-art methods for quantitative assessment of crop yield gaps and resource constraints and for identification of improved natural resource management options at field, farm and regional scales (e.g., in rice-based eco-systems of South and South-east Asia) (Ten Berge et al. 1997; Kropff et al. 1997; Teng et al. 1997; Dobermann et al. 2000; Van Ittersum et al. 2003; Hazell et al. 2005). A third line of work, focusing on integration of biophysical and socio-economic aspects for land use policy analysis, through bio-economic modelling, is having impact on policy formulation at (sub-)national level in the different continents of the South (Kuyvenhoven et al. 1998; Bouman et al. 2000; Aggarwal et al. 2001; Stoorvogel and Antle 2001; Struif Bontkes and Van Keulen 2003; Van Ittersum et al. 2004; Ruben et al. 2004; Roetter et al. 2005, 2007; Bouma et al. 2007).

The quality of the scientific work, combined with considerable investments in capacity building of National Agricultural Research Systems (NARS) in low-income countries in applying the new concepts and techniques, resulted in wide diffusion of knowledge and skills (e.g., in well-known research programmes and/or in form of models such as SARP, NUTMON, DSSAT, REPOSA, SYSNET) (ISNAR 2004). Applications of acquired knowledge, insights and techniques and dissemination of results have, among others, created awareness, fed public debates and triggered policy analyses on issues such as: soil nutrient mining in Africa, causes of and strategies to overcome stagnating or declining yields, effects of emissions from intensive cropping on the environment in Asia, and stakeholder involvement in research processes addressing the various sustainability dimensions in agricultural development and resource use.

A key factor for success has been the intimate collaboration of the various science groups at Wageningen UR and their partners in the South. In that collaborative mode, it was possible to support shaping of policies on agricultural development and environmental issues and identifying successful interventions from local (e.g., provincial and district rural development plans) to international level (e.g., in the framework of IPCC Assessments; InterAcademy Council 2004; Millennium Ecosystem Assessment 2005; UN Millennium Project, Task force

[4] www.un.org/millenniumgoals

reports; International Assessment of Agricultural Science and Technology for Development (IAASTD)). In retrospect, we may conclude that Wageningen scientists substantially contributed to the scientific challenges expressed during 'The Future of the Land' conference (Fresco et al. 1994).

Though considerable progress has been made in research, capacity building and policy-oriented activities, the efforts have often been fragmentary. Separate projects have led to insufficient attention for synthesizing results to further support policy formulation and evaluation. Fragmentation also prevented full exploitation of the potential to contribute to public debates on rural development and sustainable agriculture and the role that agricultural knowledge, science and technology can play in furthering sustainable development in the South.

In this book, we draw lessons from past projects to contribute to future thinking about issues such as poverty alleviation, increasing food security and natural resources conservation. Our conclusions stress the strategic role of agriculture in development processes. This can be more specifically defined in terms of three different roles of agriculture:

- Provide a stable basis for changing livelihoods (e.g. facilitating the gradual transition out of agriculture into other sectors of the economy);
- Provide sufficient affordable food of the quality needed to sustain a growing world population; and
- Deliver essential environmental services.

The relative significance of these three functions is, of necessity, location-specific. These three roles are neither mutually exclusive, nor necessarily in conflict with each other. They do, however, make it essential that the dominant role of agriculture in specific settings is identified, so that research can be tailored accordingly.

We start by placing the changing role of agriculture in a *Historical perspective*. Ensuring the production of sufficient food to meet the needs of a growing population has long been the focus of agricultural research and in *Food security* we acknowledge this as a continuing and major concern, while drawing attention to the increasing role of food quality to respond to the increasing consumer influence. At the same time, however, increasing agricultural production often has had serious environmental repercussions. As we show in *Agriculture and environment*, the production decisions made by rural households affect both the environment and the way natural resources are managed. As such, they play a significant role in determining the extent to which policy objectives can be achieved. Decisions taken at household level not only determine actual levels of agricultural production (food security objectives), they also affect the long-term quality of local natural resources and their capacity to support production (sustainability objectives).

The majority of the world's poor live in the rural areas of developing countries. Rural households are, therefore, a major target group in poverty reduction policies. As we make clear in *Rural livelihoods*, non-farm activities are an essential part of community and household activities and livelihoods. We conclude that analysing and interpreting the interactions between farm and non-farm activities is a particularly fruitful line of future research. In *Lessons learned* we draw together the issues raised and reflect on the future role of agriculture.

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CHAPTER 2

HISTORICAL CONTEXT OF AGRICULTURAL DEVELOPMENT

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INTRODUCTION

Agricultural development during the last 50 years has been shaped by three persistent forces of change: globalization, technology and people. *Globalization* is the force that is increasingly shifting the focus from domestic to international opportunities, as world markets become more accessible. Improved *technologies* represent forces that are improving the ability to produce and deliver what consumers want and *people* are exerting their influence, either directly as consumers, or indirectly as custodians of the environment in which food and fibre products are produced. These three forces do not act independently of course, but they interact. Moreover, the relative importance of the three forces has varied, both, in the course of time, and in different regions and/or countries. In this chapter, a broad overview is given of global agricultural and rural developments since World War II (WWII), the forces that shaped their dynamics and their interactions with society.

GLOBAL CHANGE AND AGRICULTURAL DEVELOPMENT: THE PAST

Schematically three periods are distinguished, the *period of reconstruction* (1945-1974), covering the immediate post-war period, with strong emphasis on food

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security, until the time that food supplies were more or less secure; it includes the early phase of the Green Revolution period, starting in about 1960; the *age of uncertainty* (1975-1985), with emphasis on parity farm income in the Western world, growing overproduction of food, and trade wars until the Uruguay Round of the GATT (General Agreement on Trade and Tariffs, the predecessor of the World Trade Organization), emergence of environmental concerns; consolidation of the Green Revolution in the Developing World, attention for adoption of the associated technologies in ‘less-favoured areas’; and the *age of adjustment* (1986-2001), characterized by increasing attention for environmental issues, rapid globalization and integration, emergence of information and communication technology.

The period of reconstruction (1945-1974)

Although agricultural developments differed among individual countries, in broad lines, a distinction can be made between the developed (in this period largely equivalent to the ‘Western’, industrialized) countries and the developing countries that at the end of WWII were largely ruled as colonies, and became independent in the course of this period.

Developed countries

In the aftermath of World War II, when many countries, especially in Europe, had suffered food shortages, the main objective of agricultural policy in the developed economies was to ensure adequate supplies of food. The dominant driving force for change was policy focusing on the consumer. The major concern was the need to stimulate agricultural production using improved technologies and monetary incentives. Consequently, this period was characterized by spectacular production gains (De Wit 1986), through: (i) rapid integration of mechanization into farming activities, (ii) increased use of inputs, such as fertilizers and other agro-chemicals and adoption of crop varieties that effectively could utilize these inputs, (iii) increased levels of state-funded research and development, particularly in plant and animal genetics, and farm management. In this period, the Common Agricultural Policy (CAP) of the European (then Community and currently) Union (further referred to as EU) was formulated and implemented, following the Treaty of Rome (1958).

After restoration of the food supply, government concern increasingly shifted towards supporting farmers’ standards of living. Technological innovation remained important, but the social welfare of rural communities and income parity for primary producers became dominant issues in agricultural policies. In a review of agricultural policies of developed countries, James (1971) identified similarities in policy objectives between the USA, Australia and the EU in terms of their desire to stabilize agricultural prices and the necessity to ensure an equitable standard of living for the rural communities.

These objectives can be recognized in the objectives of the CAP, as formulated in the Treaty of Rome (1958): (i) guarantee food supplies at stable and reasonable prices; (ii) ensure a fair standard of living for farmers, and (iii) improve agricultural productivity through technical progress, and develop more rational production systems that employ resources, especially labour, more efficiently. Those goals reflected widespread rural welfare problems, the relative backwardness of agricultural production in many areas, and a continuing concern for secure food supplies. Agriculture also had real political power, as it presented a large ‘agricultural vote’, comprising a substantial proportion of the total electorate, i.e., over a quarter in France, Italy, and Luxembourg. The CAP, adopted by the original six members of the European Community was consistent with the highly interventionist and protective policies previously maintained by the individual members.

The CAP produced spectacular results in terms of technical progress and production. The Community soon achieved self-sufficiency and then started generating cyclical and structural surpluses. However, despite the massive assistance measures of the national governments and the EU, average farm incomes kept falling as a result of imbalances between the supply of and demand for agricultural products. In essence, the productivity gains that resulted from investments in research and development were outstripping rises in consumer demands for food and fibre products. As a result, by the early 1970s such a persistent decline in farmers’ terms of trade[1] was evident that it placed farm reconstruction firmly on the political agenda.

Developing countries

Agricultural development was neglected in most developing countries during this period. Developing countries were bent on industrializing, and cheap cereal and feed imports (largely from developed countries) provided substitutes for the expansion of domestic grain-agriculture. The Green Revolution[2] technology, further explained below, became available for adoption towards the middle of the period and was disseminated to medium-to-large commercial farmers in the more well-endowed regions of developing countries. However, on average, productivity growth in food-agriculture was slow prior to the 1975-85 period; incentives to farmers were minimal; agricultural terms of trade were kept low to provide low-priced food for the urban population as a measure to enable maintenance of low wages in manufacturing. Export-agriculture was ‘taxed’ through parastatals, paying below world-market prices with the aim (not generally realized) of using the proceeds to finance industrialization. Public investment in agricultural infrastructure was generally below 15% of total investment, and tended to favour large commercial farms and export-agriculture.

During this period, international concerns over lagging development and the specter of famine in many poorer countries mounted, as underscored by the Pearson Report of 1969 and the Tinbergen Report of 1970. In 1969, the Development Assistance Committee (DAC) of the Organization for Economic Cooperation and

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[1] Terms of trade is the ratio of prices received to prices paid; a declining terms of trade indicates that farmers’ profit margins are being reduced – referred to by economists as ‘cost/price squeeze’.

[2] Term coined by U.S. Agency for International Development director William Gaud (March 1968), referring to a massive effort to increase yields of the major cereals (wheat, rice, maize) by using: (i) new crop varieties, (ii) irrigation, (iii) chemical fertilizers, (iv) pesticides and other biocides, and (v) mechanization.

Development (OECD) introduced the concept of Official Development Assistance (ODA), and in 1970, the General Assembly of the United Nations proposed donor countries to allocate 0.7% of their Gross National Product (GNP) to ODA.

Many of the developing countries had just achieved independence from their respective colonizers. The Food and Agriculture Organization of the United Nations (FAO) in collaboration with many (inter)national agencies developed the concept of a Green Revolution to increase the yields of cereals, comparable to the developments in cereal production in the USA and European countries. The Green Revolution originated from breeding studies on wheat, begun in Mexico in the 1940s by the Rockefeller Foundation, and was institutionalized with the establishment of the International Maize and Wheat Improvement Center (CIMMYT) in 1966 by the Rockefeller Foundation and the government of Mexico. CIMMYT included maize in its work programme. The agricultural practices promoted were based on the science founded by Von Liebig (1855) and his contemporaries. One stated purpose was to increase food production in the face of recurrent famines and increasing food scarcity as a result of increasing populations. Yet, an important intention was the creation of a growing market for farm inputs.

The strategy of the Green Revolution was to concentrate inputs and services on a few major crops, such as wheat, rice, and corn on the best arable lands and for the better-off farmers. Some critics, chiefly concerned with the social implications, denounced these provisions. They argued that many farmers were excluded from what was perceived as progress.

In South-east Asia, the International Rice Research Institute (IRRI) was established in Los Baños in the Philippines in 1960, with major financial support from the Rockefeller and Ford Foundations. In the 1970s, IRRI and other international research centres for international and tropical agriculture became members of the Consultative Group on International Agricultural Research (CGIAR), supported by various international organizations including the World Bank and a large number of developed countries. Today, the Group provides the umbrella for a range of (currently: 15) international research institutes. While CIMMYT and IRRI were commodity-oriented, most of the other CGIAR institutions concentrated on farming systems, but have often similarly promoted input-intensive farming schemes.

IRRI's first major activity after its establishment was to breed rice lines that would allow application of higher doses of fertilizer. The modern rice varieties can cope well with high doses of nitrogen fertilizer, whereas the traditional varieties tended to lodge. The new lines were also no longer photosensitive, so that they could be planted year-round, thus, strongly promoting multiple cropping.

In 1966, IRRI began to distribute seeds of the so-called High-Yielding Variety (HYV) IR8, which were mostly distributed as a package combined with chemical fertilizers. Pesticides followed soon, since the new variety was more susceptible to pests and diseases. The new practices became dominant within a few years in several South-east Asian countries. At first, the results of the these HYVs were convincing. Yields doubled or even tripled, similarly to those for wheat (Evenson and Gollin 2003). Later, similar developments were achieved in maize. Evidently, the increased yields were only possible with the help of substantial quantities of chemical inputs, so that the Green Revolution technologies created a need for chemical inputs.

Another component of the Green Revolution was the establishment of large-scale irrigation systems through construction of big dams and often flooding of previously settled areas and fertile farmland. The efficiency of large irrigation networks was and still is the subject of controversies.

The Green Revolution introduced also new machines for land preparation and a set of harvest and post-harvest technologies. Of all implements, the so-called power tiller had the most far-reaching effect on the soil. Puddling of the paddy soil with this machine destroys much of the natural soil structure and mixes the soil particles thoroughly.

The use of HYVs and chemical inputs soon became the dominant practice among farmers, and growing crops for subsistence gave way to the production of cash crops.

Age of uncertainty (1975-1985)

Developed countries

In this period, farmers increasingly protested against the forces of globalization and the reform of international trade under the General Agreement on Tariffs and Trade. The GATT was signed in 1948 with the aim to provide a forum for negotiation of tariff reduction, and the elimination of non-tariff barriers such as quota and embargoes. Important aspects of the GATT in this context included: (i) tariffs were permitted, but their rates were bound and could only be increased under explicitly specified waiver provisions; (ii) practices of dumping and subsidizing exports were prohibited and a process for determining anti-dumping and/or countervailing duties was explicitly formulated; (iii) quantitative restrictions such as quota and licenses were prohibited. In practice, GATT was relatively ineffective with respect to international trade in agricultural products, because of wide-spread exemptions for agriculture, the substantial waivers that were granted, breaches of rules that were accepted, and the ineffective ways of dealing with important questions such as subsidies and state trading (Harris 1982).

Developing countries

After more than a decade, in spite of the all-out support by governments and international institutions, the seeming success of the Green Revolution began to loose some of its brilliance (Conway and Barbier 1990). First, social concerns took the centre stage of the critique. Successful performance of HYVs required use of substantial quantities of chemical inputs. As many of the small farmers could not afford these, they had to borrow money. To some extent, government programmes provided loans to farmers so that they could avail of the package of seeds, fertilizers and biocides. Farmers that could not participate in this kind of programmes had to borrow from the private sector. Because of the exorbitant interest rates for informal loans, many small farmers did not even reap the benefits of higher yields. After harvest, they had to sell an increasing share of their produce to pay loans and interest. Thus, they became more dependent on moneylenders and traders and often lost their land to them, even with the soft loans from government agencies.

Subsequently, critics increasingly brought environmental aspects into the discussion. Since the late 1980s, scientists at CIMMYT and IRRI acknowledged the problems associated with indiscriminate pesticide use and the decreasing soil fertility (and yields) in fields continuously cropped with high-intensity cereal crops (Cassman et al. 1995; Dobermann et al. 2000). The use of HYVs and chemical inputs as the dominant practice among especially well-endowed farmers, led to a situation where farmers disregarded other means of yield improvement for a long time. Official programmes to compare methods using high external inputs (the chemical way of farming) with traditional practices only started to gain ground again in the 1990s.

Age of adjustment (1986-2001)

Developed countries

This period is characterized by continuing large-scale industrialization of agricultural production, with as its main consequences:

- Change from producing commodities to manufacturing products;
- Emphasis on the systems approach, with increased emphasis on the entire food chain from raw materials supplier to end-user;
- Re-alignment, with increasing specialization that separates ownership, operation and location of various production activities, new alliances are formed;
- Negotiated coordination, in which attempts are being made to system adjustment in response to changes in consumer demand, economic conditions and technological improvements;
- Risk management, where production and price risk can be reduced, the emphasis on the chain approach increases the risk associated with partnership selection, integration and performance;
- Changing power relations, where concentration, specialization and coordination stimulate opportunistic behaviour by value chain partners;
- Information technology development, where technical and consumer information enhance the value chain's competitive position within a market.

In terms of technological developments, this period is characterized by new product development through biotechnology, active packaging, increased production efficiency through application of precision farming, biotechnology, integrated pest management, strong development of logistics through integrated transport and storage systems, and improved preservation systems and the communication 'revolution', through electronic data exchange.

Developing countries

For the developing countries, an event with major impact in this period was the disappearance of the Soviet-Union, which effectively ended the Cold War. This resulted in several important changes through market-based economic liberalization and globalization. Farming that had no comparative advantage, because it was under policy protection has been exposed to the giant international market. One of the important factors behind the establishment of the Millennium Development Goals (MDGs)[3] was a decline in development aid to the least-developed countries, after the Cold War, by about 30% by West-Bloc countries and by some 50%, if assistance from East-Bloc countries is included. As a result, developing countries, where the agricultural sector occupies a major share of the economies and more than half of the populations depend on agriculture for a living, sought to switch from self-sufficient to commercial agriculture in an effort to cope with the impact of the international market. Meanwhile, the number of poor people has increased and the gap between rich and poor has expanded, as small farmers started contract production under large farm owners or as they lost their farm land to become tenant farmers or farm labourers – some of the negative impacts of globalization.

Within that context, many developing countries are preparing Poverty Reduction Strategy Papers (PRSP) in return for receiving financial support from the World Bank, through the International Development Association (IDA), the Bank's branch for the poorest countries. This indicates that they face a situation where they find it extremely difficult to come up with their own visions of development just by dealing with individual development issues; they have no option other than to introduce more comprehensive approaches. In dealing with the poverty issue, the MDGs emphasize "a fair distribution of the results of economic growth and implementation of cooperation focused on aid to the poor as its direct goal". It also points to the importance of "support for poor rural areas in remedying regional disparities, along with aid for basic education, health and medical care, safe water supplies as well as support for women in developing countries". PRSPs also emphasize 'human security'.

A major challenge to the agricultural industry in the developing world, associated with the increasing globalization and liberalization is to find out how to abandon a culture of opportunism in their business dealings with suppliers and buyers and replace it with trust and transparency and that in a continuous struggle to sustain economic viability.

GLOBAL CHANGE AND RURAL DEVELOPMENT: THE PRESENT

CAP reform – a long-term perspective for sustainable agriculture

In June 2003, EU farm ministers adopted a fundamental reform of the Common Agricultural Policy (CAP). This reform completely changed the way the EU supports its farm sector. The new CAP is geared towards consumers and taxpayers, while giving EU farmers the freedom to produce what the market wants. Eventually, the vast majority of subsidies will be paid independently from the volume of production. To avoid abandonment of production, Member States are allowed to

[3] www.un.org/millenniumgoals

maintain a limited link between subsidy and production under well defined conditions and within clear limits. These new 'single farm payments' that will come into effect in 2008, are linked to the respect of environmental, food safety and animal welfare standards. Severing the link between subsidies and production has made EU farmers more competitive and market-orientated, while providing the necessary income stability. More money is available to farmers for environmental, quality and animal welfare programmes as a result of reducing direct payments for bigger farms. Within the reform, a number of the commodity (milk, rice, cereals, durum wheat, dried fodder and nut) sectors have also been revised. This reform will also strengthen the EU's negotiating hand in the ongoing WTO trade talks.

Key elements of the reformed CAP

- A single farm payment for EU farmers, independent from production; a limited number of coupled elements may be maintained to avoid abandonment of production;
- This payment will be linked to the respect of environmental, food safety, animal and plant health and animal welfare standards, as well as to the requirement to keep all farmland in good agricultural and environmental condition ('cross-compliance');
- A strengthened rural development policy with more EU money, new measures to promote the environment, quality and animal welfare and to help farmers to meet EU production standards, started in 2005;
- A reduction in direct payments ('modulation') for bigger farms to finance the new rural development policy;
- Revisions to the market policy of the CAP:
  - Asymmetric price cuts in the milk sector: the intervention price for butter will be reduced by 25% over four years, which is an additional price cut of 10% compared to Agenda 2000, for skimmed milk powder, a 15% reduction over three years, as agreed in Agenda 2000, is retained;
  - Reduction in the monthly increments in the cereals sector by half, the current intervention price will be maintained;
  - Reforms in the rice, durum wheat, nuts, starch potatoes and dried fodder sectors.

WTO

Within the framework of WTO the most recent round of ministerial negotiations was held in December 2005 in Hong Kong. The role of WTO may be expected to become more important, now that China also has become a member. In preparation for the Hong Kong-meeting, the General Council concluded in mid-2005 that the Doha Round talks have reached a sticking point within both agriculture and NAMA (Non-Agriculture Market Access). It was stressed that progress must be made on all the three pillars of the agriculture negotiations in parallel (i) *export competition* is the most advanced area of the talks, (ii) *domestic support*, where agreement should be reached with respect to the degree and timing of moving away from trade-distorting support, (iii) *market access*, where the main issue yet to be resolved is the type of tariff reduction formula to be used.

The WTO Ministerial Meeting in Hong Kong made some progress in advancing the Doha Development Agenda. But much remains to be done, particularly in settling negotiating modalities in agriculture and NAMA and in putting some flesh onto the bones of the GATS (General Agreement on Trade in Services). And where progress was made it was qualified, whether in dealing with the concerns of African cotton producers or in improving market access for the products of the least-developed countries. Given the work still to do, it is not guaranteed that new deadlines will be met or that the DDA (Doha Development Agenda) will be concluded on time. There is much at stake should the momentum of multi-lateral liberalization stall; analysis at the OECD (Organization for Economic Cooperation and Development) points to the risk of both major opportunities forgone and of systemic strains to the multi-lateral trading framework. Developing countries would be among the principal losers. Charting the way ahead will require that trade policy be seen in a broader domestic context which recognizes that market opening works best when it is backed by sound macro-economic policies, flexible labour markets, a culture of competition and strong institutions. Through this lens, trade reform can be promoted as a necessary tool of growth and development rather than as a concession paid to others.

In *agriculture*, some progress was made under all three pillars of sustainability. In market access, the revised ministerial text formalizes the ‘working hypothesis’ on structuring Members’ tariffs for reduction within four bands, with bigger cuts on higher tariffs. On domestic support, the text confirms the ‘working hypothesis’ that the Aggregate Measure of Support would be classified in three bands.

The EU will be in the top band, facing the highest linear tariff cuts, the US and Japan in the middle and everyone else in the bottom band. Notably, the text specifies explicitly the necessary overall cuts in trade-distorting domestic support, to make it more difficult for countries to simply re-classify subsidies in order to dodge reduction commitments. And for export competition, the text calls for the “parallel elimination of all forms of export subsidies and disciplines on all export measures with equivalent effect” by the end of 2013, with a substantial part of the elimination to be realized by the end of the first half of the implementation period.

Cotton was for many the litmus test of success in Hong Kong. Here, agreement was reached that developed countries will give duty-free and quota-free access to least-developed country exports as of the conclusion of Doha Round negotiations. Developed countries (i.e., the US) will eliminate export subsidies in 2006. The text also provides for faster and deeper reductions in trade-distorting domestic subsidies to cotton than those that will be achieved through the general schedules for domestic farm subsidies.

In NAMA, the text provides for bigger cuts for higher tariffs. Importantly, the text links the level of ambition for agriculture and NAMA, specifying that this ambition is to be achieved in a balanced and proportionate manner consistent with the principle of special and differential treatment. And, in a key element of the development package, agreement was reached on the principle that developed countries, and developing countries declaring themselves able to do so, should provide, on a lasting basis, duty-free and quota-free access for exports from *least-developed countries* by 2008.

The Millennium Development Goals

The MDGs set by world leaders at the Millennium Summit in September 2000 represent an ambitious agenda for reducing poverty and improving lives. The eight MDGs – that include halving extreme poverty to halting the spread of HIV/AIDS and providing universal primary education, all by the target date of 2015 – form a blueprint agreed to by all the world's countries and all the world's leading development institutions. They have galvanized unprecedented efforts to meet the needs of the world's poorest. *First*, the MDGs are people-centred, time-bound and measurable. *Second*, they are based on a global partnership, stressing the responsibilities of developing countries for getting their own house in order, and of developed countries for supporting those efforts. *Third*, they have unprecedented political support, embraced at the highest levels by developed and developing countries, civil society and major development institutions alike. *Fourth*, they are attainable.

SOCIETAL REACTIONS

Following WWII, the major societal concern in the developed world was restoration of the food production (capacity), partly in response to the devastating effects of the war, partly in response to the rapid population increase, associated with technological developments in medicine. As indicated above, government policies were directed towards increasing agricultural production through technological innovation, strongly supported by public expenditure in agricultural research and development, which resulted in rapid intensification of agricultural production. Societal concerns with respect to the negative aspects of this agricultural intensification, based on increasing use of agro-chemicals, did not come to the fore until the early 1960s.

Silent Spring (Rachel Carson 1962)

In *Silent Spring*, Carson meticulously described how DDT[4] entered the food chain and accumulated in the fatty tissues of animals, including human beings, and caused cancer and genetic damage. A single application on a crop, she wrote, killed insects for weeks and months, and not only the targeted insects but countless more, and remained toxic in the environment even after it was diluted by rainwater. Carson concluded that DDT and other pesticides had irrevocably harmed bird and animal populations and had contaminated the entire world food supply.

The most important legacy of *Silent Spring* was a new public awareness that nature was vulnerable to human intervention, i.e., at times, technological progress

[4] Dichlorodiphenyltrichloroethane is a pesticide once widely used to control insects in agriculture and insects that carry diseases such as malaria.

could be so fundamentally at odds with natural processes that it must be curtailed. Conservation had never raised much broad public interest, as few people really worried about the disappearance of wilderness. But the threats Carson outlined – the contamination of the food chain, cancer, genetic damage, the deaths of entire species – were too frightening to ignore. For the first time, the need to regulate industry in order to protect the environment became widely accepted, and environmentalism was born.

Criticism of the Green Revolution

Following initial enthusiasm about the 'magic' of the Green Revolution, that had resulted in substantial increases in food production, especially in developing countries and, thus, reduced the risks of widespread famine, critical notes were gradually developing.

The scale issue – Early evidence from India suggested that small-scale farmers were not adopting Green Revolution seeds (HYVs), because (i) seeds are part of a 'package' of inputs (fertilizer, irrigation, pesticides, mechanization), that is more accessible to larger farms; (ii) lack of information and knowledge, i.e., extension agents usually work with large farms; (iii) insufficient credit availability, i.e., banks don't lend to peasants; (iv) minimum size needed for some inputs, especially pumps and tractors; (v) lower price for produce because of higher yields would hurt small farmers.

Technological treadmill – Pre-Green Revolution agriculture is in fact more efficient, although lower-yielding. The real change in the Green Revolution is in fertilizer use. Green Revolution requires farmers to loose control of their productive system and to become dependent on outside sources of energy.

Food insecurity increased – The Green Revolution technology is a less stable and riskier strategy and poor farmers are exposed to greater dangers of crop failure and hunger with HYVs than with local technology. Causes of instability: (i) genetic vulnerability – danger of susceptibility to diseases, pests, or weather is increased by replacing heterogeneous crops with monocrops and single varieties; (ii) market integration means that farmers in different places tend to respond to the same 'signals' in the economy to increase or decrease production; (iii) higher mean yields naturally have larger standard deviations.

Ecological problems – Agricultural intensification with Green Revolution technology leads to negative ecological consequences. The main reasons are: (i) use of chemicals (fertilizers and pesticides) pollutes the environment and harms wildlife; (ii) use of HYVs eliminates landraces, causing genetic erosion and genetic vulnerability; (iii) agricultural intensification leads to soil degradation (salinization, acidification).

In response to these criticisms, science developed a number of new foci (Mann 1997): (1) Methods to increase participation by small farms in Green Revolution technology; farming systems research (FSR), participatory research methods. (2) Integrated rural development programmes to focus on 'basic needs' and income generation. (3) New techniques to reduce environmental impact (integrated pest management, sustainable agriculture, on-farm conservation).

The farming systems research (FSR) approach (1970s)

In the mid-1960s, there was little interaction between technical scientists (who were mostly on experiment stations) and social scientists (who tended to be concentrated in planning units).

Thus, in the Green Revolution areas, because of the spectacular nature of the technology, experiment-station based technical scientists were very successful in their work. However, the lack of success in using a similar approach in poorer agricultural areas (i.e., with resource-poor farmers), led to the evolution of the FSR approach, in which there is close cooperation between technical and social scientists. Work with farmers in various countries in the late 1960s and early 1970s revealed that these limited-resource farmers (Norman 1993):

- Are rational (i.e., sensible) in the methods they use. For example, in Africa, there was little support from station-based research on mixed cropping until the early 1970s, although earlier farm-based research had revealed the rationality of the practice (Norman 1974).
- Are natural experimenters (Biggs and Clay 1981). Obviously, the methods farmers naturally use will be those that appeal to them and are informal in nature (Lightfoot et al. 1989), in the sense that they are not usually amenable to formal statistical analysis.
- Understand the environment in which their rather complex farming systems function. These systems consist of crops, livestock, and off-farm enterprises (Norman et al. 1981). In fact, it could be asserted that such systems are often more complex than the specialized farming systems in many high-income countries. Unlike the case with limited-resource farmers in low-income countries, many of the constraints in specialized agriculture in high-income countries can be broken or avoided through seeking advice and taking advantage of and receiving external help (Norman and Collinson 1986).

Consequently, considerable respect developed for limited-resource farmers. The FSR approach evolved because of increased awareness on the part of researchers that such farmers:

- Had a right to be involved in the technology development process, because they stood to gain or lose most from adoption of the technology;
- Could productively contribute to the development of appropriate improved technologies.

Therefore, the fundamental principle of FSR was that farmers could help in identifying the appropriate path to agricultural development. It is now recognized that limited-resource farmers can be involved productively in all stages of the FSR approach. Farmers' participation at all stages relates in one way or the other to the selection, design, testing, and adoption of appropriate technologies.

FSR rapidly became popular and was strongly supported by many donor agencies (Brown et al. 1988). Thus, the FSR approach evolved primarily as a result of lack of success in developing relevant improved technologies. The strong technical focus that characterized the evolution still persists to this day, although increasingly many, including FSR practitioners, are advocating that the approach can be used constructively in addressing not only technological solutions but also those relating to policy/support systems (Collinson 2000).

Integrated Pest Management (IPM)[5]

Chemical control of agricultural pests has dominated the scene, but its overuse has adverse effects on farm budgets, human health and the environment, as well as on international trade. New pest problems continue to develop. Integrated pest management, which combines biological control, host-plant resistance and appropriate farming practices, and minimizes the use of pesticides, seems an attractive option for the future, as it guarantees yields, reduces costs, is environmentally friendly and contributes to the sustainability of agriculture (UN 1992). Agenda 21 (UN 1992) states that IPM should be the guiding principle for pest control. Many countries and donor organizations have explicitly committed themselves to implementing IPM, and their number is increasing. All major technical cooperation and funding organizations are now committed to IPM, and many have developed specific policy or guideline documents.

A number of factors have influenced the evolution process of IPM and Integrated Vector Management (IVM). These include:

Ecological factors – In the past, strategies that relied mainly on the use of chemicals to achieve pest control repeatedly led to failure. In agriculture, frequent treatments disturb the agro-ecosystem balance by killing the natural enemies of pests and cause resurgence and secondary pest release. In addition, populations of previously unimportant pests can increase when primary pests and natural enemies are destroyed. In both, agriculture and public health, repeated applications favour the development of resistance in pest and vector populations to the pesticides used, as well as cross-resistance to other pesticides.

Economic factors – Costs of pesticide use have been on the increase, both to individual users and to national economies. The pesticide treadmill is caused by ecosystem disruption. Unnecessary applications (e.g., calendar spray schedules)

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[5] Integrated Pest Management (IPM) means a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible, and maintains the pest populations at levels below those causing economically unacceptable damage or loss (FAO 1967).

increase agricultural production costs. Failing control has led to increased use of pesticides, while yields have declined. The economic costs and externalities associated with the impact of pesticide use on health and the environment have drawn greater attention.

An increased knowledge base – A growing body of scientific knowledge has contributed to more detailed understanding of ecosystems and of the interactions of the different elements within them. Understanding has also increased how certain pesticide-based practices threaten the sustainability of ecosystems. IPM and IVM have evolved based on increasing scientific evidence.

Public opinion – Increasing concern over effects of pesticides on health and the environment has led to public pressure to reduce their excessive use. For example, groundwater contamination and poisoned wells are a matter of grave concern in countries with intensive agriculture, and in some countries concern over pesticide residues in food is already changing consumption patterns.

IPM at field level

Farmers manage often complex agro-ecosystems. IPM is holistic in its approach, which builds on knowledge about the different elements in the system (soil, water, nutrients, plants, pests, natural enemies, diseases, weeds, weather) and their interactions, to arrive at sound management decisions. As the decision makers, farmers, are central to this process and should have the opportunity to improve their knowledge through suitable adult education methods. Farmer Field Schools (FFSs) provide such an opportunity (Braun et al. 2002; Feder et al. 2003). Their programmes aim at strengthening farmers' knowledge and understanding of the agro-ecosystems they manage. They also aim to develop farmers' skills to observe and analyse agro-ecosystems, to come to informed management decisions. FFSs use non-formal adult education approaches, farmers learn by taking part in solution-seeking in a problem-based setting. Education is field-based, study fields are part of any FFS. FFSs are season-long and follow the development of a crop from seeding through harvest.

Participatory approaches

In both, FSR and IPM it was increasingly recognized that farmers, as the final decision makers on land use and, therefore, on agricultural production need to play an active role in agricultural development. In the 1980s, therefore, participatory approaches in agricultural development research and extension became a focus of attention. The emergence of participation as an issue to be addressed within extension approaches was slower in coming to the forefront, as compared to the attention participation received within research systems. One key element of participation is an emphasis on *developing the capacity* of local people as *an end in itself*, as opposed to the purely mechanistic emphasis of participation as a means within the technology development flow that has often characterized research and extension programmes. During the late 1980s and early 1990s, increasingly more field-based experiences emerged, creating more space for methodological and institutional innovations for agricultural research and extension. Within these participatory approaches – as they became commonly known – special emphasis was placed upon participation of local people and their communities, especially working with and through groups; and building upon the traditional or indigenous knowledge that they held (Chambers et al. 1989; Waters-Bayer 1989; Haverkort et al. 1991).

The rise of Farmer Participatory Research (FPR) was a deliberate effort among agricultural professionals to combine farmers' indigenous traditional knowledge with the more widely recognized expertise of the agricultural research community. The approach aimed to distinguish itself from FSR in its more deliberate attempt to actively involve farmers in setting the research agenda, implementing trials and analysing findings and results (Farrington and Martin 1988). FPR has gone beyond the on-farm trials which became the standard of FSR, and actually called for farmers to design, monitor and evaluate experiments – in collaboration with researchers – carried out in their own fields (Okali et al. 1994). Some have argued that while FPR approaches can increase participation among farmers, as a research methodology, it has not brought about impact and output (Bentley 1994), or may require more than short-term technology development efforts (Humphries et al. 2000). Research from Africa supports this argument by showing that less than 15% of 'experiments led by farmers' resulted in the definition of new knowledge or the development of new technologies (i.e., were not already in existence elsewhere). The study concluded that farmers' experiments are in fact more 'complementary' than 'synergistic' to formal agricultural research efforts, and that farmers' experiments are more closely linked to agricultural extension activities rather than to agricultural research accomplishments (Sumberg and Okali 1997).

Ecological/biological/organic agriculture

In response to the increasing concern on the use of chemicals (fertilizers and biocides) in intensive agricultural production, pleas emerged for a 'more natural, sustainable' agriculture. Although already in the early parts of the 20th century a movement promoting 'chemical-free' agriculture did exist[6], it really gained momentum in the 1980s and 1990s.

Different terms are used more or less interchangeably to denote this type of agricultural practices, i.e., biological agriculture, ecological agriculture, organic agriculture, and different definitions are used, depending on the source and on the purpose of the definition[7] a very general definition reads like "*both a philosophy and a system of farming. It has its roots in a set of values that reflects an awareness of both ecological and social realities. It involves design and management procedures*

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[6] The term organic, as a descriptor for certain 'sustainable' agricultural systems, appears to have been first widely used by Lord Northbourn (1940) in his book 'Look to the land'. The term organic was first widely used in the USA by J.I. Rodale, founder of Rodale Press, in the 1950s.

[7] We will use the term 'organic' in the remainder of this text.

that work with natural processes to conserve all resources and minimize waste and environmental damage, while maintaining or improving farm profitability. Working with natural soil processes is of particular importance. Such agricultural systems are designed to take maximum advantage of existing soil nutrient and water cycles, energy flows, beneficial soil organisms, and natural pest controls. By capitalizing on existing cycles and flows, environmental damage can be avoided or minimized. Such systems also aim to produce food that is nutritious and uncontaminated with products that might harm human health". The interest in organic agriculture is driven by three main concerns: (i) that our present agricultural practices are having a negative impact on environmental quality, and on resource availability and use; (ii) that these practices are contributing to deterioration in human health; and (iii) that the economic situation for producers continues to decline.

Although in research some attention was paid to organic agriculture in the 1970s (cf. Nauta 1979), only in the 1980s did that branch really take off, partly associated with integrated pest management.

THE FUTURE

The persistence of hunger in the developing world means that ensuring adequate and nutritious food for the population will remain the principal challenge for policy-makers in many developing countries (Roetter and Van Keulen 2007). However, the rapid transformation of diets and the changes in food systems at all levels (production, processing and distribution/retail) pose a number of important additional challenges to food security, nutrition and health policy. Urbanization is likely to increase the 'effective demand' for food security, safety and quality.

The global economy is becoming increasingly integrated through information systems, investments and trade, and agriculture is part of this trend. For some countries, agricultural trade expansion – sparked by agricultural and trade policy reforms – has contributed to a period of rapid pro-poor economic growth. Indeed, some of the countries that have been most successful in reducing hunger and extreme poverty have relied on trade in agricultural products, either exports or imports or both, as an essential element of their development strategy. Many of the poorest countries however, especially in Africa, have not had the same positive experience. Rather, they are becoming more marginalized and vulnerable, depending on imports for a rising share of their food needs without being able to expand and diversify their agricultural or non-agricultural exports (Sachs 2005). For the least-developed countries, the benefits from trade reform will only come with a complementary effort in domestic policy and institutional reform and with substantial investment in physical and human infrastructure.

Over the past fifty years, humans have changed the face of the earth more rapidly and extensively than in any comparable period of time in human history before, largely to meet rapidly growing demands for food, fresh water, timber, fibre, and fuel. As a consequence, many ecosystem services are being degraded or used unsustainably, including fresh water, capture fisheries, air and water purification, the regulation of regional and local climate, natural hazards, and pests. The Millennium

Ecosystem Assessment (Millennium Ecosystem Assessment 2005) concluded that the degradation of ecosystem services could grow significantly worse during the first half of this century and is a barrier to achieving the Millennium Development Goals. For example, observed recent changes in climate, especially higher regional temperatures, have already had significant impacts on biodiversity and ecosystems, especially in dryland environments such as the African Sahel (Dietz et al. 2004). Degradation of ecosystem services is exacerbating the problems of poverty and food insecurity in the developing world, particularly in the poorest countries. Global climate change is taking place against a natural environment that is already stressed by resource degradation as a result of various factors, including certain forms of agricultural technology and input use. Agricultural activities occupy and influence vast landscapes. Farmers, ranchers, and agro-foresters manage, work and live in watersheds, grasslands, hillsides, coastal plains, forests, and river deltas. These various agro-ecosystems provide a wide range of local, national and global benefits and services in the form of positive externalities and public goods. The precise impacts of climate change on agriculture and food production are difficult to gauge. But two basic messages seem to emerge from the various assessments that have been undertaken so far. For the world as a whole, climate change is unlikely to alter the overall production potential. The benefits of warmer climates for some areas may just be offsetting the problems arising in other areas. In some of the adversely affected areas, however, climate change could jeopardize the livelihoods of millions, particularly where the impacts of climate change are compounded by other factors or where existing poverty and hunger makes it extra difficult to cope with its impacts. Such areas of multiple stresses are expected to emerge primarily in the poorest developing countries, but also some of the emerging Asian economies could well be affected. Because many ecosystem services are not traded in markets, markets fail to provide appropriate signals that might otherwise contribute to the efficient allocation and sustainable use of the services. The Millennium Assessment suggests a wide range of economic and financial instruments for influencing individual behaviour with respect to the use of ecosystem services. These include elimination of subsidies that promote excessive use of ecosystem services and promotion of market-based approaches, including user fees and payments for environmental and ecosystem services. In addition to market instruments, strengthening institutional and environmental governance mechanisms, including the empowerment of local communities, is crucial for the effective management of environmental resources.

Harnessing the best of scientific knowledge and technological breakthroughs is crucial as we attempt to 'retool' agriculture to face the challenges of an increasingly commercialized and globalized agriculture sector. Modern science and technology can also help provide new impetus for addressing the age-old problems of production variability and food insecurity of rural populations living in marginal production environments. In a similar vein, science and technology both enable and drive the creation of increasingly sophisticated food chains that can deliver fresh and minimally processed food to demanding consumers. Whilst the real and potential gains from science and technology are apparent, it is also necessary to take into consideration the fact that research and technology development are more and more in the private domain: biotechnology is a prime example. Biotechnology holds great promise, but may involve new risks. In most countries, the scientific, political, economic and institutional basis is not yet in place to provide adequate safeguards for biotechnology development and application, and to reap all the (potential) benefits. Clearly, the question is not what is technically possible, but where and how life sciences and biotechnology can contribute to meeting the challenges of sustainable agriculture and development in the 21st century, based on a science-based evaluation system that would objectively determine, case by case, the benefits and risks of each individual Genetically Modified Organism. Similarly, the evolution of food chains has been led by the private sector, with obvious benefits in terms of food safety and food price reductions. However, there have been casualties as some farmers and firms have been marginalized. In this case, the question becomes one of whether there are technical solutions and business models that can enable engagement of such marginalized groups. Modern science can also provide opportunities for enhancing input efficiencies and for developing more sustainable production systems. The extent to which farmers in developing countries benefit from such technologies, which are often highly knowledge- and labour-intensive, is a matter of debate. Furthermore, it is doubtful whether they are compensated for the environmental goods that such changes affect. Also to be discussed is the appropriate role of traditional knowledge and local genetic resources in future food systems.

Public investment in infrastructure, agricultural research, education and extension is essential for stimulating private investment, agricultural production and resource conservation.

However, the marginal production environments have historically received extremely low levels of public investments, even though they are home to a large proportion of the world's poor. The Green Revolution has bypassed these environments and future technological prospects seem to be limited. These marginal environments could benefit from breakthroughs in genomics and genetic engineering, coupled with resource conserving technologies such as conservation agriculture, but current investments in biotechnology are not targeted to the problems of these areas (Fan and Hazell 1997). Significant scientific efforts in developing effective resource management techniques would also be crucial for the fragile soils and other resources in these environments (InterAcademy Council, 2004). Even if the technologies are available, getting them to into the hands of poor farmers in marginal environments continues to be a formidable challenge.

The challenge is complicated by the fact that the ultimate goal must be to increase the income of the farmers (Kuiper et al. 2007). Thus, there is a need to develop business models that enable these farmers to access higher value markets, so that they can afford improved inputs and their disposable income increases.

The ongoing challenge for agricultural science for both the developed and developing world thus is the design, monitoring and evaluation of sustainable agricultural systems that are technically feasible, ecologically maintainable, economically viable and socially acceptable.

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CHAPTER 3

FOOD SECURITY

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INTRODUCTION

Definitions

The ultimate aim of activities and interventions aimed at guaranteeing food security is to arrive at a healthy and well-nourished population that can take on, to the maximum of its capacities, the development of its own community, area or country. In these efforts, agriculture, in its role as food producer, plays a crucial role. (Sufficient quality) food should be available now, and in the long(-er) run. However, it is increasingly recognized that limited accessibility and unequal distribution of food, often linked to economic underdevelopment and poverty, frequently are more important causes of food insecurity and malnutrition than limited availability of food. Since the 1980s various definitions of food security have emerged, both in academic literature and in national and multi-lateral policy documents. Also field programmes on food security have greatly contributed to a more comprehensive view on the issue. This has led to a definition of food security, accepted in the late 1980s, and reconfirmed at the World Food Summit (WFS) in 1996: Food security represents "a state when all people at all times have physical and economic access to safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (World Food Summit 1996). In a food-secure region the land

R.P. Roetter, H. Van Keulen, M. Kuiper, J. Verhagen and H.H. Van Laar (eds.), Science for Agriculture and Rural Development in Low-income Countries, 27–56.

would have the biophysical capability to produce food of the quality and quantity required by the people, its farmers would have access to capital, credit, and technology, and consumers would have enough purchasing power to acquire food (Aggarwal et al. 2001; ACC/SCN, 2004; Heidhues et al. 2004; Falcon and Naylor 2005).

While this definition of food security was widely accepted, in parallel developments, it was increasingly realized that food security is a necessary, but not sufficient condition to guarantee adequately nourished children. Fair intra-household distribution of food, adequate sanitary conditions and access to safe drinking water and to health facilities are additional conditions for sufficient intake of food of adequate quality, guaranteeing sufficient and effective absorption of nutrients, leading to healthy individuals. The consequences of this concept are that a fully integrated and inter-sectoral approach is needed to ultimately realize the objective of a healthy productive population. In addition to agricultural and economic development, social development, education and health should be integral components of integrated development initiatives. This concept is illustrated in Figure 1, the UNICEF Conceptual Framework that is currently widely accepted and implemented.

Food insecurity or malnutrition, caused by a combination of insufficient food intake (quantity and quality) and lack of good care practices, health services and sanitary conditions, may be acute, chronic or hidden. Acute food insecurity is commonly associated with acute hunger and starvation occurring during famines and disasters. This type of hunger accounts for roughly 10% of the global prevalence of food insecurity, while 90% of the world's hungry are chronically undernourished, due to recurrent lack of availability of or access to food of sufficient quality. Consequences of chronic hunger and malnutrition are, among others, underweight, stunted growth and poor health, resulting in high morbidity and mortality for children. Child malnutrition at a young age is irreversible and translates into poor health (both physical and mental) and reduced labour productivity at the adult stage. The third form of hunger and malnutrition, known as 'hidden hunger', affecting more than two billion people (Von Braun et al. 2005), is associated with micronutrient (minerals, vitamins) deficiencies.

Issues

The world population has doubled since the 1950s, currently surpassing 6.5 billion, and is expected to increase by another 2 billion during the next 25 years – mostly in regions stricken by poverty and hunger. Currently, between 15 and 20% of the world population suffers from hunger and malnutrition. Regional food shortages, mainly in South Asia and Sub-Saharan Africa persist and acute and chronic undernourishment still affects some 800 million people (UN Millennium Project 2005; FAO State of Food Insecurity in the World 2002, 2003, 2004, 2005; Pingali et al. 2006). At the same time, different studies and data, including the FAO Food Balance Sheets, agree that in the last three decades, at global scale, food supplies have been adequate and average food energy availability per capita is gradually increasing (by almost 1% per annum) (Smil 2000; Von Braun et al. 2005). Till recently, most scenario studies on future food prospects have suggested that this trend will not significantly change in

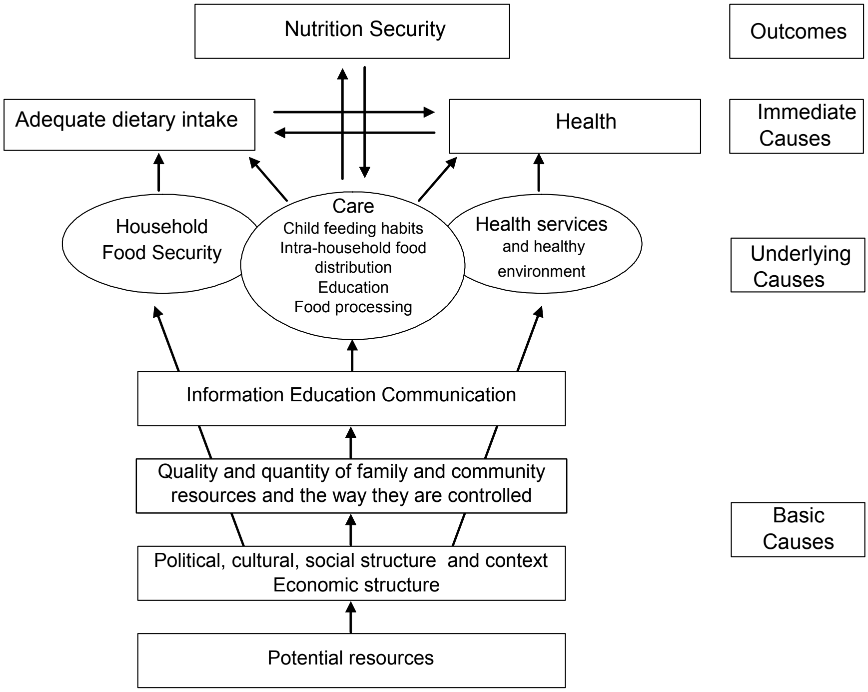

Figure 1. *The UNICEF framework (modified, based on UNICEF, 1998)*

the next few decades. The data underpin the well-known conclusion "that if all food were equally distributed, no one would go hungry". More recently, there is increasing concern about new threats to global food supply – in the short-term due to growing competition from feed production for the livestock sector and increasing petrol prices and cultivation of competing crops for the bio-fuel industry, and, in the longer term due to expected severe negative impacts of climate change on food supply (Parry et al. 2004; IPCC 2007; IAASTD, www.agassessment.org) (see also Verhagen et al. 2007).

This picture is corroborated by data on declining growth of cereal yields in developing countries (Table 1), and by recent trends in staple food prices and stocks (as illustrated in Figure 2 for rice (Hossain 2007)). Currently, the major problem in food security is access to food (Pingali et al. 2006); people lack the economic means to buy food, or are insufficiently embedded within social networks to access food. Food can, instead of being bought in the market, also be obtained through barter, in social exchange or through help from relatives, neighbours or friends.

Continued urbanization increases the number of urban poor lacking the social structures to fall back upon in times of need. Moreover, social safety nets provided by (local) governments are out of reach for many countries in development. This

Table 1. *Growth (%) of cereal yield, area, and production, developing countries: 1970-90 and 1990-2005 (source: Hossain 2007; based on analysis of trend with FAO time series data)*

	1970-90			1990-2005		
	Yield	Area	Production	Yield	Area	Production
Rice	2.35	0.49	2.84	0.92	0.31	1.23
Wheat	3.75	0.88	4.62	1.27	–0.35	0.91
Maize	2.65	0.97	3.61	1.64	0.66	2.30
All cereals	2.68	0.73	3.41	1.20	0.21	1.41

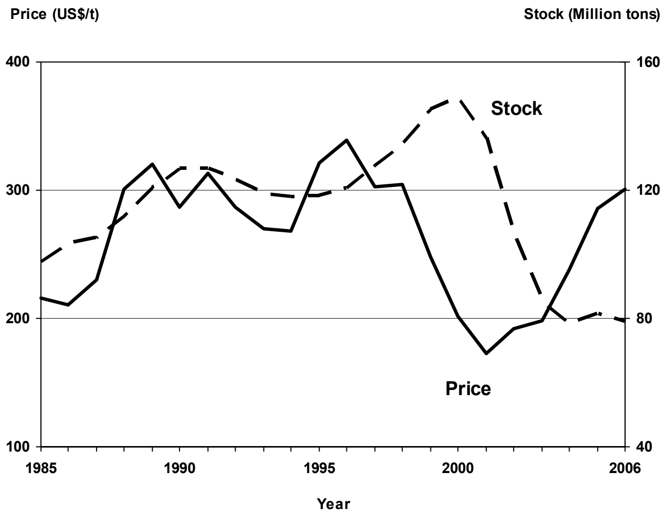

Figure 2. *Trends in international rice prices and stocks (end-period), 1985-2006 (source: Hossain 2007; Stocks data: Papanos, R.S. 2007. The Rice Report, Feb 28 2007 Issue. The Rice Trader LLC. Houston, TX, USA. Price data: Development Policy Group. World Bank online)*

implies that poverty reduction is the most effective means to achieving food security.

A central question that has received relatively little attention so far is: “Can we feed the world without degradation of the natural resource base?” Scenario studies can provide us with images of possible futures. However, many of such studies in the past have neglected one or more of the consequences of likely changes in food demand, consumption patterns, investments required for development of improved science, agricultural knowledge and technologies, shifts in geographical location of food production and consumption, consumer behaviour, resource constraints and the impacts of such changes on food prices and the environment. There is a clear need for more integrated scenario studies on the interactions between agriculture, environmental factors and food supplies (see, IAASTD, www.agassessment.org; Verhagen et al. 2007; Kuiper et al. 2007).

Challenges

Despite the great successes of the 'Green Revolution' (especially in Asia) that made it possible for food production to outpace population growth over the last 40 years, there is, thus, no reason for complacency, as there are serious concerns, especially for the less developed countries, about water scarcity, soil nutrient depletion, political and civil conflict, the HIV/AIDS epidemic, impacts of climate change and lack of technology adoption and dissemination of agricultural knowledge, threatening food security. It is undisputed that eventually the world population needs to reach a stable situation, to avoid resource utilization at rates disastrous to mankind. However, disagreement exists with respect to the extent to which human impact has already triggered irreversible environmental changes (and associated risks for the stability of agro-ecosystems). Concurrently, consumers in the developed and increasingly in the developing world, become wealthier, and change their diets, away from staples such as rice or wheat and tuber crops towards more meat, vegetables and dairy products. Such dietary changes in some prospering regions already have implications for cropping pattern and resource use in other regions (e.g., outsourcing of maize and soybean production) – leading to shifts in the global food system, and in combination with increasing competition for scarce natural resources, create new challenges to agricultural production (Hossain 2007). Hence, further increases in food and feed production per unit area will be required, while optimizing resource use to save land and water for other use(r)s. Water and fertilizer use efficiencies in current crop production systems are far below what would be attainable with appropriate technology and available production ecological knowledge. In many developing countries, water and nutrient use efficiency gains in the order of 30-50% would be possible through adoption of knowledge-intensive farming practices (Smil 2000; Cassman et al. 2002; Pathak et al. 2003; Dobermann et al. 2004). In terms of interventions, wider diffusion and development of knowledge-intensive farming systems is one means to achieve increased food security. However, what matters most in increasing food security is to reduce income inequalities that prevent people from accessing the food they require to lead healthy and productive lives. Moreover, education can help to stimulate people to assume a (more Asian-Mediterranean type as opposed to the Western type of) dietary pattern that reduces the need to increase animal feed production and the inefficient use of food and energy.

While the international community has repeatedly demonstrated concerted efforts in helping the victims of acute hunger, there is less support for reducing chronic and hidden hunger – as these receive less public attention. Adequate nutrition begins at the household scale. It is obvious, that any attempt to properly deal with the complex problem of freeing people from *hunger* and *food insecurity* must go much further than boosting yields and improving water and fertilizer use efficiencies. To overcome food insecurity, policymakers and scientists are faced with an enormous agenda, including more and better-targeted investments, technological innovations and policy interventions – supported by in-depth understanding of the dynamic factors that influence people's access to food (Von Braun et al. 2005).

As most of the world's hungry live in less-endowed rural areas (Roetter et al. 2007), strategies to reduce hunger and poverty in rural areas must be tailored to the specific regional biophysical, economic and socio-cultural settings. In the following we present examples from Sub-Saharan Africa and South-east Asia, regions on which the DLO International Cooperation programme concentrated, to illustrate the required regional differentiation in responding to the complex problems related to food security.

NUTRITION AND HUMAN HEALTH

Food security and quality, nutrition and health

In addition to the problem of access to food, food quality and safety have entered the debate on food security, implying that food should be of sufficient diversity to meet all dietary needs (for both the macro-nutrients and the micro-nutrients), and sufficiently safe, both hygienically and toxicologically. Food safety also relates to the absorption of nutrients from food, and thus to the physiological use that the human body can make of food and nutrients.

Translating food security into nutrition security is yet another step. Where food security is usually defined at the national, district, community or household scale, nutrition security always refers to an individual. Food security at the household scale should translate into balanced meals and meal preparation that enhances absorption of nutrients and minimizes potential food safety hazards. Intra-household distribution of food should be such that all members of the household, also the more vulnerable, receive food in such portions and diversities that their dietary needs are met, whereas their health situation should allow optimal absorption of nutrients from food, which may be hampered by intestinal parasites and/or the presence of diarrhea. Adequate health services, but also the availability of safe drinking water and a clean environment are crucial in ensuring a good health situation (UNICEF 1998).

Hunger and malnutrition

Hunger and malnutrition persist in the world (Figure 3), despite the pledges of the international community, through the World Food Summit and through ratifying the Millennium Development Goals, including the target to half hunger by 2015. According to the State of the World Food Insecurity (SOFI) of 2005 (FAO 2005), by 2015, only Latin America and the Caribbean will achieve MDG 1 for reducing hunger, if eradication continues at the current pace. However, reducing hunger is crucial to other developmental processes, as food security and a good nutritional status provide the physical and mental strength necessary to fully pursue development. Nutrition has been called the foundation for development (ACC/SCN 2002).

There is a clear difference between food insecurity or undernourishment, as defined by FAO and in the MDGs, and malnutrition. FAO calculates the number of undernourished or hungry people in a country on the basis of average energy availability per person per day (dietary energy supply, DES), based on food balance sheets, which often lack sufficient accuracy (Smil 2000). Malnutrition reflects the clinical status of being malnourished or undernourished. In malnutrition, chronic and acute malnutrition are distinguished, and expressed by different indicators. Usually, malnutrition is measured in children (0-5 years of age), as their nutritional status is assumed to be representative for the nutritional situation of the community. Nutritional status in children is expressed in different combinations of the parameters age, weight and height.

Acute food shortage is reflected in a lag in weight gain, or even in weight loss in a child of a certain age, and is expressed in Weight for Age (WFA). Subcutaneous fat tissue has disappeared and in severe cases muscles may have been affected. Acute food shortage can be caused by natural or political situations, but also by sudden changes in the health situation of a child. Acute food shortage, resulting in ‘wasting’ of the child, is reversible.

Chronic food shortage leads to reduced and delayed growth of a child, reflected in a lag in growth in stature, and is expressed in Height for Age (HFA), and children below certain cut off points are considered stunted. Stunting is irreversible, and not only leads to a short stature for age, but is associated with higher prevalence of diseases, higher mortality rates, shorter life expectancy, lower rates of cognitive development, etc. Maybe most important is that stunted adolescent girls and women in the reproductive ages have higher chances to deliver malnourished children, who have little chance to overcome their burden of malnutrition, thus perpetuating the

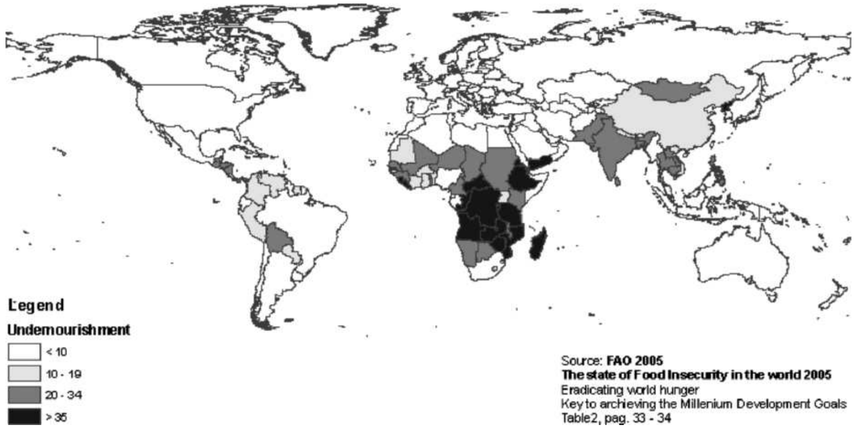

Figure 3. *Map on prevalence of undernourishment (% of population), 2000-2002 (based on data from: FAO 2005)*

intergenerational cycle of malnutrition. Persisting malnutrition leads to the vicious circle of hunger, poverty, and continued underdevelopment. Weight for age (WFA), finally, is an easy to measure indicator and is therefore often reported. However, it is difficult to judge whether low values result from chronic or acute malnutrition.

Micronutrient deficiencies (qualitative malnutrition)

Micronutrient deficiencies, often referred to as hidden hunger, are the world's most threatening nutritional problems, especially because of the associated sub-clinical changes in physiology that have a strong impact on health and functioning of large numbers of people. Micronutrient deficiencies, visible in the ultimate clinical symptoms, are considered just the 'top of the iceberg' in terms of prevalence. For many vitamins and minerals, deficiencies with associated sub-clinical physiological changes may occur. Three micronutrients show such high prevalence that they are considered a public health problem, i.e., Vitamin A, iron and iodine. In the following, each of these will be discussed, with consequences and possible interventions.

Vitamin A

The typical first noticeable symptom of Vitamin A deficiency is night blindness. In later stages, the epithelial tissue of the eyes is affected and infections of the cornea can occur, leading to corneal ulcers and scar tissue after healing, ultimately leading to irreversible blindness (xerophthalmia). However, of much greater importance is sub-clinical Vitamin A deficiency, undermining the condition of the epithelial tissue of all parts of the body and leading to higher susceptibility for infections and infectious diseases. Since Vitamin A also plays a role in fighting infections, infectious diseases further deplete body stores of Vitamin A, leading to a vicious circle of undermined immune systems, enhanced susceptibility to infections, further depletion of Vitamin A stores, etc. The relation between Vitamin A deficiency and prevalence of measles is notorious.

At global scale, 140 million pre-school children (2-5 years of age) are Vitamin A-deficient, of which every year 250,000-500,000 go blind, half of whom die within 12 months after loosing sight (because of the reduced immune response due to the low Vitamin A status). Vitamin A-deficient children that do not suffer (as yet) from blindness will have severely reduced immunity against infections, and thus suffer from sub-optimal health.

Vitamin A deficiency is not only a problem of young children. Over 7 million pregnant women suffer from night blindness and Vitamin A deficiency, because of their increased need during pregnancy and lactation. Vitamin A deficiency in pregnant women is a precursor of maternal mortality, as shown by a reduction by almost half, following supplementation with Vitamin A.

Vitamin A naturally occurs in foods of animal origin and is fat-soluble. It can also be synthesized in the body from beta-carotene, the yellow pigment in green leafy vegetables and orange-fleshed fruits and vegetables. However, bio-availability from fruits and vegetables is limited. Vitamin A can be added to (fatty) foods (fortification), such as cooking oil and margarine. An alternative is semi-annual supplementation of Vitamin A as pills or oil capsules. A diversified diet, with the right composition for optimal absorption is the preferred intervention for solving the Vitamin A problem. However, in times of food insecurity, a well-balanced and diversified diet, containing expensive foods from animal origin or fruits and vegetables is all but impossible.

Iron

Iron deficiency is probably the best-known and most common micronutrient deficiency. An estimated 2 billion people, or one third of the world population, both in developing and in developed countries, suffer from iron deficiency anemia (IDA). It is often thought to be mainly a problem of women in the reproductive age, in which it is indeed common, but IDA is also common in young children and is then often associated with intestinal parasites. Almost 60% of the pregnant women and one third of the young children (0-4 years) in developing countries suffer from IDA. Of children 5-14 years of age, more than half suffer from IDA; of adult men and women on average 43% (women) and 34% (men), respectively. IDA leads to fatigue, reduced labour output, slower learning and concentration problems in school children, and higher prevalence of maternal mortality.

Haem iron, the form of iron in the diet that is best absorbed by the human body, naturally occurs in foods of animal origin, mainly in red meat. Iron also occurs in foods of plant origin (green leafy vegetables, cereals), but its absorption is then often limited by anti-nutritional factors present in these products, such as tannins. Dietary habits influence bio-availability of iron in the diet: Drinking tea with a meal inhibits iron absorption, because of the presence of tannins, Vitamin C (orange juice) enhances iron absorption.

Interventions to reduce iron deficiency include recommendations for dietary adaptations, supplementation (with daily or weekly supplements), fortification of industrially produced foods, and, more recently, bio-fortification or 'breeding for enhanced levels of micronutrients'. As for Vitamin A deficiency, a diversified and well-balanced diet might be the 'ideal' solution. However, such a diet is relatively expensive as it requires sizeable quantities of foods of animal origin (mainly meat and fish), and fruits and vegetables containing Vitamin C to enhance iron absorption and providing some iron themselves.

Iodine

Clinical symptoms of iodine deficiency are enlargement of the thyroid gland and the development of (irreversible) goiter in more or less advanced stages. However, the major problem is the high prevalence of babies born with physical and mental retardation in populations living under conditions of iodine deficiencies. Iodine deficiency in a woman during pregnancy can lead to the birth of a cretinous baby, a child that appears normal at birth, but shows slow growth and development, possibly never reaching normal length (dwarfism), being mentally retarded and sometimes deaf-mute. Cretinism is the ultimate and most severe form of iodine deficiency. Populations with lower or less severe levels of iodine deficiencies might show reduced learning capabilities in the younger generation. Reductions in IQ up to 10-13 points have been documented.

It is estimated that 35% of the world population or around 2 billion people, living in areas with iodine-poor soils, are at risk of having too low intakes of iodine. This is especially the case in hilly or mountainous areas, relatively far from the sea, where iodine has been washed out, and seafood is usually not available. In these areas, a change in dietary patterns is not feasible. The preferred and most successful intervention is the widely applied technology of fortification of (table) salt with iodine, which hardly affects its price. A drawback is that the salt after having been fortified does not mix well with water, so that after packaging, iodine distribution is heterogeneous. A second point is that in areas where salt is naturally occurring, the natural salt is preferred (mostly for its taste, and the lower price).

The nutrition transition: nutritional diseases of affluence in developing countries

Urbanization

While the largest proportion of the world's food insecure live in rural areas, due attention is necessary for the situation of the urban poor. Continued urbanization will lead to a situation where, by 2020, more than half of the population of Africa and Asia will live in urban centers. In Latin America, already over 70% of the population is urban. The characteristics of urban food insecurity are different from those in rural areas, requiring different interventions.

Where in rural areas, underlying causes of food insecurity include insufficient availability of and/or access to land, inadequate management of natural resources, lack of labour, water and agricultural inputs and/or information on appropriate technologies, in urban areas the major cause is lack of income, and thus no access to food. Social networks, considered of high importance for food security in rural areas, are generally weaker in urban areas, especially in neighborhoods with high numbers of new migrants. More or less formal safety nets, organized at municipal level, are lacking.

Nutrition transition

The trend of continued urbanization leads to changes in dietary patterns and in lifestyle. A diet richer in (saturated) fats, animal products, sugars and alcohol and lower in complex carbohydrates and fibres, accompanied by a lifestyle that favours use of convenience products (because of lack of time to prepare food) and requires less physical activity, leads to higher prevalence of obesity. In many developing countries, starting in the higher socio-economic classes, this is, indeed, a sign of wealth.

However, in various other countries obesity is increasingly becoming a problem of the less wealthy: often the cheaper food products contain the least healthy food components, and the lower socio-economic groups have the least information on healthy diets. Obesity often does not come on its own: it predisposes to chronic non-communicable and diet-related diseases such as diabetes (type 2), cardiovascular diseases, and even to some forms of cancer. Some middle-income countries or certain groups in low- or middle-income countries show rates of obesity that match those of the USA (South African and Egyptian women, Mexico, Indonesia, Philippines). It is estimated that worldwide already over 1 billion people suffer from overweight, of which 300 million are classified as obese, among which 17.6 million children under 5 years of age.

The double burden of nutrition

The 'double burden of nutrition' indicates the co-existence within one country, or even one household, of malnutrition and over-nutrition: an overweight mother with an underweight child is no longer uncommon. This situation is related to food habits, lack of knowledge of appropriate food habits for various groups, and culture or traditions. Moreover, 'fetal programming' may play a role, hypothesizing that a fetus/ baby developing, in the last trimester of pregnancy and the first 3 months of life, in a situation of relative food shortage is 'programmed' to survive on relatively low supplies of energy. Should this individual go through a 'nutrition transition' in the course of its life, the excess energy will more readily be deposited as fat than in individuals programmed for a 'normal' energy balance. Hence, in countries where malnutrition is prevalent, also in women of reproductive age, obesity and diet-related non-communicable diseases can be expected to increase, should economic development and/or urbanization cause a change in diets and lifestyle (Von Braun 2005).

CAN FOOD PRODUCTION KEEP PACE WITH POPULATION GROWTH ?

As a result of post-World War II agricultural policies, technology development and implementation, especially in North America and Europe, and the 'Green Revolution' in Asia (see Van Keulen 2007) we have seen striking successes in food production at global scale (Smil 2000; Gilland 2002; Hafner 2003; Pingali et al. 2006):

- Food production has more than doubled since the 1950s;
- Food production per capita has grown;
- Energy intake per capita has grown in the last decades;
- Food prices have fallen (with some exceptions mainly in recent years – see, e.g., Hossain (2007)).

Despite these impressive achievements in the past decades, the UN Millennium Task Force on Hunger (2005) reports persistence of hunger in many developing countries. Globally, still 800 to 850 million people suffer from chronic or acute hunger. The lion's share of these people is found in Asia and Africa – foremost in India (220 million), China (142 million) and Sub-Saharan Africa (204 million). While in Asia the absolute numbers of hungry people are high, their proportion is declining. The situation in Africa is different: both, proportions and numbers of undernourished, adults as well as children, are increasing. Total food demand will double within the next 50 years, primarily in developing countries. The demand pattern and type of food will change, i.e., increased demand for meat, dairy products and fish. Increasingly, this food needs to be produced in an environmentally and socially sustainable manner to meet higher food safety standards, environmental regulations and consumer requirements.

The supply side

Hafner (2003) found for the major cereals (maize, rice, wheat) at global scale (based on data from 188 nations) substantial growth in yields per unit area. For instance, the 40-year (1962-2002) average annual yield increases were 62 kg ha^{-1} for grain maize and 43 kg ha^{-1} for wheat. In EU-25, the annual yield increase was even considerably higher (Table 2) with 145 kg ha^{-1} for grain maize and 77 kg ha^{-1} for wheat. Also for other crops, such as rapeseed, sugar beets and potatoes, yield increases were enormous – whereby, obviously, it did not make a big difference whether 1962 levels were high or low. De Wit (1986) showed similar yield trends for the United States and the UK after WWII.

Whether such crop yield increases are required and/or can be maintained in the future will depend on various developments: future population growth, dietary changes and consumer preferences, technological innovations and their diffusion, food policies, education on health and nutrition, global economic development and energy demand and their regional distribution, as well as the particular features of regional climate change. Most of these factors are important in determining future food demand (Smil 2000; IPCC 2001; Hossain 2007).

Table 2. *Trends in yields (Mg ha^{-1}) of five major crops for EU-25, EU-15 and selected countries from 1962 to 2002 (source: FAOSTAT)*

	Year	Wheat	Grain maize	Rape-seed	Sugar beets	Potatoes
Denmark	1962	4183	n.a.	2090	34389	18711
	1982	6673	n.a.	2212	47017	35616
	2002	7040	n.a.	2592	58362	39904
Germany	1962	3390	3232	1886	27485	22508
	1982	5243	6572	2719	443415	21737
	2002	6960	9376	2986	583246	40453
Spain	1962	1131	2141	n.a.	21118	10160
	1982	1659	5570	731	35037	15435
	2002	2824	9649	1594	70096	25993
EU-15	1962	2326	2249	1956	29998	18437
	1982	4076	6188	2535	48861	23593
	2002	5800	9193	3035	62069	36549
EU-25	1962	2252	2326	1737	28100	15947
	1982	4007	6336	2366	44844	18965
	2002	5353	8140	2782	58247	28298
Yield increase EU-25		3101	5814	1045	30147	12351
annual average increase		77.5	145.4	26.1	753.7	308.8

However, to estimate how much food *is* available, is not that easy (Smil 2000). First of all, crop and livestock production data are wrought with many inaccuracies. In establishing a country's food balance for a particular time period (in the form of food balance sheets (FBS; FAO 1995), many assumptions and uncertainties on food supply are introduced. Especially in low-income countries, significant supplies of available food seem not to be accounted for, as found in comparative local and regional assessments (Smil 2000). Food balance sheets do not provide data on actual food consumption. Such information can only be obtained from detailed household surveys. Smil (2000) concludes that for most of the low-income countries the accuracy of estimating either food supply or actual intake is less than +/– 100 kcal a day per capita.

Yield increases as realized in Europe during 1962-2002 may not be required, if the developing countries will be able to maintain or increase yield growth. Depending on the actual decline in cultivated area per capita, increase in yield growth may well be necessary to compensate for losses of land to other uses. Recently, Hossain (2007) has shown that this will be difficult for rice and wheat. Regionally, production could stagnate or even fall. For instance, production statistics for 2002 and 2003 have shown substantial declines in rice and wheat production in China – illustrating that economic developments, combined with land scarcity (Lu et al. 2007) may reverse production trends in some regions. Another example is the increasing demand for maize by a rapidly growing bio-fuel industry, that recently has led to declining supply for human consumption and considerable price increases in, for instance, Mexico.

What is happening on the food demand side?

Adequate knowledge about the food demand side is essential for judging the effort that will be required to increase yield and optimize resource use efficiencies. Factors that co-determine potential food demand are: population growth rate, population ageing and activity level, changes in diets and shifts in food consumption patterns. Population growth estimates have been adapted in recent years on the basis of an observed decline in fertilities. The median population projection for 2025 is 7.8 billion, compared to the present 6.4 billion; the high variant comes to 8.3 and the low variant to 7.3 billion. For the year 2050, the central projection is around 9 billion (UN 2003). In Asia, the population will grow by 650 million people between now and 2025, i.e., an annual growth rate of approximately 1%. An illustration of adjusting food demand estimates is provided for rice in Asia by Smil (2005) (see, Box 1).

FOOD SECURITY IN SELECTED REGIONS/COUNTRIES

Overview

In general, the total demand for food worldwide is expected to double in the next 50 years, with the highest increase coming from developing countries. In addition,

Box 1. *Assessing rice demand in Asia**

Population ageing is not only a phenomenon of the Western world, but is spreading rapidly in Asia. The ageing of Japan's population is well-known; China experiences rapid ageing due to its effective one child policy enforced in the 1970s; many more Asian countries will face the ageing phenomenon due to increasing urbanization and welfare. By the year 2025, the share of the population over 60 years in the ten most populous rice-eating/-consuming Asian countries will increase by 15% (i.e., about 500 million people). On average, people above 60 years of age consume 15-20% less food energy per capita than the average adult in the population (Smil 2000). If this estimate is correct, it would reduce the 2025 demand by about 2% compared to the current age structure. A reduction in activity level, because of continuing mechanization (as a consequence of increasing industrialization and expansion of the service sector) is estimated to reduce food demand by another 2%.

Dietary changes are expected to affect rice demand in two directions:

(i) In spite of progress in eliminating malnutrition, FAO estimated the total number of malnourished people at the end of last century at around 800 million (FAO 2002). About 480 million of these lived in the world's ten most populous rice-eating countries – with India counting some 230 million undernourished people and China 120 million. We may well assume that there will be at least a partial reduction in the number of undernourished people in Asia. If we assume that elimination of malnourishment requires increases in average food intakes by 25% and that reduction of malnourishment follows the trend of the 1990s, this results in an increased rice demand by about 4% in the year 2025.

(ii) Future dietary trends are likely to be country-specific; however, industrialized countries, such as Japan, South Korea and other Asian countries, show a general decline in average per capita rice consumption with rising economic performance. Every tripling of purchasing-power parity-adjusted (PPP-adjusted) per capita GDP (Gross Domestic Product) appears to be accompanied by a 50 kg decline in average annual per capita rice consumption (Smil 2005). Based on conservative estimates on future economic growth (1.5% per year) in the ten most populous rice-eating countries, that will result in a demand by the year 2025, 20% below the level for an unchanged dietary pattern.

Taking into account all these (correction) factors, for 2025 we arrive at an overall increase in rice demand of the order of 16%. This is far below earlier projections of the required increase that were of the order of 30-40% (e.g., Khush 2005). This is also less than the increases in global rice production achieved in the past 25 years (next section). Hence, the primary aim of future rice production should be to maintain or slightly increase existing yields at lower environmental costs (e.g. through increased nitrogen-use efficiency) on the highly productive rice lands, and to reduce the large yield gaps in rainfed rice environments.

* Source: Smil (2005) Feeding the world: How much more rice do we need?

changes are taking place both in the pattern of demand and the type of food.

Recently, the International Food Policy Research Institute (IFPRI) explored food supply and demand scenarios for 2015 and 2050 using the IMPACT model (Von Braun et al. 2005). Three major scenarios were distinguished:

- Progressive policy actions scenario;
- Policy failure scenario; and
- Technology and Natural Resource Management failure scenario.

(1) The progressive policy actions scenario assumes increased investment in rural development, health, education and agricultural research and development. Results indicate that this would lead to a substantial reduction in hunger and in the number of food-insecure people. Latin America and China could eliminate child malnutrition by 2050. Improved technologies and better infrastructure are major factors stimulating increases in crop yields and average incomes in developing countries.

(2) The policy failure scenario assumes greater political discord and more extensive agricultural protectionism, in conjunction with the failure of policies to deal with food emergencies related to conflict. Slow economic growth and trade restrictions result in stagnation in average per capita energy availability – which remains just above the minimum requirements until after 2030, when availability increases.

(3) The technology and natural resource management failure scenario shows the worst results in terms of yield growth. This decline in yield growth forces farmers to expand production to marginal lands, which causes a more rapid expansion of the area cultivated with cereals into less productive land – which causes land degradation and cannot compensate for yield shortfalls. Per capita energy availability for developing countries is essentially unchanged and hardly remains at an adequate average level. Child undernourishment is higher than under the policy failure scenario.

The factor contributing most to uncertainty: large shifts in demand, i.e., dietary changes and needs in the developed and the developing world (Smil 2000; Council of the European Union 2004, 2005).

As mentioned earlier, most of the people suffering from hunger are found in Asia and Africa, foremost in India (220 million), China (142 million) and Sub-Saharan Africa (204 million). In the following sub-sections, we, therefore, illustrate developments in supply for major cereals in those regions.

Rice production and yields in South, East, and South-east Asia

Rice production

Production in the main rice-producing countries in Asia has increased rapidly since the early 1960s. Between 1961 and 1998, rice production has more than tripled in China, Vietnam and Indonesia, with the strongest relative increase in Indonesia.

Increases and total rice production in Thailand and Vietnam are lower, and limited by a larger share of areas with low soil fertility and/or less reliable water supply and rainfall.

The steep increase in rice production in China started already around 1960 and was triggered by the release of new semi-dwarf and hybrid rice varieties (Peng et al. 2004) (Figure 4). India followed in the second half of the 1960s, and Indonesia in the second half of the 1970s, while in Thailand growth continues at a low but steady rate. Due to the turmoil caused by war, Vietnam re-entered this competition only in the 1980s, however, with remarkable success.

The main producers and consumers of rice in Asia are China and India and to a lesser extent, Indonesia. In the first two countries, production tends to decrease in the last years and shows a strong inter-annual variation. In particular in eastern China, rapid economic growth and urbanization has resulted in a change in cropping pattern and agricultural systems in response to changing demand (i.e., higher incomes result in a more luxury consumption pattern which leads to replacement of staple foods like rice by, e.g., vegetables, fruits, dairy products and meat), resulting in a larger market and more stable and much higher prices (than for rice), and in a reduction in arable land through expansion of urban land uses (Lu et al. 2007). These developments are expected to result in a reduction in rice production in China in the coming years.

The production decreases in low-production years during 2000-2004 in China and India appear large compared to rice production in the main exporting countries like Thailand and Vietnam (Figure 4). This implies that these countries will not be able to fill the rice gap, if production in, for example China, continues to decrease and consumption patterns do not change rapidly. On the other hand, an increase in rice price, if rice production is clearly lagging behind demand and economic growth continues, might well result in an accelerated shift to consumption of other staple products (wheat, maize), vegetables, dairy products and meat and in a reversal in

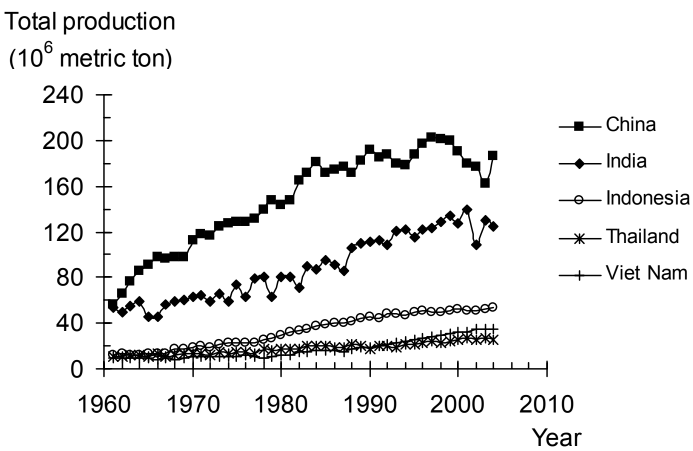

Figure 4. *Development of rice production, in selected Asian countries: 1961-2004*

production decline, as was observed in 2004. Increasing competition for water between industrial and domestic use and rice cropping in China may be an additional reason to replace wetland rice by dryland crops.

Rice yields

Rice yields in all countries in Asia were about 2000 kg/ha in the period around 1960. From then on, yields rapidly increased as a result of adoption of improved rice varieties (hybrids, short-straw varieties) and improved crop management (i.e., increased fertilizer nutrient supply, improved irrigation management, crop protection, soil tillage, and later also more mechanized farm operations). The yield increase started earliest (around 1960) in China, leading to a tripling in 30 years to about 6000 kg ha^{-1} in the 1990s and then to stabilization (Figure 5). In Indonesia, yields increased rapidly from about 1975 to about 2.5 times the 1960 level in the 1990s. Yield increase in India and in particular in Thailand (only 55% higher than in 1961) was more limited due to less favourable growing conditions (large areas with poor soils and with uncertain water supply and rainfall). In Vietnam, yield increase started later (second half of the 1980s), and recently, yields attained values exceeding 4500 kg ha^{-1}. It already surpasses mean yields in all other countries in Asia, except for China (Figure 5).

While increases in rice production and yields in the last 50 years have been spectacular, there are major constraints to further increasing food supply in Asia. One of these constraints is presented by stagnating cereal yields on intensively used agricultural lands. Others include strong competition between agriculture and other sectors for scarce land and water resources, and possible yield reductions as a consequence of climatic change. Associated research challenges are presented at the end of this chapter.

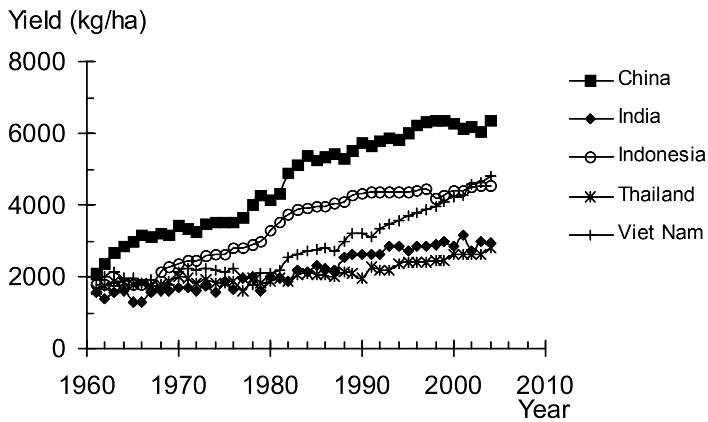

Figure 5. *Development of rice yields in selected Asian countries: 1961-2004*

Maize production and yields in Sub-Saharan Africa

Maize production

Most of the maize produced in Sub-Saharan Africa originates from South Africa, with, however, very strong variations, i.e., between 4 and 12×10^6 Mg between low- and high-rainfall years. Production has almost doubled over the last 40 years, with strong increases particularly in the 1970s and 1980s in Tanzania and to a lesser extent in Kenya (with around the year 2000, values of 4 and 2.5 times, respectively, those around 1960). In Mozambique and Ethiopia, maize production started to increase towards the end of the 1980s, but has more than tripled over the period 1985-1995, which clearly is related to the end of (civil) wars. In Zimbabwe, maize production is extremely variable, but clearly decreases over the last years. Production in 2001-2004 is similar to or less than that in the beginning of the 1960s, related to counter-productive government policies.

Maize yield

Maize yields in South Africa have increased from 1300 kg ha^{-1} in the beginning of the 1960s to about 2500 kg ha^{-1} at present. Inter-annual yield variation is very large due to the large rainfall variability, i.e., less than 1000 kg ha^{-1} in drought years to over 3000 kg ha^{-1} in high-rainfall years. Yields in Zimbabwe in the 1960s were about similar to those in South Africa, showed a slight increase in the following years, but with an inter-annual variation between 700 and 2000 kg ha^{-1}, and then clearly decreased after 1990 (to about 600 kg ha^{-1}) due to policy failures and political turmoil. In the 1960s, yields in Kenya were about 1250 kg ha^{-1} and about 900 kg ha^{-1} in the other African countries and have increased to about 1600 kg ha^{-1} in Kenya at present. Yields in Ethiopia had almost doubled to about 1700 kg ha^{-1} at the beginning of the 1980s and remained (except in drought years) roughly at that level. Mozambique showed about a 50% decrease in yield from the beginning of the 1980s to the beginning of the 1990s, associated with civil war. From halfway through the 1990s, yields rapidly increased again, attaining a level of about 950 kg ha^{-1}, slightly higher than at the beginning of the 1960s (Figure 6).

The Sub-Saharan African agricultural production data clearly illustrate that despite the gloomy picture that is often painted, technological progress has resulted in substantial improvements in food production (cf. Breman and Debrah 2003). However, in addition to the poor soils and the low and erratic rainfall patterns that form major biophysical constraints to sustainable yield improvements, the socio-economic environment is not conducive to intensification. Civil unrest, counter-productive policies and the devastating effects of the HIV/AIDS epidemic, all constrain adoption of improved yield-increasing technologies. Economic incentives are all but absent, labour availability is insufficient and land tenure is highly uncertain in many regions, and their effects are clearly illustrated in the yield dynamics in Figure 6.

Yield increases, realized in the past have, in many instances, come at considerable environmental costs (Van Keulen 2007; Verhagen et al. 2007). In the following section we shed some light on some environmental impacts of increasing food supplies in the past and present, and examine possibilities to reduce the environmental

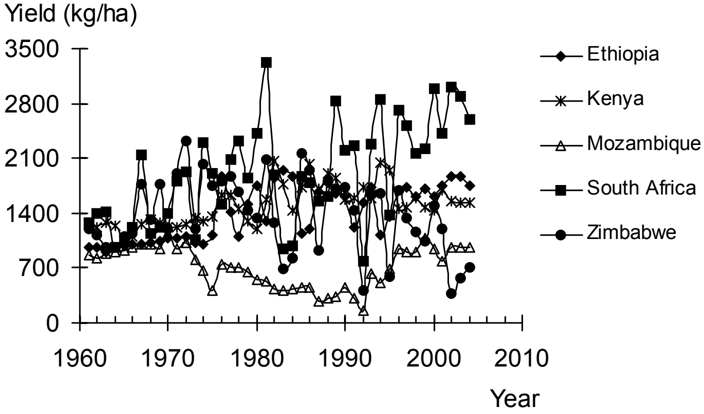

Figure 6. *Development of maize yields, in selected African countries: 1961-2004*

impacts in the future, by achieving gains in resource use efficiency, through management and policy interventions.

INPUT REQUIREMENTS, RESOURCE USE EFFICIENCY AND ENVIRONMENTAL SUSTAINABILITY

Increasing competition for scarce natural resources between agriculture and other use(r)s is a strong incentive for targeting further increases in resource use efficiencies, in particular for nutrients and water. This, basically, applies to both, East and Southeast Asia and Sub-Saharan Africa. However, significant differences exist in the type and magnitude of the resource use problems. In Asia, in addition to the economic aspects of reducing costs and increasing yields (for instance through better synchronization of crop nutrient demand and supply), an important incentive for stimulating improved nutrient management is reducing pollution through non-productive nutrient emissions to water and air, resulting from excessive fertilizer use. In Sub-Saharan Africa, on the other hand, the incentive for improving nutrient management is rather to stop nutrient mining and/or replenish depleted soils, and enhance soil fertility status to enable a reasonable crop cover and yield, and make the most efficient use of precious scarce inorganic and/or organic fertilizers (Heerink 2004).

Input requirements and environmental impacts under current conditions

Yield increases in the past were heavily linked to availability and application of man-made nitrogen fertilizer (Goudriaan et al. 2001; Frink et al. 2001; Mosier et al. 2004). Man's interventions in the global N-cycle are much more dramatic than in the C-cycle (where just 10% is anthropogenic). Currently, at global scale, more than 85 Tg of nitrogen originate from fertilizer application (of which almost 24% is being applied in China). Out of the 20 Tg of nitrogen fertilizer annually applied in China, about 12 Tg is lost to the environment, i.e., exceeding the total quantity of about 10 Tg currently applied annually in the US (Smil 2002, 2005).

Asia

Past productivity gains in East and South-east Asia would not have been possible without the use of fertilizers during the last four decades (Khush 2005). NPK fertilizer consumption in developed countries, such as the US has stabilized or declined since the early 1980s, while it still shows a distinct upward trend in China (Figure 7). The extensive use of fertilizers increasingly results in severe local pollution problems, and may even show impact at global level (Li et al. 2005). It is estimated that 25% of the lakes in China show signs of eutrophication, while a recent study on water quality in northern China showed that nitrate concentrations in groundwater exceeded the permissible limit of 50 mg l^{-1} in half of the investigated locations (Fang et al. 2005).

A combination of high nitrogen (N) fertilizer inputs and a low proportion of applied N taken up by the crop (= N recovery) is at the basis of these pollution problems. In contrast to crop yields, N recoveries in East and South-east Asia do not show significant improvements over time. However, during the 1990s, a major effort to improve nutrient management in rice-based systems in Asia was launched, applying a network mode (composed of 12 National Agricultural Research Systems and the International Rice Research Institute), in which researchers worked with farmers in multi-annual experiments (on-station and on-farm in the major rice environments of the humid and subhumid tropics of Asia) to determine the causes of low nutrient use efficiencies, and jointly develop more efficient, site-specific management packages (Dobermann et al. 2004). In more than 200 seasonal data sets, on average, N recovery in rice was below 30% (Cassman et al. 1995, 1996), while

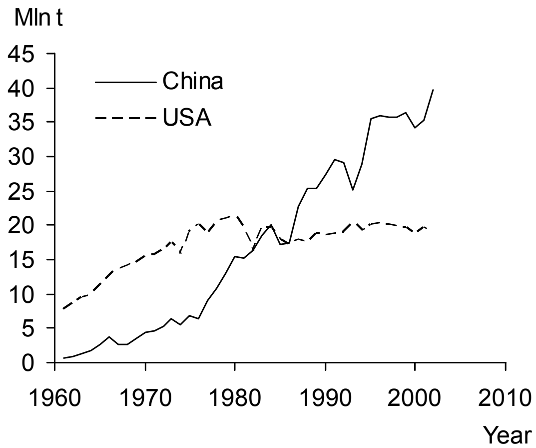

Figure 7. *NPK fertilizer consumption (10^6 t) in China and the USA*

typically values in the range from 45-60% would be possible under best crop management practices (Cassman et al. 2002).

The necessary increases in staple food supplies in the next 20 years in Asia, equaling those achieved in the recent past, will have to be realized mainly on highly productive land where yields are high and labour becomes increasingly scarce. There is, however, the complication of stagnating cereal yields in those areas where long-term mono-cropping has been practiced – such as the Indo-Gangetic plains with its rice-wheat systems or the humid tropics of South-east Asia with multiple (double or triple) rice systems (Aggarwal et al. 2001; Dobermann et al. 2000; Cassman and Harwood 1995).

As shown by recent research results from several DLO-IC projects in Asia (such as VEGSYS, MAMAS, RMO Beijing and IRMLA; see De Jager et al. 2007), diversification of agricultural production – away from rice and towards vegetable and livestock production – creates substantial additional environmental pressures that require a whole set of new management practices and policy interventions to avoid serious damage to the environment (Wolf et al. 2003; Hengsdijk et al. 2007; Van den Berg et al. 2007).

Another serious constraint to food production in Asia is water scarcity. In the North China plain, known as the granary of China, water tables have been dropping continuously over the last two decades as a consequence of excessive extraction (Figure 8).

In short, current resource management practices cannot cope with the challenges facing East and South-east Asia. Past productivity growth was based on the increasing use of resources, but future developments should be aimed at more efficient use of resources.

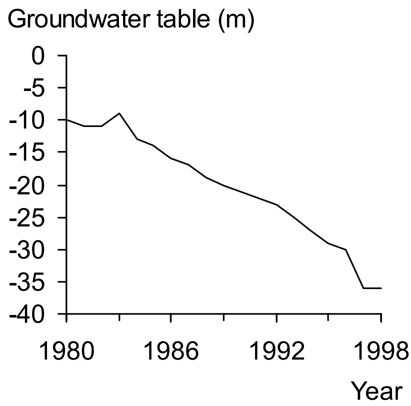

Figure 8. *Dynamics of groundwater table depth (m) over the past 25 years in Hebei province, China (based on Jianxia et al. 2005)*

Sub-Saharan Africa

In many parts, low yields, low land productivity and low labour productivity are common. This is because of poor soils, low and erratic rainfall and the poverty that undermines the purchasing power of many potential consumers.

Low and declining soil fertility is one of the major causes of poor yields and the loss of fertile topsoil as a result of erosion and desertification has seriously reduced the production potential of previously fertile lands. Opportunities to reverse soil mining, raise yields and increase land and labour productivity through improved soil management and water conservation are likely to rely heavily on the use of external (yield-increasing) inputs. Box 2 gives an overview of collaborative soil fertility research projects with substantial Wageningen participation – conducted during the last 20 years in Kenya.

Box 2. *Research on nutrient management in Kenya (from project FURP to NUTMON, NUTSAL and INMASP)*

A long-term strategic research alliance, established in the 1970s, between Wageningen UR and the Kenya Agricultural Research Institute (KARI) eventually resulted in a nation-wide soil fertility project to generate an empirical database on yield response of maize and other major food crops to inorganic fertilizer and manure in all suitable agro-ecological zones of Kenya: This Fertilizer Use Recommendation Project (FURP), sponsored by GTZ (German Agency for Technical Cooperation) and the EU, was launched in 1985. Following a careful inventory of agro-ecological information and results of earlier fertilizer trials (Smaling et al. 1992), agronomic experiments (both, on-station and on-farm) were conducted at 70 sites from 1987 to 1992. The resulting comprehensive database was used to calibrate and refine research tools of the 'Wageningen School', such as QUEFTS for the assessment of soil fertility of tropical soils, and WOFOST for the simulation of growth and yield of tropical crops (Smaling 1993; Roetter 1993; Roetter and Van Keulen 1997). The generated yield response data were further tested and disseminated via district-wise fertilizer verification trials and recommendations were disseminated through different national media (including the newspaper 'Daily Nation'). By the time the recommendations became available to gain national impact, however, fertilizer subsidies had largely been abandoned, the political situation in Kenya had become much more unstable, and investors/donors were shifting their interests to other regions (such as Eastern Europe). Despite these constraints, the valuable database inspired a large number of follow-up projects, related to quantification of nutrient balances for Kenya, and for Africa as a whole – and follow-up research to better quantify and monitor nutrient flows at farm and village level in different agro-ecological zones (Smaling 1998). This further evolved into participatory and interdisciplinary research on integrated nutrient management, applying the Farmer Field School approach as in the INMASP project (Onduru et al. 2003; Van Beek et al. 2004).

Interestingly, in the mid-1990s, this combination of experimental research and quantification/modelling of nutrient balances and yield response inspired the work and was successfully carried to guide nutrient management research in the intensive rice eco-systems in South-east Asia (Dobermann et al. 2000, 2004).

Risks, threats and opportunities for resource use efficiency gains

Lack of knowledge, the absence of economic incentives and policies to support sustainable management practices, climatic variability, as well as a shortage of labour are among the factors that obstruct the realization of potential increases in resource use efficiency.

In Asia, the intensification of agricultural production, especially animal production, has increased nitrogen emissions to the environment. Human health and ecosystem quality have also been negatively affected by the excessive use (and loss) of agro-chemicals in vegetable production systems. In many regions, clean and safe water is a scarce resource and competition for available water resources is intense. This indicates the need for research into water-saving technologies and improved water use efficiency in agriculture. In many of the 'food baskets' of Africa, it is foremost the unpredictable and highly variable rainfall that represents considerable production and financial risks, preventing many farmers from implementing management practices that increase resource use efficiency (Roetter and Van Keulen 1997; Bouma et al. 2007) It has been realized during recent years that climate change has increased the severity and frequency of drought (Dietz et al. 2004) and this – in combination with the devastating impact of HIV/AIDS – has significantly reduced the capacity of the rural labour force to maintain adequate and nutritious food supplies. It is very likely that climate change will further increase weather and yield variability (IPCC 2001; Parry et al. 2004).

The major measure to improve N recovery of crops is to improve the synchrony between crop N-demand and N-supply, including N provided by soil reserves, fertilizer and manure. In practice, this means that the crop-available N pool should be maintained at the minimum size required to meet crop-N requirements during each growth stage. More accurate N management results in improved N-recovery, higher yields and, because less fertilizers are required, increased profits of farmers (Dobermann et al. 2004). Adoption of such knowledge-intensive management typically requires additional skills, labour and investments in new equipment, for example, to monitor crop N status in the course of the growing season.

In the most important crops in South, East and South-east Asia, i.e., rice, maize and wheat, biomass production per unit water use (= water productivity) is highly variable, with a factor of 2 between the highest and lowest reported values. Soil (nutrient) management, water management and crop varieties among others contribute to these differences. Therefore, crop management offers ample scope to increase water productivity. Even in rice, which is commonly grown under continuously flooded conditions, at least 20% of current water inputs can be saved using intermittent flooding conditions without affecting yields. Thus, combining reduced water inputs and N fertilizer may increase simultaneously yields, water productivity and N recovery. However, in addition to a very secure and reliable water delivery system, thorough knowledge on the timing and amount of inputs to be delivered is required to achieve sustainable water savings.

In Africa, reduction of the protective plant cover by practices such as deforestation and excessive grazing has increased the rates of soil erosion and runoff. This type of land degradation can in many cases be reversed by soil and water conservation practices – as developed during many decades of research. Disappointing results in the field are, in the first place, the result of poor planning of these measures, rather than unwilling farmers or other resource managers (Bouma et al. 2007). In recent years, the so-called 'catchment approach' that takes into account an entire geographic area, draining its precipitation to a single outlet and involving farmers and other stakeholders in a participatory manner has been applied to develop appropriate measures and improve soil and water conservation planning – as done in the EROAHI project in the East African Highlands (see De Jager et al. 2007).

Since it is very likely that agricultural systems and management practices need to be adjusted or re-designed to become less vulnerable to climate change and reduce their greenhouse gas emissions, the above-mentioned efficiency gains in nutrient and water use will have to be achieved under management conditions that are changed accordingly.

CHALLENGES AND FUTURE OPTIONS

Interlinkages between food security and other development issues

In general, the total demand for food worldwide is expected to double in the next 50 years, with the highest increase coming from developing countries (Falcon and Naylor 2005). In addition, changes are taking place, both, in the pattern of demand and the type of food – increasing for meat, dairy products and fish – being consumed. Increasingly, this food needs to be produced in an environmentally and socially sustainable manner in order to comply with higher food safety standards, environmental regulations and consumer preferences. As competition for scarce natural resources intensifies, agriculture has to find ways of making more efficient use of productive resources, land and water in particular, to provide high quality affordable food. The Millennium Ecosystem Assessment (MA 2005) concluded that the degradation of ecosystem services might grow significantly worse during the first half of the 21st century, and become one of the most severe constraints to achieving the Millennium Development Goals (MDGs) (Verhagen et al. 2007). In less-endowed regions, improved agricultural practices must be tailored to local bio-physical and socio-economic conditions, to provide a solid base for poor farm households' livelihoods, if they are to have a positive impact.

Meeting these challenges implies that the agricultural sector must become more productive (e.g., through improved technologies, improved institutions, etc.). Scientific research will need to contribute to generating knowledge on how to:

- Feed the growing world population, and meet consumer needs;
- Enhance rural livelihoods (by increasing (stability of) income);
- Safeguard the environment (maintain resource quality and protect biodiversity).

Our programme experience clearly supports that scientific and technical solutions are not 'magic bullets'. In isolation, they cannot resolve the complex problem of food insecurity which is closely related to poverty. Poor people do not have access to food and health services, and lack of education, poverty and hunger seriously limit economic growth (Sachs 2005). However, it should be recognized that economic growth in itself is not a remedy for hunger. It cannot guarantee equitable access to natural resources and markets and it does not ensure that people can claim their rights. More insights and knowledge are needed on this topic and inter-disciplinary research should make a contribution there. To have impact, higher investments in science, technology and education are needed to break the poverty trap. Moreover, to make rapid progress in achieving the MDG of hunger and poverty reduction requires coherent international as well as domestic policies and harmonization between the two – including coherence in setting research priorities and financing of agricultural and rural development (Pingali et al. 2006; Kuiper et al. 2007; IAASTD 2005-2007; www.agassessment.org).

Research challenges

Research continues to be necessary in plant breeding, agronomy, farm management, human nutrition and rural sociology in order to work jointly with communities to attain the knowledge and technologies necessary to adapt to environmental change, limit yield losses and identify the best land use options in the given local biophysical and socio-economic settings. For example, for the rice-based systems in Asia, Hossain (2007) emphasizes that the most important strategy for sustaining food security is to increase the productivity of scarce land and water resources. He further concludes that rice research needs (i) to raise yield ceilings of available rice varieties, (ii) protect past yield gains in irrigated ecosystems using advancements in genomics, genetics and biotechnology, and (iii) developing high-yielding varieties for rainfed systems that are tolerant of drought, submergence and problem soils.

At the same time, research related to food security, human nutrition and health will need to deal with several new challenges. In the following we will address some of the new challenges and how they could be met.

Change in diets

Currently, a major transition in diets is taking place (mainly in Asia) from staple food to animal products. The extent to which and the rate at which this transition takes place is uncertain, and results in considerable differences in food demand projections (example rice: Khush (2005) versus Smil (2005): 30-40% versus 10-20% increase); Smil's (2005) comprehensive analysis, guided by the assumption of increasing demand for animal products in the future, indicates some of the enormous consequences for global food systems and resource requirements. Demand for feed crops will increase (soybean, maize) and for staple crops decrease (rice and wheat). Animal production will be concentrated in peri-urban areas around mega-cities. Increased efforts will be needed to reduce environmental pollution in such regions with intensive animal production – to reduce the negative consequences of imported nutrient excesses. In other regions, the additional demand for feed and bio-fuel crops will compete with the land/natural resources needed for food crop production. Scenario studies should be conducted to make these complex interactions transparent.

Psychology of consumer's change in preferences
Other negative consequences of higher animal production include higher transport costs and export of animal diseases (e.g., avian influenza). Higher energy costs in combination with occurrence/out-breaks of animal diseases, and consumer influence and changed risk perception could stimulate transition of agriculture towards more risk-avoiding practices: more emphasis on quality, transport cost and energy-saving regional production, re-emphasizing regional marketing. These interrelations and the influence of consumer's preferences on changes in/design of new farming systems and production methods require further investigation.

Development and adoption of new technologies
Further development and adoption of modern crop varieties and knowledge-intensive management techniques has continued its important role in sustaining productivity growth in the post-Green Revolution (1990s onwards) areas, i.e., the intensive irrigated systems of Asia. The contribution of resource- and input conserving practices (such as conservation tillage, site-specific nutrient management (SSNM) and Integrated Pest Management (IPM), including the impact of participatory technology generation, to productivity growth (especially, when expressed on a per day basis) has increased over time (Gollin et al. 2005). This was associated with increasing intensification, made possible by shorter duration crop varieties, and labour-saving mechanization. Furthermore, scenario studies and empirical evidence show that in post-Green Revolution areas farm consolidation and further mechanization offer substantial scope for increased food security and maintenance of sustainable rural structures, as they not only raise incomes through diversification into high value products (Hengsdijk et al. 2005), but also create rural employment based on the associated processing and marketing of these products. In less-endowed and/or less connected regions, more research on constraints for adoption of ecologically sound, knowledge-intensive technologies is needed.

Integrated analysis of rural development options
An example: Vitamin A, iron and zinc deficiencies cause early death of children and women and seriously limit economic growth in many poor rural areas. Better linkages between agricultural research and research dealing with nutrition and health, combined with better education, a focus on gender issues and higher investments in rural development may help in overcoming the wide-spread phenomenon of 'hidden hunger'. Furthermore, it is obvious that any attempt to properly deal with the complex problem of alleviating hunger and food insecurity requires more than boosting yields and improving water and fertilizer use efficiencies: food security can only be achieved by paying due attention to its interdependencies with other Millennium Development goals, such as poverty reduction and sustainable environmental management. We, therefore, conclude that more integrated approaches to the design and analysis of rural development options are necessary, as a basis for informed decision-making, formulation of supportive policies and implementation.

Impacts of climate change and increased demand for bio-based energy

In recent years, deforestation and climate change have been identified as responsible for the increased incidence of flooding. In addition to floods, climate change has increased the risk of high temperatures and the frequency of drought. Together these factors have had a severe and negative impact on crop yields and pose a serious threat to food security. Effects of climate change are local and vary among systems and regions. Climate change affects all aspects of rural development. Scenario studies need to be conducted using state-of-the-art climate scenarios in combination with impact models that adequately consider weather variability, farm level adaptation and risk management strategies, and associated policy options – taking into account macro-economic conditions. There is a clear lack of such studies. The same applies for global and regional future-oriented assessments that look at potential conflicts between ensuring food security and the increasing demand for resources to produce bio-based energy (IAASTD, see, www.agassessment.org).

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CHAPTER 4

AGRICULTURE AND ENVIRONMENT

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INTRODUCTION

Of the global land area, about 38% is agricultural land of which some 30% is arable land (faostat.fao.org). The relations between agriculture and the natural environment are complex. Agriculture is of vital importance to many societies and is the sector with the most intensive interaction between man and environment. Agriculture has, by its very nature, a strong impact on the natural environment and the natural environment sets limits to agricultural production systems. Simply put, changes in agriculture affect the natural environment and vice versa (De Wit et al. 1987). In this chapter, we will examine some of the important interactions and challenges for low income countries.

Agriculture utilizes natural processes to produce the goods (food and non-food) that we need to support the demand of an ever-growing population. Agriculture also contributes to economic development in terms of income generation and employment. Paradoxically, however, economic growth and poverty reduction lead to declining relative importance of the agricultural sector (Dorward et al. 2004; Kuiper et al. 2007).

Which goods are needed and hence what agriculture should produce is largely determined by society. Changes in consumption patterns and preferences are reflected in agricultural land use. These societal and political changes are also visible in the

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manner in which development is framed. After World War II, the concept of 'catch-up development', in which underdeveloped economies were expected to catch-up to achieving economic growth in a similar manner as developed economies, provided the framework in which development projects and policies were framed (Van Keulen 2007). This changed as soon as the environmental impacts of this biased focus on economic development became clear. After a period in which economy and environment were perceived as conflicting objectives, societies and policymakers moved to a multi-dimensional approach of development. Sustainable development embraces the concept of an economically viable, socially just and ecologically sound development not only for the present, but also for the future (Agenda 21, UN 1992). In this approach, the three pillars are set on equal footing for present and future generations (see also Roetter et al. 2007c). Following this concept, the responsibility lies with present societies to manage natural, human and economic resources in such a way that future generations are not constrained in their development.

Agricultural land use has the potential to damage or destroy the natural resource base, thus undermining future development potentials. It often is the focus on short-term economic gain and disregard of long-term impacts and needs that lead to environmental degradation. Clearly, part of the solution lies in a change in demands from society, e.g., via changes in diet and lifestyle, but also the agricultural sector has a responsibility to find ways to reduce the negative environmental impacts. Agriculture, rooted in the natural resource base and serving as a major contributor to development, is at the forefront of shaping the concept of sustainable development (WSSD 2002).

AGRICULTURE-ENVIRONMENT INTERACTIONS

Agriculture is the major user of land and water resources and competes with other users for these limited resources. The sustainable development challenges for agriculture are strongly related to this competition and the role of agriculture in rural development. Agenda 21:

> *Major adjustments are needed in agricultural, environmental and macro-economic policy, at both national and international levels, in developed as well as developing countries, to create the conditions for sustainable agriculture and rural development. The major objective of sustainable agriculture and rural development is to increase food production in a sustainable way and enhance food security. This will involve education initiatives, utilization of economic incentives and the development of appropriate and new technologies, thus ensuring stable supplies of nutritionally adequate food, access to those supplies by vulnerable groups, and production for markets; employment and income generation to alleviate poverty; and natural resource management and environmental protection.*

Ten years after Rio at the WSSD conference in Johannesburg the importance of Agenda 21 was reaffirmed and a strong commitment to implementation of Agenda

21 and the Millennium Development Goals (MDGs), agreed at the Millennium Summit in September 2000, was given. Concrete steps and quantifiable targets for implementing Agenda 21 were formulated in, amongst others, framework papers on Water, Energy, Health, Agriculture and Biodiversity (WEHAB Working Group, 2002). The MDGs, specifying the key targets for the most urgent and immediate development needs, seek to:

- Eradicate extreme poverty and hunger;
- Achieve universal primary education;
- Promote gender equality and empower women;
- Reduce child mortality;
- Improve maternal health;
- Combat HIV/AIDS, malaria, and other diseases;
- Ensure environmental sustainability;
- Develop a global partnership for development.

As for most developing countries agriculture is, currently, the main economic activity and has traditionally been the key livelihood strategy for most people living in rural areas, it is a key sector in achieving the MDGs.

Recently, the Millennium Ecosystem Assessment (MA 2005), a review of scientific information on the consequences of ecosystem change for human well-being, ultimately aiming at informing decision makers and the larger public, arrived at the following conclusions:

- Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel.
- The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people.
- The degradation of ecosystem services could grow significantly worse during the first half of this century and is a barrier to achieving the Millennium Development Goals.
- The challenge of reversing the degradation of ecosystems while meeting increasing demands for their services can be partially met under some scenarios that the MA has considered but these involve significant changes in policies, institutions and practices, that are not currently under way (MA 2005). To get more understanding of the kind of policy and institutional changes required, an international assessment on the future role of agricultural knowledge, science and technology for development is under way (www.agassessment.org; Bouma et al. 2007).

In the MA, the interdependency of the production capacity of (agro)ecosystems and the provision of the necessary goods and services for human societies are highlighted. Again it is agriculture, claiming, amongst others, land and water resources, that is at the heart of providing ecosystem goods and services.

As argued by Roetter et al. (2007a, b), increasing production is essential to eradicate extreme poverty and hunger (MDG 1). As total production is a function of agricultural productivity and the area cultivated, two agronomic strategies are distinguished to achieve the desired increase in production: (i) increase in productivity and (ii) expansion of area. An increase in food production is not only achieved via a technical fix, in which environmental constraints are lifted; alleviation of institutional, technological and political constraints is also essential. Access to land, fertilizers, knowledge, finance and water are examples of such non-environmental factors.

Area expansion still remains a strategy, but as competition for land increases, is becoming of less importance compared to yield increase. Yields of major food crops such as rice, maize and wheat have tripled during the second half of the 20th century (Hafner 2003; see also Roetter and Van Keulen 2007). A consequence of this science- and technology-based agriculture that resulted in increased yields, was a decline in the rate of conversion of natural and fragile areas into agricultural land.

High-yielding varieties require more care and external inputs, mainly nutrients and water, and consequently a good understanding of the agro-ecosystem. The negative environmental impacts of intensive high-input agriculture are indisputable: soil degradation, and excessive use of agro-chemicals such as fertilizers, pesticides and herbicides, resulting in groundwater pollution (Van Keulen 2007). Loss of soil fertility, resulting from shorter fallows and poor land management, was among the first signs that the intensive agricultural systems caused problems and were undermining the quality of the natural resource base (Tilman et al. 2001).

In this chapter, we will address some of the most pressing environmental issues related to agricultural land use and discuss their link with the MDGs. The issues are: (i) soil and land degradation; (ii) chemical pollution of soil and water; (iii) impact on biodiversity and (iv) climate change. Some of these problems have long been recognized and local, national and international actions are ongoing to reduce or halt the negative impacts of agriculture. In addition to local and regional initiatives, several key international environmental treaties are in place: the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention on Biological Diversity (UNCBD) and the United Nations Convention to Combat Desertification (UNCCD) (see Box 1).

THE NORTH-SOUTH INTERNATIONAL COLLABORATION PROGRAMME

The North-South programme did not have separate environmental foci, but, for good reasons, concentrated on their integration in studies on poverty reduction, economic development and exchange of knowledge (Research Programme North-South 2001). During 1998-2000, environmental issues were strongly embedded in the various projects. In 2001, the programme expanded its mandate and reformulated its aim:

"to contribute to economic development and poverty reduction in developing countries, with special attention to the strengthening of sustainable agriculture and production chains, and nature management". In the revised programme, the themes sustainable agriculture and nature management are closely related to environmental issues.

Soil and land degradation

Land (FAO 1976) is the key resource for agricultural production systems. The potentials of both, arable crop and livestock production strongly depend on the quality of land. Land degradation, i.e., a reduction in land quality, is, therefore, a core problem in many countries, with enormous consequences for people living in affected areas (Eswaran et al. 2001). The term land degradation is used to refer to a complex of processes resulting from anthropogenic interventions, such as over-exploitation, overgrazing, and bad irrigation practices, illegal and excessive logging, bush and forest fires and deforestation due to population increase (UNCCD). Along with these human activities, a range of climatic factors can trigger or aggravate the process of land degradation (year-round aridity, high variability in rainfall, recurrent drought). Because of these multiple causes, combating degradation and desertification involves a wide range of measures and contributes to combating poverty, to structural reforms and to sustainable development. Land degradation leads, among others, to soil erosion and loss of topsoil and fertile land, and is especially severe in arid, semi-arid and dry sub-humid areas. Soil and land degradation including erosion are complex issues that are linked to many other environmental and social problems.

Box 1. *A selection of Multi-lateral Environmental Treaties (1970-2005)*

	1970	1975	1980	1985	1990	1995	2000
Soil & related		S1		S2	S3		
Biodiversity	B1	B2				B3	
Climate & related			C1	C2	C3	C4	

S1 POPs Stockholm Convention on Persistent Organic Pollutants
S2 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
S3 UNCCD: United Nations Convention to Combat Desertification
B1 The RAMSAR Convention on Wetlands
B2 Convention on the Conservation of Migratory Species of Wild Animals
B3 UNCBD: United Nations Convention on Biological Diversity
C1 Convention on Long-Range Transboundary Air Pollution
C2 Montreal Protocol
C3 UNFCCC United Nations Framework Convention on Climate Change
C4 Kyoto Protocol

Box 2. *INMASP and NUTSAL*

In Africa, soil fertility decline is considered to be one of the principal causes of food insecurity and environmental degradation. Building on the vast knowledge and fundamental insights generated by science, the integrated nutrient management project (INMASP) and the nutrient monitoring and management strategies project (NUTSAL) aimed at operationalizing improved soil fertility and water management strategies.

A participatory approach was used, including 310 farm households in 11 Farmer Field Schools (FFS) in East Africa, to diagnose and analyse current farm and nutrient management strategies, formulate improved strategies and train extension workers and farmers in applying these new strategies.

The success of this methodology is that it brings all the stakeholders together in a learning process that leads to effective decision-making and action. The approach proved to bridge the gap between research and extension in addition to building community capital and stimulating the improvement of gender relations and good governance at local level.

Current soil fertility management practices in the farming systems in the semi-arid areas in Kenya result in slightly negative nutrient balances. The losses, however, represent only a very small proportion of the total soil nutrient stocks, especially for phosphorus and potassium.

Nutrient flows into and out of the farm are generally low, but considerable variability exists among the studied research clusters. Use of mineral fertilizers and import of organic materials (animal feeds) correlated positively and significantly with crop yields, financial returns and degree of market-orientation (marketed proportion of crop products and distance to market) of the farms. This indicates that due to the relatively high price of fertilizers and the high risks of crop failure in these rainfed systems, use of mineral fertilizers is restricted to the market-oriented farms with access to irrigation facilities.

In the North-South programme, special attention was paid to the role of poor soil fertility as a limiting factor in food production. A decline in soil fertility, related to an imbalance between removal of nutrients and replenishment, is a creeping disaster that undermines the production capacity of the land.

Starting from the mere observation that soil fertility is declining by, e.g., Penning de Vries and Djitèye (1982), Stoorvogel and Smaling (1990), Smaling et al. (1992) and others, soil fertility studies in Africa have evolved to integrated nutrient management strategies, rooted in participatory farm research without becoming detached from higher-scale economic drivers (Koning et al. 2001; Breman 2002). Indeed causes of soil degradation are complex, scale- and location-specific and, so are possible solutions (Koning and Smaling 2005; De Jager et al. 2005). Key findings of the studies were (i) combinations of fertilizers, manure and crop residues are needed to maintain soil fertility and support stable crop production levels and (ii) responses by farmers are crucial in maintaining and regaining soil fertility (Box 2).

Another focus of the North-South programme has been on combating soil erosion. Loss of topsoil via erosion reduces the productivity of the land and the resulting silt and nutrient loads impact on lake and river systems. Erosion is a serious problem in the loess regions of China, representing a serious obstacle to

***Box 2.** Continued*

During the two stakeholders' consultations, the results of the diagnostic and participatory and action research (PLAR) activities in the project were combined with the experiences, goals and aspirations of the major stakeholders in the arid and semi-arid lands (ASAL) to arrive at a set of research and development orientations.

System characterization	Rainfed; Low population density	Rainfed High population density	Irrigated systems
Clusters	Enchorica, Kiomo	Kionyweni, Kasikeu	Kibwezi, Matuu
Short-term measures	• Control livestock numbers • Improve animal health care • Increase local food production through water harvesting, use of manure and rotation	• Breeding and using improved cattle • Mono-cropping maize and dual purpose legumes • Application of Rock Phosphate • Efficient nutrient recycling through crop residues and manure	• Maintenance and management of small-scale irrigation system • Reduce transaction costs: market information, physical infrastructure, marketing channels, cooperatives, micro-finance
Long-term measures	• Design of development plan for livestock-wildlife-tourist industry • Establishment of feedlots for high intensity beef production • Establishment of manure processing facilities • Infrastructure: feed grains and processed manure transport, marketing infrastructure meat • Ecological niche market development	• Introduction dairy breeds • Import of feed grains from high potential areas • Cultivation of mono-cultures of maize and grain legumes • Cultivation of forage legumes • Efficient manure management • Establishment milk marketing system • Infrastructure for transport feed grains	• Establishment of effective production-marketing chain in public-private partnership • Development of skills for all links in chain (production, quality control, transport, marketing)

sustainable agricultural production (Hessel 2002; Ritsema 2003). The nutrients exported via erosion and runoff negatively affect agricultural production and surrounding natural and urban environments. EroChinut was launched to address the topic of soil erosion in part of the Yangtze watershed. Using a combination of participatory and modeling research the team was able to determine effects of different land management strategies on water, soil and nutrient losses by erosion at farm and watershed level and evaluate the economic impacts of the different strategies. Using the model, the team could, via biophysical optimization, reduce discharge, soil loss and nutrient losses most effectively. However, this scenario also showed the strongest negative effect on the economic situation of the area (EroChinut 2003; Ritsema 2003).

Chemical pollution of soil and water

Food production increase has more than kept pace with global population growth over the last decades. This has mainly been achieved through intensification. The irrigated area has increased, and the use of purchased inputs (e.g., fertilizers, crop protection agents) and new technologies has grown, leading to increased production per hectare (Hengsdijk et al. 2005; Fang et al. 2005; Roetter et al. 2007a). Several environmental problems are related to high input levels that result in nutrient and pesticide leaching. The combination of high inputs and advanced technologies clearly has consequences for the sustainability of agro-ecosystems. Overuse and misuse of agro-chemicals works in two ways, it pollutes soil and water needed to sustain production and it directly and indirectly undermines human health.

The North-South programme addressed the issue of pesticide and fertilizer use in intensive aquaculture and vegetable production in Asia via the projects MAMAS and VEGSYS and, in the Pujiang case study of the IRMLA project (Roetter et al., 2007b). Asia is in the process of rapid changes in agricultural production. The fast adoption of high-yielding varieties (Van Keulen 2007; Roetter et al. 2007c) was directly associated with an increase in the use of agro-chemicals. The rapid transition from traditional farming systems to intensive industrialized farming systems as we currently see in parts of Asia has similarities with the transition of agriculture witnessed in Western Europe, following the introduction of the Common Agricultural Policy (Van Keulen 2007). Unfortunately, also the environmental effects of intensive agriculture bear similarities in the emissions of agro-chemicals to the environment, and these problems require immediate action.

The fuel of the development engine is the increased demand for vegetables in urbanized regions in Asia, which provides strong incentives for farmers to change production systems and increase inputs. Lack of knowledge at farm level and lack of awareness at government level result in lack of action, leading to accumulation of negative environmental effects. Hence, the risks related to pesticide use for human health and the environment are clear. Understanding and minimizing the risks related to the use of agro-chemicals requires active participation of a range of stakeholders and a systems approach to research. In both, the MAMAS and VEGSYS project a combination of participatory research and modeling was used to quantitatively assess risk in different production systems. A decision support tool to assess the risks has been developed (Van den Brink 2005).

The negative environmental impact of fertilizers has been subject of research and both, scientific and public debate for several decades, concentrating mainly on intensive farming systems in the developed world (especially Western Europe and North America) and started much more recently in tropical regions. Also in this research, a systems approach was followed. Initially starting with understanding of the effect of the biophysical environment and the role of management at plot and field scale, the analyses moved up to the farm and regional scales, to include socio-economic aspects of farm level decision-making. Following this approach, trade-offs and possible synergies of management and policy options can be identified.

Loss of biodiversity

Agriculture is regularly criticized because of its adverse effects on biological diversity. The reason it is seen as a major threat to biological diversity is twofold. The largest losses of wild biodiversity are those associated with habitat destruction and fragmentation, mainly the result of conversion of natural vegetation for agriculture purposes. Moreover, the environmental impacts of agricultural activities leading to physical, chemical and biological degradation of the environment negatively affect biodiversity.

However, agriculture also contributes to biodiversity, as the biological diversity in agricultural crop species and varieties and livestock species and breeds is on one hand the result of adaptation to environmental conditions, while economic, social and cultural factors also play a role in their diversification. This diversity in crop and livestock species, varieties and breeds provides the genetic base for enhancing productivity. However, changes in agricultural production only resulted in a decline in agro-biodiversity when most traditional crop varieties were replaced by modern high-yielding varieties.

The mainstream in biodiversity focuses on the so-called hotspots or regions that accommodate large numbers of species at risk of extinction (Myers et al. 2000). Because of the low success rate of this approach, recently a plea has been made to concentrate more on the economic value of biodiversity (Odling-Smee 2005). Also the MA (2005) stresses the importance of goods and services provided by ecosystems. So far, the best example of this approach is the carbon market, developed under the UNFCCC, in which a global public good has been made private and linked to market-based mechanisms. At more local scales, payment schemes for landscape and biodiversity have been developed, the latter two mainly in industrialized countries, with Costa Rica being perhaps the only example in a developing country.

The importance of biodiversity has been acknowledged in the North-South programme and two separate research themes were developed. One theme *Conservation and utilization of agrobiodiversity* focused on research aiming at increasing knowledge on the nature and function of agro-biodiversity and genetic resources in tropical production systems, and at developing options to strengthen local markets for products derived from current local diversity. The other theme *International nature management* was designed to contribute to the protection of ecosystems and landscapes of international value and effectuate conservation of biodiversity in the developments of various sectors of the economy. Both themes have a clear focus, and attention is paid to their integration in the sustainable agriculture and rural development theme. This relationship has been worked out in, for example, the STRAPEAT/RESTORPEAT projects.

STRAPEAT/RESTORPEAT focus on the peat areas of central Kalimantan (Indonesia), where large areas are under threat from land clearing, degradation and fire, jeopardizing their natural functions as reservoirs of biodiversity, carbon and hydrological buffers (see Box 3). The project aims at promoting sustainable

Box 3. *Restoration of tropical peatland, RESTORPEAT*

Large areas of globally important tropical peatland in South-east Asia are under threat from land clearance, degradation and fire, jeopardizing their natural functions as reservoirs of biodiversity, carbon stores and hydrological buffers. Many development projects on tropical peatlands have failed through a lack of understanding of the landscape functions of these ecosystems. Utilization of this resource for agriculture or plantation crops requires drainage which, unavoidably, leads to irreversible loss of peat through subsidence, resulting in severe disturbance of the substrate and creating problems for cultivation.

The RESTORPEAT project, a follow-up of STRAPEAT, aims at restoring degraded tropical peatlands and promote wise use via sustainable management strategies integrating biophysical, hydrological and socio-economic dimensions. It specifically seeks to implement the strategies for practical implementation in peatland areas in Borneo. Local research capability is strengthened, enabling peatland managers to better understand and address the different, interrelated processes operating in tropical peatlands. The work started in 2005 and will finish in 2007.

The overall objectives of the project are to:

- Coordinate international activities that address global and regional issues of carbon balance, water management, biodiversity conservation and poverty alleviation related to restoration and management of tropical peatland;
- Provide access to existing knowledge and expertise and conduct targeted research on restoration of tropical peat swamp forest to promote sustainable livelihoods of local people;
- Provide a scientific and technological framework for knowledge transfer and human capacity development related to restoration of tropical peatland to the benefit of the EC and DCs.

The five priority areas for research are:

1. Restore tropical peatland by re-creating environmental conditions for reinstatement of ecological and natural resource functions and promote integrated, multiple land use to minimize damage to the peat carbon store and maximize potential for carbon sequestration.
2. Promote sustainable livelihoods for members of local communities to alleviate poverty and protect and enhance natural resources.
3. Develop a fire hazard warning system for forest and peatland, based on remote sensing and linked to local community awareness, prevention and suppression measures, so that peatland restoration can be effective.
4. Forge partnerships between local communities, local governments, DC Government Agencies, NGOs, international experts and other stakeholders to promote restoration and sustainable management of tropical peatland natural resources and ensure sustainability of the project objectives and outputs in the DCs after EU funding ends.
5. Transfer knowledge of peatland restoration from EC partners to DCs by appropriate information dissemination activities, case studies and training programmes.

development by combining the different activities and functions (carbon, biodiversity, agriculture, water) in the context of regional development.

Climate change

Global climate change is currently one of the most pressing development problems. The effects of climate change are local, and they vary for different systems, sectors and regions. Climate change has an overarching effect on development. In addition to the urgency to reduce emissions of greenhouse gases to the atmosphere, attention is necessary for possibilities for adaptation of systems to the changing environmental conditions. This is expressed in the UNFCCC as follows:

> *"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner." (UNFCCC, article 2)*

Although climate change seems marginal compared to the pressing issues of poverty alleviation, hunger, health, economic development and energy needs, it is becoming increasingly clear that realization of the MDGs can be seriously hampered by climate change. Therefore, linkages between development and climate change are receiving increasing attention in scientific and policy circles (Davidson et al. 2003; Swart et al. 2003; Huq et al. 2006).

Clearly, agricultural land use will be affected by the effects of changes in climate and climate variability. Houghton et al. (2001) concluded that in the tropics, yields would decrease with even a small increase in temperature. Semi-arid and arid areas are particularly vulnerable to changes in temperature and rainfall. Shifts in agro-ecological zones will, in some regions, require dramatic changes in production systems. Climate change will also have an indirect effect on crop production via changes in water availability and in susceptibility to and incidence of pests and diseases. High intra- and inter-seasonal variability in food supplies is often the result of unreliable rainfall and insufficient water for crop and livestock production. In addition to being a victim, agriculture is also a major contributor to greenhouse gas emissions, via land use change, land management, land conversion and livestock husbandry.

Most climate change studies have focused on either reductions in emissions or response strategies to the adverse effects of climate change and climate variability (see Box 4). Recently, however, the climate change issue has been incorporated in the larger challenge of sustainable development (Smith et al. 2003; Huq et al. 2006; Biemans et al. 2006). As a result, climate policies can be more effective when

***Box 4.** Climate change*

Climate change has evolved from a complex environmental issue to a even more complex development issue. Climate change is not a peripheral issue for development. This is especially true for the arid and semi-arid regions of the world. Today already, the natural variability in rainfall and temperature are among the main factors underlying variability in agricultural production, which in turn is one of the main factors behind food insecurity. Availability and quality of water are closely related to amount and frequency of rainfall. The dryland areas of the world are among the most vulnerable regions to climate change. At the same time, the resilience of human and natural systems in the dryland areas and in the West African Sahel in particular, has been remarkable over the last three decades.

Climate change is an additional stress to the Sahelian region which is already under stress from other pressures. A timely signaling of impacts of climate change, including changes in climate variability, and identification of adaptation strategies in this complex environment are important for its development. Clearly, adaptation to environmental change is not new, as changes and variations in climate and other environmental factors have occurred naturally. Both, human and natural systems have had to adapt to these changing conditions. The Impacts of Climate Change on Dryland (ICCD) project has tried to draw lessons from the past with the objectives to understand the current situation and define successful adaptation strategies to future changes in climate. Climate change will increase the probability of extreme weather conditions, leading to catastrophic income shortfalls. National governments need to review past interventions and develop innovative ways to assist rural communities in coping with, and recovering from, massive and large economic and environmental shocks. That is required to increase understanding of climate change and its effects and for the development of technologies adapted to location- and sector-specific conditions.

In a workshop, experts gave the highest priority to developing an adequate early warning system with an efficient strategy to communicate with households and institutions. In addition, high priority was given to maintaining social security mechanisms, understanding migration strategies and regulating land and water entitlements. Adequate attention is needed for potential conflicts when resources become scarce. Local government and non-governmental organizations need support to monitor economic changes and to implement local policies. Agricultural research plays an important role in developing technologies that perform well under drought conditions. International agreements on climate change implications may be exploited for example by redefining subsidy policies. Finally there is plenty of scope for improving scientific research on climate change by extending research networks, by fine-tuning existing models, and by expanding the geographic area of research. (After Dietz et al. 2004).

consistently embedded within broader strategies designed to make national and regional development paths more sustainable. Such policies deal with issues such as land resource management, and energy and water access and affordability (Smith et al. 2003; Easterling et al. 2004; Halsnæs and Verhagen 2007; www.developmentfirst.org).

SUSTAINABLE AGRICULTURE AND RURAL DEVELOPMENT

The relation between agriculture and environment is complex. Agricultural production affects other land uses, directly via competition for land and water or indirectly via inadequate management, leading to degradation and pollution of soil, water and atmosphere.

Often it is the focus on short-term needs or economic gains and the disregard of long-term impacts that underlie decisions leading to degradation and pollution; in other cases, it is the lack of awareness or know-how that are to blame. This observation is not new, but so far, solutions and pathways to move to more environmentally-friendly production systems have not been very successful. However, by not only focusing on environmental issues but also considering economic and social criteria, a more harmonious picture of problems and possible solutions will emerge.

The MDGs provide a policy framework with well defined achievable targets. With the prominent role of agriculture in achieving these goals we also need to consider how the discussed environmental issues might interfere with these goals. In Table 1, a short overview of how climate change soil and land degradation including chemical pollution of soil and water and biodiversity are linked to the MDGs is provided.

Looking for new economic incentives is essential when aiming at environmentally-friendly production systems. Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. They maintain biodiversity and the production of ecosystem goods, such as forage, seafood, biofuels, timber, natural fiber, and many pharmaceuticals, industrial products, and their precursors. In addition to the production of goods, ecosystem services are the actual life-support functions, such as cleansing, recycling, and renewal, in addition to conferring many intangible aesthetic and cultural benefits. (Costanza 1997; Daily 1997). The Millennium Ecosystem Assessment (2005) classified ecosystem services into four main types: provisioning, supporting, cultural, and regulating services (see also the international assessment IAASTD, with focus on agriculture; www.agassessment.org). Agricultural systems are typically managed to maximizing provisioning services to provide food, but they require several other supporting and regulating services to support production. Agriculture both depends on ecosystem services and also generates them. Agricultural ecosystem services can be grouped into three categories: services that directly support agricultural production (such as maintaining fertile soils, nutrient cycling, pollination), services that contribute directly to the quality of life of humans (such as cultural and aesthetic values of the landscape) and services that contribute towards global life-supporting functions (such as carbon sequestering, maintenance of biogeochemical cycles, supply of fresh water, provision of wildlife habitats). Monetarizing these services is part of the solution to more environmental-friendly production systems.

Table 1. *The relation of three environmental issues with the Millennium Development Goals*

Millennium Development Goal	Climate change	Soil and land degradation and use of agro-chemicals	Biodiversity
Eradicate extreme poverty and hunger	Direct impact via the reduction of livelihood assets: e.g. water, houses, infrastructure. Negative affects on regional food production and deteriorate food security.	Loss of soil fertility reduces land productivity, leading to a decline in food production capacity. Destruction of infrastructure (land slides, mud slides)	Control of pests and diseases. Diversity of gene pool of crops and livestock. Flood control modifies wetland conditions and re-duces biodiversity.
Reduce child mortality	Direct via area expansion of vector borne diseases such as malaria and dengue. In areas with reduced rainfall a decline in water availability will result in an increase of water borne diseases. Deteriorating food security will undermine the health of vulnerable groups.	Direct impact via pollution of drinking water and chemical residues on food and fruit crops.	
Ensure environ-mental sustainability	These are core issues in defining environmental sustainability.		
Develop a global partnership for development	These issues require global cooperation and the development of trading and finance mechanisms.		

Changes in society also influence agriculture. Support from the science, business and policy communities is needed to develop more sustainable rural economies and re-assess the role of agriculture. Redesigning agriculture to provide services and common goods creates opportunities to move to integrated solutions. This, however, requires political will and the creation of new markets. Increased water and nutrient use efficiencies, for instance, will be essential in sustainable agricultural systems, as that reduces both the pollution load to the environment and the costs.

However, there are inevitable trade-offs between various activities. Not only trade-offs between the three pillars of sustainability, but also scale- and resource-dependent trade-offs. Biophysical scales are linked and understanding the effects of, e.g., management activities, requires up- and down-scaling of biophysical processes. The same holds for the socio-economic environment, the various actors and institutions (e.g., public and private, profit and non-profit) which operate at different scales. Decisions at higher scales tend to restrict or influence lower scale decision making.

In agricultural systems, typically, decisions and activities at the lower scales interact with and affect the biophysical environment (Figure 1). Policies at higher scales aim at creating incentives for lower-scale decision makers to achieve policy goals such as food security, sustainable production, and/or a reduction of greenhouse gas emissions. In agricultural systems, the decision making unit is in most cases the farm household. This is the pivoting point for these systems: here decisions on consumption and production are made that affect the biophysical environment. It is the institution where the socio-economic domain and the biophysical domain interact. Decisions at household scale also affect higher scales for example revenues from agriculture will feedback into the regional economy or reductions in greenhouse gas emissions at field and farm level contribute to the mitigation of global climate change.

As in the socio-economic environment, the scales in the biophysical environment are nested, i.e., lower-scale processes and higher-scale processes are interlinked. Soil and land degradation, starting at the field level can lead to the destruction of entire landscapes, and greenhouse gas emissions related to agricultural activities such as fertilizer application and tillage contribute to global warming. In turn, higher-scale effects, such as changes in temperature and precipitation regime, have an impact on options for agriculture at the lower scales. Often, the higher-scale effects draw attention (signaling) from governmental and non-governmental organizations and lead to action (Figure 1).

Sustainable agriculture will need to take into account both, the socio-economic and biophysical environment, acknowledging scale and process linkages.

How to operationalize the sustainability concept for agriculture is not clear. Economic development does not automatically lead to cleaner products and production processes and policies are needed to promote (or maybe enforce) the transition to

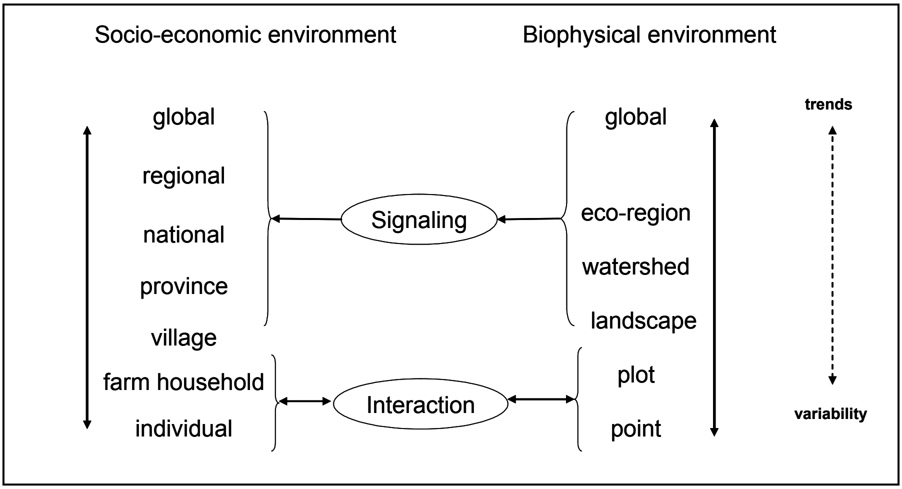

Figure 1. *Man-environment interactions (after Dietz et al. 2004)*

Table 2. *Research questions related to achievement of the MDGs*

Millennium Development Goal	Agriculture and environment
Eradicate extreme poverty and hunger	Is labour productivity low because of adverse natural or physical circumstances? How can we increase land productivity? How can we utilize (agro) biodiversity to increase productivity? How can we increase resource use efficiencies? How to adapt agricultural systems to climate change?
Ensure environmental sustainability	Are degrading environmental impacts intrinsically linked to agricultural production? How to analyse vulnerability and resilience in agricultural landscapes? How to analyse agricultural landscape mosaics?
Develop a Global Partnership for Development	How can we link global issues and local action? What are the roles of policy, science and the private sector?

more sustainable production systems. However, with retreating government influence and increasing influence of producers, consumers and markets, this task is becoming increasingly difficult. The concept of sustainability needs to be incorporated into these markets. In Western markets producer and consumer groups can make a difference, but in emerging markets, such as China and India this still seems far away. Combining forces of the public and private sectors, to get the best of both worlds, is a promising direction.

The role of science in shaping sustainability lies in developing and making effective use of technologies and methods that will allow for integrated quantitative spatial assessments. In this context, increased production and improved resource use efficiency will play important roles in the operationalization of sustainable agriculture and conservation of the natural resource base. Integration of landscape and farm household processes is essential in identifying feasible development pathways for land use systems, i.e., linking scales is a daunting scientific challenge. Farming systems and farm household systems comprise different spatial scales than ecosystems or watersheds. Conceptual approaches in agricultural sciences and ecological sciences do not always match. Biophysical analysis of land mosaics comprising farm fields, forests and nature areas and their competing claims on natural resources is a challenging scientific task. Several concrete research questions linked to realization of the MDGs are listed in Table 2 (based on Dietz 2003; Thritle et al. 2003; Dorward et al. 2004).

Conflicts arise from the tensions between what is feasible, affordable, acceptable and effective in a given situation. Science can assist in shaping sustainable development pathways by create methodologies, guidelines and indicators to quantify trade-offs and identify possible synergies for decision makers at local national and international levels.

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CHAPTER 5

RURAL LIVELIHOODS: INTERPLAY BETWEEN FARM ACTIVITIES, NON-FARM ACTIVITIES AND THE RESOURCE BASE

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Despite ongoing urbanization, over 70% of the world's poor are located in rural areas (IFAD 2001). Agriculture plays an important part in their livelihoods. Rural households play a central role in realizing policy objectives. Production decisions at farm household level determine the current availability of agricultural produce (food security objectives; Roetter and Van Keulen 2007), as well as future production potentials (sustainability objectives; Verhagen et al. 2007). The majority of the poor are furthermore located in the rural areas of developing countries. Rural households are, thus, also key to poverty reduction policies.

Farm households, however, do not live of farming alone. Parallel to the developments in agricultural science, the view on rural households has changed in the past decades. Analyses of single production systems have given way to a view on rural households as diversified enterprises. Rural household enterprises are not limited to the agricultural sector. Non-farm activities play an important role in income of these households all across the world, even in regions commonly thought of as subsistence-oriented, such as Sub-Saharan Africa. In a rare worldwide comparison of the importance of non-farm income in developing countries, Africa ranked first with 42% of total rural income, followed by Latin America (40%) and Asia (32%) (Reardon et al. 1998).

Rural areas play a prime role in two of the Millennium Development Goals: reducing poverty and hunger and ensuring environmental sustainability. The omnipresence of non-farm income in rural areas implies that any policy aimed at realizing

R.P. Roetter, H. Van Keulen, M. Kuiper, J. Verhagen and H.H. Van Laar (eds.), Science for Agriculture and Rural Development in Low-income Countries, 77–95.

these two Millennium Goals needs to look beyond households' agricultural activities. Non-farm activities play a prime role, directly by contributing significantly to household income and indirectly by shaping agricultural activities with implications for sustainability. However, the effect can be positive or negative. Pressure on natural resources may be reduced when households have alternative sources of income (Bahamondes 2003). Non-farm income may also (partially) be invested in sustainable agricultural practices. Soil nutrient mining is a key issue in the African context (see Verhagen et al. 2007). Inorganic fertilizers are an important source of nutrients. These fertilizers require cash which may be generated by non-farm activities. Non-farm activities would then contribute to sustainability. In the Asian context, excessive use of pesticides and herbicides is a prime concern (see Verhagen et al. 2007). Farm households that are engaged in non-farm activities could replace hand weeding by herbicides. In that situation, non-farm activities would threaten the sustainability of agricultural practices.

Regarding sustainable agricultural development, the DLO research programme International Cooperation (DLO-IC) has reflected the shift from a pure technical to a broader perspective on rural households' activities and their institutional environment. Within DLO-IC, research on poverty reduction has tended to focus on agricultural technologies and on the impact of (poor) households' land use decisions on natural resources to safeguard productivity. So far, no explicit attention has been devoted to interactions between non-farm and farm activities. Our objective is to analyse the role of non-farm activities in rural households' livelihood strategies and their implications for the sustainability of natural resource use. Based on existing literature, we develop a conceptual framework for analysing links between non-farm activities and agriculture. The conceptual framework indicates the importance of local conditions and changes over time in the links between farm and non-farm activities. This implies that analyses and policies need to be location- and time-specific. Using a unique household-level dataset pulled together from different DLO-IC projects and covering different regions in Africa and Asia, we analyse the importance of non-farm income for households, as well as the distribution of income across households. Based on the agricultural activities of households, we assess the potential for forward and backward production linkages. We then analyse the impact of non-farm income on sustainability of agricultural activities. We conclude by deriving implications for policies aimed at reducing poverty and promoting sustainable rural development through promoting both agricultural and non-agricultural household activities.

CONCEPTUAL FRAMEWORK

In the literature, different terms (off-farm, non-farm, non-agricultural, non-traditional) are used interchangeably to denote non-farm income. We, therefore, first need to define what we mean by non-farm income. Barrett et al. (2001) propose a three-way classification based on (i) *sectors* as defined in national accounts; (ii) *location* distinguishing at-home, local away-from-home and distant away from-home (domestic or foreign migration); (iii) *self-employment or wage labour*. Using such a three-way classification allows a study of the dependence of rural households on the local or more distant economies, (local) intersectoral linkages, rural-urban linkages, and the importance of foreign sources of income.

Households engage in non-farm activities for various reasons. These are commonly divided in push and pull factors. *Push factors* result from diversification to reduce risk (for example because of climatic variability), diminishing factor returns, liquidity constraints, crises and a need for self-subsistence in goods and services due to high transaction costs. *Pull factors* result from opportunities created by skills or endowments or by complementarities between activities. The latter are accumulating strategies generating surpluses, while push factors result in coping or survival strategies running down stocks (Start 2001). The role of non-farm activities in household livelihood strategies thus matters for their impact on household income. This suggests addition of the role of non-farm activities as a fourth dimension to the classification of Barrett et al. (2001) discussed above.

The scope for rural non-farm employment opportunities is to a large extent determined by geographical factors. The role of geography, or, more specifically, topology (spatial neighbourhood) in economic development is well-known, dating back to the work of Von Thünen in 1826. Interest in the role of geography in economic development was revived by the work of Krugman and co-workers in the 1990s (Fujita et al. 1999). The finding of these models is that urbanization arises because of agglomeration effects (large local market, skilled workers, variety of inputs, technological spill-overs, lower costs of infrastructure) (Lanjouw and Lanjouw 2001). These benefits of concentrating activities that are not bound to immobile natural resources, limits the scope for developing non-farm activities in rural areas. Immobility of natural resources results in agriculture, forestry, fishing and mining in rural areas. Distance to urban centres plays a central role in determining the options

Table 1. *Likely 'activities' in different rural zones*

	Remote rural areas	Rural area in between	Peri-urban areas
Agriculture	Subsistence farming, livestock, forestry and fishing; limited surpluses of which only high value items can be sold elsewhere due to high transport costs	Arable farming, livestock, forestry and fishing with intensity and market surpluses depending on natural resources and distance from urban areas	Market gardening and dairying
Resource extraction	Depending on natural resources	Depending on natural resources	None
Manufacturing and services	Crafts and services for local markets	Some crafts and services for local markets (depending on accessibility); rural industries	Industries avoiding congestion in city
Migration	Migration	Migration	Daily commuting

Source: based on Wiggins and Proctor (2001) and Barrett et al. (2001).

for local non-farm employment. Based on distance to urban areas we can distinguish three zones, remote rural areas, rural area in between and peri-urban areas, each with different likely 'activities' (Table 1).

Note, that these likely activities are not specific for developing countries, but apply with equal force to high-income countries. The main difference is that in high-income countries investments in infrastructure have reduced transport costs for most regions, so that few remote areas remain. Access to urban markets is important for selling agricultural surpluses and for determining the scope for local manufacturing and services. High transportation costs prevent sales of all but very high-value crops, thus, limiting the scope for agricultural activities. At the same time, limited access to urban markets also implies that goods and services have to be produced locally, increasing local non-farm employment opportunities if local demand suffices.

The importance of transport costs is also illustrated in Figure 1, presenting a stylized representation of the development of rural non-farm employment opportunities in relation to transport costs and agricultural growth. Agricultural and non-agricultural sectors are linked through production and expenditure linkages[1]. Production linkages refer to backward (through agricultural inputs) and forward (through processing of agricultural output) linkages. Expenditure linkages consist of consumption and investment expenditures. Expenditure linkages work in both directions. Additional income in agriculture will increase the demand for non-agricultural goods for consumption and investment. Similarly, an increase in non-agricultural income will increase the demand for agricultural goods for consumption and investment. The production and expenditure links imply that growth (or lack of growth) from one sector can spill over to another sector (FAO 2002).

Access to urban markets and links between the agricultural and non-agricultural sectors determine the different stages of non-farm employment in rural areas. In the traditional stage, the rural area faces high transportation costs to urban areas. Limited agricultural productivity limits non-farm employment opportunities. As agriculture develops, it promotes local non-farm employment through local production and expenditure links (locally linked stage).

When infrastructure investments reduce transport costs to urban areas, local goods and services face competition from urban goods and services. This results in a leakage of positive spill-over effects from agriculture (that may well benefit from the reduced transportation costs) to urban areas. Although reduced transport costs may reduce local non-farm employment, it at the same time promotes access to urban employment through (temporary) migration. Finally, with increasing congestion in the urban areas there may be a relocation of urban production to rural areas through sub-contracting of production, using comparative advantages of rural areas such as

[1] The discussion on the links between agriculture and non-agricultural sectors originates in the Green Revolution period. The increases in production needed to be absorbed, drawing attention to consumption linkages in rural economies (Stokke et al. 1991). One of the first publications that stresses the growth potential of modern (input-intensive) agriculture and consumption links is J.W. Mellor's *The new economics of growth* (Mellor 1976). Most case studies on the role of these linkages in development are from Asia. The scope for these linkages in Africa seems more limited (Haggblade et al. 1989).

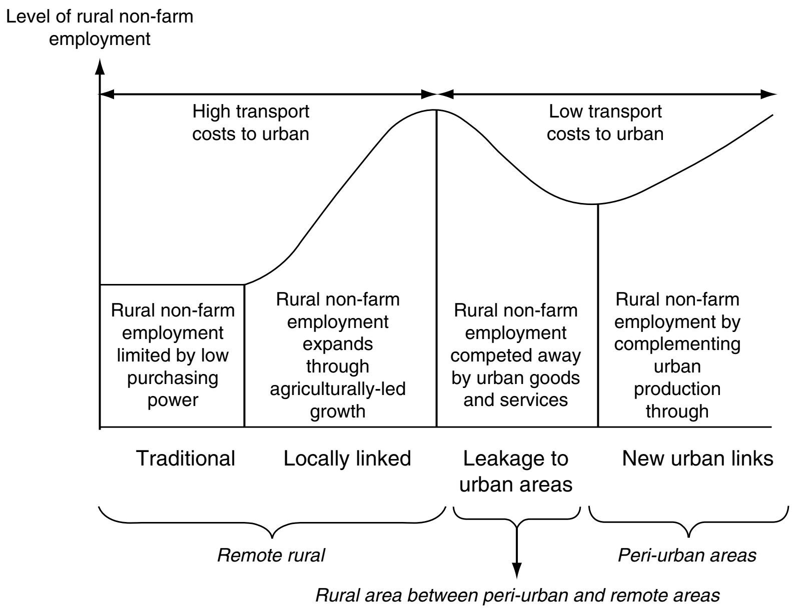

Figure 1. *Stages of rural non-farm employment and relevance for different rural areas. Source: based on Start (2001) and Wiggins and Proctor (2001)*

cheap labour. Local production then complements instead of competes with urban production (Start 2001).

The importance of transport costs implies that the four stages are only relevant for the rural area between the peri-urban and remote areas. Local production in peri-urban areas always has to compete with the nearby urban production, leaving only room for complementary production. Local non-farm production in the remote areas, on the other hand, will always be protected from urban competition by high transport costs. This, at the same time, limits the relevance of sub-contracting of production as in the last stage in Figure 1. Finally, the representation of the development of rural non-farm employment in Figure 1 is highly stylized. In reality, developments will vary across regions and sectors. Recession and disasters may result in a decline in agriculture, which through negative spill-over effects leads to a contraction of the non-farm sector. There is, thus, by no means a homogeneous and linear process that irreversibly leads to development of rural employment.

The discussion so far has concentrated on a rather aggregate level, comparing the scope for non-farm employment in different geographical locations. These non-farm income opportunities vary from well-paid formal employment to casual unskilled labour. Access to these opportunities depends on skills, wealth, gender, class and race (Start 2001). The ability of households to exploit available opportunities is, thus, not evenly spread. This has sparked a discussion on the extent to which non-farm employment reduces or increases income inequality (Stokke et al. 1991). The empirical evidence suggests that the effect can go both ways, thus, preventing any general conclusions to be drawn on the impact of non-farm income on inequality (Haggblade et al. 1989; Lanjouw and Lanjouw 2001). Analyses of the factors influencing individuals' participation in non-farm employment shows that household endowments (land, labour and capital) and individual characteristics, mainly education and gender, play important roles (Ezumah and Di Domenico 1995; Ruben and Van den Berg 2000). Finally, investments in non-farm opportunities are often related to ethnic or kin ties, limiting access to non-farm opportunities to certain subsets of a rural population. The involvement in rural non-farm employment activities for households or individuals, thus, strongly varies temporally, spatially and socially (Start 2001).

It is assumed that an increase in non-agricultural income will lead to increased demand for agricultural goods for consumption and investment (FAO 2002). However, to our knowledge, the impact of non-farm income on (specific) investments in agriculture has not been investigated extensively. This last issue has implications for the natural resource base. Intensification of agriculture (to attain higher yields per unit of land and labour) is seen as a necessary step to support population growth and reduce the pressure on land (especially on natural areas). Soil degradation through nutrient depletion is a major factor underlying declining yields. The use of fertilizer is constrained by various factors, such as limited availability (because of lack of infrastructure) and lack of purchasing power of farmers. Closer proximity to urban areas and an increase in non-farm income could alleviate these constraints and thus contribute to increasing soil fertility.

There are several factors to be considered in how non-farm income is spent. Firstly, when access to non-farm opportunities depends on skills, wealth, gender, class and race, members within the same household may have different opportunities. Enrolment rates in schools are higher for boys than for girls, and male household members are, therefore, likely to have higher education rates than female household members, thus, increasing their non-farm employment opportunities. This means that the involvement in non-farm activities may be gender-segregated within a household. This raises the question what implications there are for expenditure of non-farm income within the household. Can all family members (or husband and wife) decide on how this income is spent, or do the family members (or husband and wife) have 'separate purses' (as is the case in many African countries).

Secondly, there is the question whether farm households decide to invest non-farm income in agricultural activities, or spend it on strategies that will increase the opportunities for increased non-farm income. Put differently, are rural households investing in agricultural activities to intensify their farming system, or are they investing in strategies out of agriculture?

DATA DESCRIPTION

Differences in non-farm employment opportunities will imply differences in the impact of non-farm income on sustainability indicators. A unique dataset collected in six countries in Africa and Asia allows us to explore links between non-farm employment, agricultural practices and sustainability indicators. Data have been combined from five multi-disciplinary DLO-IC research projects addressing sustainability issues in developing countries. The data were all collected using the

***Box 1.** Traditional areas: Gobo Deguat village in Tigray, Ethiopia*

Gobo Deguat is a remote village in the highlands of Tigray, Northern Ethiopia. There are no roads leading to the village, and the only nearby town is Hawzen, located 100 km from Mekelle, the regional capital. In this poor region, rural households have various coping strategies when farming does not generate sufficient food or income. There are several strategies that rely on own resources, such as selling livestock or donkeys, selling high-value cereals (such as teff) and buying low-value cereals (such as linseed) in return, and selling timber (from eucalyptus trees). However, the farmers indicated this is usually only an option for the relatively better-off households. The poor households will go begging in richer downstream valleys or start using wild foods such as *Opuntia ficus-indica*. For poor households the food-for-work programmes organized by the Ethiopian Government offer the most important opportunity to obtain food. At least according to women, this was the most important source of food in times of need for poor households. However, men usually also mentioned migration to the regional capital Mekelle or other cities in Ethiopia, and even to Sudan as the most important strategy. Some mentioned masonry as a specialized skill that some households used to earn non-farm wages and trading salt with the Afar region.

Thus, it appears that poor rural households in Tigray will revert to non-farm activities sooner than better-off rural households, who will first rely on their own resources. And it turns out that men and women within a household follow different strategies.

Source: PIMEA project (www.boci.wur.nl/UK/Archive/Sustainable+agriculture/PIMEA)

same methodology for surveying farm households and intensive monitoring of farm activities (involving frequent visits by enumerators) over one or more calendar years (Vlaming et al. 2001). This has resulted in a rich dataset of 449 households (including data on 3305 individuals) that is consistent across households and countries.

The surveyed villages cover the spectrum of locations/rural-urban distance relations (depicted in Figure 1) as shown in Table 2. The sample is strongly biased towards Africa. The two Asian locations provide a strong contrast to the African locations, being in a more densely populated continent and being located close to urban centres. This confounds the differences we find between areas with new urban links and the other more remote areas. Nonetheless, the distribution of location and distance to urban centres is fairly even (similar number of observations within each zone) which gives an even distribution in access to markets and institutional environments. Illustrations of individual cases are given in Boxes 1 to 3.

The importance of non-farm employment

Obtaining reliable data on non-farm employment and especially on revenues derived from non-farm work is not easy. In general, people are rather reticent about disclosing how much they have earned, and what their sources of income are. We,

Table 2. *Description of data*

Country[a]	District/ Province	Village(s)	Period[b]	No of households	No of individuals	Household members engaged in non-farm employment (%)
Traditional				121	1122	17.2
Burkina Faso	Zoundwéogo	Béré, Bindé, Gogo	1997	104	1002	14.1
Ethiopia	Tigray	Gobo Deguat	2001	17	120	36.3
Locally linked				98	874	17.7
Ethiopia	Tigray	Teghane	2000	20	138	17.8
Kenya	Mbeere	Kamugi	1997	18	164	24.5
Uganda	Palissa	Kakoro	1997/2000	60	572	15.6
Leakage to urban areas				107	801	26.1
Ghana	Ashanti Region	Attakrom, Nyame Bekyere, Dyankwanta	2004	62	421	25.4
Kenya	Kiambu	Kibichoi, Ngaita	1997/1999	45	380	27.1
New urban links				123	508	46.8
China	Chengdu	Shengli, Xibei	2002	60	221	38.8
Vietnam	Hanoi	Tang My	2002	63	287	54.5
Whole sample			n.a.	449	3305	27.5

[a] Countries are grouped under the headings used in Figure 1 (see text for details).
[b] Period during which data were collected.

Box 2. *In between villages: Leakage to urban area (Kiambu) and locally linked area (Mbeere) in Kenya*

Kiambu district is located close to Nairobi (20 km north) and is characterized by a relatively high altitude, high precipitation and high population density in comparison with Mbeere district. Kiambu district was considered a high agricultural potential area, while Mbeere was considered to have low/medium agricultural potential. Mbeere district is located some 100 km north-east from Nairobi. In Kiambu, 66% of the people see their main occupation as farmer, while 16% are mainly involved in non-farm employment (or commercial activities). In Mbeere the figures are around the same, with 71% farmers and 13% non-farm employment. Data on the impacts of commercial activities on family income and food security gives some insight into how non-farm income is being spent by farmers:

Impact of non-farm activities on family income and food security (% of farm households reporting type of impact)

	Kiambu		Mbeere
	Kibichoi (*n*=19)	Ngaita (*n*=19)	Kamugi (*n*=17)
Purchased food items	84	74	59
Purchased non-food items	32	32	24
Agricultural inputs, hired labour	11	26	88
Increased income	37	21	6
Additional production for consumption	-	21	6
Paying school fees	21	16	12
Paying group contributions	26	5	
Market share	3.6	–18	–28

In Kiambu, non-farm income has most impact on food and non-food items. In Kamugi, Mbeere however, the non-farm activities do have a significant impact on investments in inputs and labour.

The market share is a measure for self-sufficiency of the farm, where low values indicate highly self-sufficient (i.e., few interactions with the market) and high values indicate highly market-oriented farms. Positive market shares indicate that more products were sold on the market than bought. Data in the table show that with the exception of Kibichoi, market shares were negative, i.e. more products were bought on the market than sold.

Source: INMASP (www.inmasp.nl)

therefore, use multiple indicators to gauge the importance of non-farm employment (Table 3). The first indicator is whether household members' main occupation is non-farm (non-agricultural) employment, signalling the importance attached to non-farm activities (column 1). There is a clear pattern that the closer one lives to urban areas, the more important non-farm activities become as the main source of income. The second indicator measures the share of household members involved in non-farm

Table 3. *Importance of non-farm employment by location (in percentages; standard deviation in parentheses)*

	Main occupation[a] (1)		Proportion of household members[b] (2)		Proportion of income[c] (3)	
Traditional	2.2	(8.7)	17.2	(23.5)	12.0	(26.0)
Locally linked	9.7	(19.1)	17.7	(23.5)	15.2	(21.2)
Leakage to urban areas	10.3	(15.9)	26.1	(22.9)	25.5	(65.8)
New urban links	16.4	(21.8)	46.8	(27.1)	35.3	(25.1)
Total sample	9.7	(17.8)	27.5	(27.3)	22.2	(38.0)

[a] Percentage of household members identifying non-agricultural/non-farm activities as their main type of employment;
[b] Proportion of household members involved in any non-farm (agriculture and non-agricultural) activities;
[c] Proportion of household income derived from non-farm activities.

activities, thus including household members engaged in non-farm activities next to agricultural production (column 2). Comparing the first two columns we find much higher values for the share of household members involved in non-farm employment in all zones. Even in the remote traditional zone, 17% of the household members is involved in non-farm activities, signalling their general importance. The third indicator presents the share of non-farm income in total household income (column 3). Despite the likely underreporting of non-farm earnings in the surveys, they still account for 12 to 35% of household income. This confirms the importance of non-farm activities found by Reardon et al. (1998), even in remote areas.

Households in the locally linked zones are less involved in non-farm employment than those in the leakage to urban areas zone, while we expected the opposite, based on our theoretical framework (see Figure 1). The three indicators in Table 3 all point towards a growing importance of non-farm activities the closer one gets to urban areas. This finding may result from the cross-sectional nature of our data, as opposed to time-series data, following the developments in an area as links to an urban centre are developing. Another possible cause is that we are unable to distinguish rural (or local) non-farm employment from urban employment. It may well be that in the leakage to urban areas zone there is less local and more urban employment. The higher share of non-farm income in total income (with similar participation rates in non-farm activities) for the leakage to urban areas zone points in that direction. Urban wages are, as a rule, higher than rural wages, suggesting a higher share of urban employment in the leakage to urban areas zone.

Box 3. *New urban linkages: Tang My village in Vietnam*

Many smallholder farmers in China and Vietnam become trapped in a cycle of ever-higher chemical input use with lower productivity and profitability and reduced sustainability of the natural resource base. Tang My village, situated in the Red River Delta in Vietnam, is situated near Hanoi. Various developments have led to a shift towards a very intensive farming system in which land is used during three seasons (spring, summer and winter). (i) Construction of the irrigation pumping station in the early 1960s, allowed farmers to cultivate vegetables during the dry winter season; (ii) The policy reforms during the late 1980s, when the collectivization system was dismantled and replaced by a system with land use rights for individual households made farmers free in their decision making. There are good tarmac roads linking the village to the outlet markets. And in a period of forty years the population of the village increased from 600 to 2,400.

The farmers in Tang My generate their income mainly through agricultural activities and to a smaller extent through non-farm activities. People on average and poor households engage in non-farm activities mostly to meet their basic needs. However, in rich and well-off households, the off-farm income is used to increase savings. All households in the latter groups own land, some have higher quality land, which they obtained through exchanging land with others. However, the general opinion is that currently, agricultural land of poor households becomes less fertile, because poor households can not adequately invest in fertilizer inputs. There is quite some difference in agricultural production between the household classes distinguished. The rich and well-off invest more in high-value crops such as green squash, cauliflower, onion and tomato.

In Tang My, 75% of all households can be typified as "pure" agricultural households. Around 20% can be described as semi-agricultural households, in which one of the household members (e.g. wife and/or husband) has a permanent non-farm job. The other households specialize in e.g. aquaculture, or are involved in non-farm employment (and do not cultivate their land, or only to a limited extent).

Source: VEGSYS (www.vegsys.nl)

Access to non-farm employment

The key finding of Table 3 is that location (or relative distance to urban areas) is an important driving factor for non-farm activities. We, therefore, analysed the role of location in relation to other factors, such as age or education, in individuals' engagement in non-farm employment by estimating an econometric model (see Appendix to this chapter). The results tend to confirm the pattern seen above with respect to the effect of location. The probability of an individual having some non-farm employment generally increases with proximity to urban areas, as does the probability of an individual being employed full-time in non-farm activities.

Household and individual characteristics are also related to participation in non-farm employment. Individuals from larger households are more likely to engage in non-farm employment, while individuals from larger farms (in terms of area owned or cultivated) are less likely to do so. However, the effect of such factors is relatively small, compared to the individual characteristics. These results indicate the importance of gender. Men have a higher probability of engaging, particularly exclusively, in non-farm employment. Age does not appear to be a strong determinant of non-farm employment, although children under 15 years of age have a much lower probability of engaging in non-farm employment. Also not surprisingly, education is quite important. Primary schooling increases the chance that an individual will be employed in non-farm activities. A secondary education increases this probability almost fivefold and a post-secondary education has a somewhat stronger effect. This underlines the importance of education for girls in improving both, their own livelihoods and those of their families. But opportunities to capitalize on the investment in education and human capital through non-farm employment are still much greater the closer one is located to urban centres.

The role of non-farm employment in external input use

Another issue of interest is the relationship between non-farm employment and farm management practices, including both intensification and sustainability perspectives. Two more econometric models were therefore estimated and are also presented in the Appendix. These analyses are all at household level. First, the effect of location, as well as of various household and farm characteristics on expenditures on cropping inputs per hectare (primarily fertilizers, pesticides and extra hired labour) was examined. These expenditures are an indicator of intensification or general investment in agricultural production. Input expenditures are, of course, far higher for the intensive horticultural production activities in the new urban links zone. But it also turns out that farms in the locally linked and leakage to urban areas zones tend to use significantly lower input levels than those in the traditional zone. Furthermore, non-farm income, either in absolute terms or as a percentage of total household income, does not seem to affect expenditures on inputs. Combined with the findings on individual access to non-farm employment, these findings suggest that farms closer to urban areas, but not in the new urban links or peri-urban zones around cities, are not investing more in agricultural production than those further away. In particular, increased incomes from non-farm employment opportunities are not being invested directly in farm production (at least not in improving crop production). This suggests that income earned from non-farm activities is not used to substitute the labour withdrawn from agriculture.

As expenditures on crop inputs also capture differences in production systems and their profitability, a more detailed analysis was performed on the use of inorganic fertilizer. Fertilizer use and its relation to soil nutrient balances (discussed below) are key concerns in the African context, where most of our data come from, given the extent to which soil nutrients are being mined. Our dataset indicates that a farm household's decision to use fertilizer can be separated from the second decision on how much to apply (for those farms choosing to do so). The results indicate the possible importance of structural factors, or impediments to accessing fertilizer among African farms. For example, fertilizer use is considerably lower in localities with higher prices, although we should add here that we have not been able to account for potentially differential access to credit. Furthermore, large and significant differences among the countries point to possible effects of other differences in input supply chains and associated institutions. The decision to use fertilizer is also influenced by the availability of farm labour.

The quantity of fertilizer applied by farmers in the different zones matches the pattern seen above for input expenditures. Farms in the new urban links apply much more (kg nitrogen per ha), but farms in the traditional zone are still likely to use more than those in the locally linked zone, with those in the leakage to urban areas zone likely to apply the smallest quantity. Again, farms with more available labour tend to use more fertilizer, while farms that are somewhat larger tend to apply less. Aside from similar differences among countries, it appears that income from non-farm employment has little or no influence on fertilizer use.

As mentioned above, we are also interested in possible linkages between location, non-farm income and the sustainability of farming practices. The available data allow us to estimate the effects of various factors on the net soil nutrient balance for nitrogen which is estimated as the total input of nitrogen from fertilizers (both, organic and inorganic) minus what is removed in crop produce. Even though this ignores other losses such as through erosion or leaching, for a majority of the African farms in the sample, this partial balance is already negative. Despite the large differences in fertilizer use among zones, the only zone with significantly deviating soil nitrogen balances is the new urban links zone of the Asian horticultural producers. The results (also presented in the Appendix) provide few other clues, but they do not suggest any link between non-farm income and soil fertility management.

Summarizing the results in general though, location does matter. With respect to the role of non-farm employment and income in agricultural livelihoods, one general interpretation of results is that households do not invest additional non-farm income in agricultural production, but rather use this income for other purposes, such as consumption or school fees. These conclusions are supported by the evaluation of the impact of commercial activities on household expenditures in Kiambu and Mbeere Districts in Kenya (see Box 2). Households indicate spending income derived from this source mainly on purchasing food and non-food items. Investments in agriculture are only frequently mentioned in one village out of three. This would suggest the need for a more integrated view on household livelihood strategies and investment behaviour than one considering farm production as the central activity.

CONCLUSIONS

Despite the qualifications with respect to the stylized representations of non-farm income in Table 1 and Figure 1, they offer a useful framework for analysing non-farm employment and deriving some general policy recommendations. The analyses of the available data only provide a first glimpse at relations between non-farm activities and agricultural production decisions. The (preliminary) conclusions suggest that non-farm activities are of key importance for rural household decision-making and do influence future production potential.

Non-farm activities play an important role in reducing rural poverty, and affect agricultural production decisions. Analyses of investments in farm production suggest that non-farm income is generally not correlated with expenditures on external inputs or with fertilizer use. In the African context, from which the majority of our data originate, soil mining is a major issue, but increased non-farm activities and associated income do not seem to have an impact on the sustainability of soil fertility management. Apparently, income from non-farm activities is neither invested in agriculture, nor in ensuring future production. We do find that being located nearer to an urban centre, which increases the scope for non-farm employment, reduces the likelihood of using external inputs in general and inorganic fertilizer in particular. This suggests that the additional income derived from non-farm activities is not used to substitute the labour withdrawn from agriculture.

The analysis has also made clear that farm households do not necessarily invest in the continuation of farming, but may instead focus on increasing the opportunities of (young) household members to find non-farm employment. Non-farm employment thus has become an opportunity for diversification. However, non-farm employment may only pay slightly better than farming, fill the gap of a non-productive farming period, or absorb hidden unemployment within the agricultural sector. When non-farm employment is not very profitable or secure, as in most of Sub-Saharan Africa, people are not likely to give up their land. This means that it cannot be expected that the growing importance of non-farm employment will lead to a movement out of agriculture, an increase in land availability and/or the possibility for remaining farms to expand, as has happened in for instance Europe. One of the key elements is understanding the institutional setting in which households operate. Secure land ownership, allowing the emergence of land rental markets, for example, may facilitate a transition out of agriculture by providing an option to return to farming. Thus, what happens to the agricultural sector depends on the profitability of non-farm employment *and* on the institutional setting.

The results of our analyses highlight furthermore that no one-size-fits-all policy exists that provides a path out of poverty. Policies need to be targeted, based on geographical features (extended beyond agro-ecological zoning to include access to non-agricultural employment), and individual endowments (education, skills). This means that specific policy recommendations are required for each social group being targeted. It may well be that a specific group, although living in a peri-urban area and, thus, close to an urban centre in spatial terms, does not have access to opportunities due to social restrictions. The group is then, in practice, remote from these opportunities due to social barriers. The analysis of the data shows that this group may well consist of women, who have fewer opportunities for non-farm employment and who become the *de facto* farmers (i.e., managers of the agricultural enterprise). Social barriers include lower education levels, responsibilities for taking care of the household (thus, binding them to the farm), and/or cultural constraints (e.g., it not being acceptable that women travel alone).

Targeted policies need to be based on the recognition that rural economies are by no means homogenous and nor are rural households. Raising agricultural productivity has been an important objective for a long time, and will continue to be so in the future. However, this is not feasible, and may not even be desirable, everywhere. (Biophysically) high-potential areas should be identified, where intensive agriculture is possible and profitable, and increasing agricultural (land and/or labour) productivity in these areas should include a pro-poor growth strategy. At the same time, however, the reality of a rural economy in transition, towards one in which non-farm activities play a major role, should be accepted. Facilitating and stimulating profitable non-farm employment should be on the agenda of policymakers, for instance by supporting the informal sector. Policymakers need to formulate agricultural policies that are designed for a farming sector that is extensively managed, that serves as only one among many sources of income, and from which no high productivity gains, but foremost a stable supply of food and income is expected. The relevant focus is different groups of households and not so much the entire sector. Households are, by manner of speaking, the node in which the farm sector and non-farm sectors interact.

The analysis has raised some important issues, which link up with the renewed interest in non-farm activities. This interest has a long history. While many questions are still open, it is clear that non-farm activities constitute an important component of rural economies and therefore should be considered an integral part of analysis and policy aimed at sustainable rural development.

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APPENDIX: ECONOMETRIC RESULTS

Two sets of econometric analyses were carried out. The first examined the determinants of individual access to non-farm employment. The second concentrated on the possible effects of non-farm income on farm decision-making and natural resource management.

Access to non-farm employment

Table A1.1 presents the detailed results from the estimation of an ordered probit model with the extent of individual participation in non-farm employment as the dependent variable. This takes three possible values: 0 for absence of non-farm employment, 1 for some non-farm employment, and 2 for only non-farm employment. The table presents the coefficients for the various explanatory variables, as well as the marginal effects (together with standard errors) evaluated at the means of the explanatory variables, for each of the three possible values of the extent of non-farm employment. Various specifications of explanatory variables were evaluated, using information criteria tests (as described in Cameron and Trivedi 2005).

The principal results have been summarized in the main text of the chapter, in particular the increase in probability that an individual engages either part-time or full-time in non-farm employment associated with zones closer to urban centres. Note that the traditional zone is the benchmark and is, thus, not listed in Table A1.1. An additional point worth mentioning here is the marginal effect of location on the extent of non-farm employment. This is actually somewhat higher in the leakage to urban areas zone than in the new urban links. But the difference is modest and we concentrate attention on the comparison with the locally linked and traditional zones.

Use of external inputs by households and soil fertility management

Table A1.2 presents results of two simple lognormal regression models of farm management variables: use of variable inputs and the soil nitrogen balance. As with Table A1.1, the traditional zone is the benchmark. The main results are described in the text, as well as those of the more detailed analysis of fertilizer use, where the models are interpreted primarily from a descriptive perspective.

Table A1.1. *Ordered probit estimates of individual participation in non-farm employment*[a] *(standard error in parentheses)*

	Coefficient	Marginal effects[b]		
		No non-farm employment	Some non-farm employment	Only non-farm employment
	(1)	(2)	(3)	(4)
Zone[c]				
Locally linked	0.369*	–0.128***	0.045***	0.083***
	(0.191)	(0.017)	(0.015)	(0.031)
Leakage to urban areas	0.812***	–0.292***	0.086***	0.206***
	(0.176)	(0.012)	(0.022)	(0.027)
New urban links	0.720***	–0.259***	0.079***	0.180***
	(0.179)	(0.013)	(0.020)	(0.028)
Household characteristics				
Number of members	0.027*	–0.009*	0.003*	0.005
	(0.016)	(0.005)	(0.002)	(0.004)
Farm size (ha)	–0.053*	0.017*	–0.007*	–0.010*
	(0.028	(0.009)	(0.004)	(0.006)
Ratio land/members[d]	0.130	–0.042	0.017	0.026
	(0.142)	(0.046)	(0.018)	(0.029)
Individual characteristics				
Age	–0.006*	0.002*	–0.001*	–0.001*
	(0.004)	(0.001)	(0.0004)	(0.001)
Gender (F = 0; M =1)	0.446***	–0.144***	0.056***	0.088***
	(0.125)	(0.013)	(0.016)	(0.025)
Child (under 15)	–0.345*	0.104***	–0.044***	–0.060*
	(0.181)	(0.029)	(0.003)	(0.036)
Education: primary[e]	0.120	–0.040*	0.015	0.024
	(0.079)	(0.020)	(0.011)	(0.032)
Education: secondary[e]	0.459***	–0.160***	0.055***	0.106***
	(0.110)	(0.016)	(0.016)	(0.030)
Education: post-secondary[e]	0.626***	–0.232***	0.065***	0.166***
	(0.208)	(0.017)	(0.019)	(0.032)
Constant	–1.166***	n.a.	n.a.	n.a.
	(0.218)			

* Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level.

[a] An ordered probit model was fitted using maximum likelihood estimation. Number of observations = 1797. Log likelihood function = –1281. Covariance matrix was adjusted for clustering according to 30 villages.

[b] Marginal effects are evaluated at means of regressors.

[c] The ‘traditional’ zone is used as the benchmark.

[d] Ratio of land to household members is calculated as total hectares divided by total number of household members using an adjustment factor for children.

[e] For education level, ‘no (formal) education’ is used as the benchmark.

Table A1.2. *Estimates from Ordinary Least Squares (OLS) regressions of external input use and soil nutrient balance*[a] *(standard error in parentheses)*

	Variable input costs (log $ per ha) (1)		Soil nitrogen balance (log kg N per ha) (2)	
Zone[b]				
Locally linked	–1.672***	(0.373)	1.182	(0.798)
Leakage to urban areas	–2.906***	(0.497)	–0.824	(1.064)
New urban links	6.226***	(0.377)	3.759***	(0.883)
Household characteristics				
Non-farm income (amount $ '000)	0.006	(0.093)	0.015	(0.199)
Percentage of income from nonfarm employment	–0.002	(0.002)	0.006	(0.004)
Number of members	–0.042	(0.032)	0.133*	(0.068)
Number of individuals consuming	0.068	(0.060)	–0.001	(0.128)
Gender head (F = 0; M =1)	–0.082	(0.197)	0.250	(0.421)
Percentage women in household	0.301	(0.344)	0.028	(0.736)
Education head				
Primary	0.052	(0.172)	0.087	(0.369)
Secondary	0.173	(0.160)	0.449	(0.343)
Post-secondary	0.512**	(0.250)	0.082	(0.537)
Farm characteristics				
Labour available for farm	0.077	(0.057)	–0.142	(0.122)
Land area	–0.098*	(0.059)	0.106	(0.125)
Ratio of land area to number of individuals consuming	0.160	(0.188)	0.091	(0.402)
Square of land area	0.002	(0.001)	–0.003	(0.003)
Livestock units	0.003	(0.010)	0.041**	(0.020)
Fertilizer use (kg N per ha)			0.003**	(0.001)
Regional characteristics				
Price fertilizer	–1.220**	(0.487)	–0.014	(1.043)
Country				
Burkina Faso	3.674***	(0.422)	–1.575*	(0.904)
China	0.185	(0.220)	–0.437	(0.480)
Ethiopia	5.573***	(0.437)	0.079	(0.935)
Ghana	7.805***	(0.657)	–3.203**	(1.410)
Kenya	7.245***	(0.573)	–2.430**	(1.231)
Uganda	5.142***	(0.541)	–4.854***	(1.160)
Vietnam	benchmark		benchmark	

* Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level.

[a] Both equations are estimated with OLS using logarithms of dependent variables. For model of cost of external inputs, $R^2 = 0.61$, Number of observations = 379; Chi-squared statistic of LLR test = 361.92 (significant at 1% level, given 23 degrees of freedom). For model of soil nutrient balance, $R^2 = 0.68$, Number of observations = 379; Chi-squared statistic of LLR test = 440.47 (significant at 1% level, given 24 degrees of freedom).

[b] The 'traditional' zone is used as the benchmark.

CHAPTER 6

LESSONS LEARNED

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BACKGROUND

The research programme International Cooperation of the Agricultural Research Department (DLO-IC) of the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) was founded in 1998 with the aim to support agricultural and environmental research for development and strengthen North-South partnerships. The programme that embraced contributions from all five science groups of Wageningen University and Research centre (Wageningen UR) consisted of two phases (1998-2001 and 2002-2005). Within those eight years, about 70 multi-annual collaborative North-South projects were carried out under the umbrella of DLO-IC, of which about half were related to Rural Development and Sustainable Agriculture (RDSA). The remaining half was classified in the themes global food chains, agro-biodiversity, nature management, integrated water management and enabling policies (North-South Centre 2004).

The objective of this chapter is to summarize the results from the scientific, capacity-building and policy-oriented activities, draw major lessons and outline the way ahead on the basis of the experiences and new developments as outlined in previous chapters, and emerging opportunities. We will first reflect on ideas that

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shaped research approaches in agricultural and environmental sciences for development, then re-visit the objectives of the DLO-IC research programme between 1998 and 2005 (DLO 404) and, finally, provide a frame for assessing the programme's accomplishments and future challenges in the field of sustainable agriculture and rural development.

Detailed summaries of selected DLO-IC projects and inventories of lessons for each project are presented in Chapter 7 of this volume (De Jager et al. 2007).

UNCED Agenda 21 and Millennium Declaration 2000

The World Commission on Environment and Development, in its report 'Our Common Future' (WCED 1987), challenged policymakers and society (including the scientific community) by defining sustainable development as 'development that meets the needs of the present, without compromising the ability of future generations to meet their own needs'. This report marked an important shift, i.e., from raising awareness of global environmental problems to a focus on actions in support of the integration of environmental, economic and social imperatives – as underlined, subsequently, in the United Nations Conference on Environment and Development in Rio (UNCED) and its Agenda 21 (UN 1992). The second Club of Rome report 'No limits to learning: Bridging the human gap' (Botkin et al. 1979) stressed the existence of a gap between the task to deal with the growing complexity of the sustainable development challenge and the ability of societies to learn about it, respond to and cope with it (Leeuwis 2004; Van Paassen et al. 2007). Growing concerns about the lack of progress following Rio 1992, triggered establishment of the UN Millennium Project in 2000. In the project, eight goals (The Millenium Development Goals (MDGs; see Box 1)) and 18 specific targets to combat world poverty, hunger and environmental degradation, in support of sustainable development were formulated (www.millenniumproject.org). The eight goals address the world's main development challenges and have become an important guide for policy formulation and donor communities.

The debates that followed the Earth Summit at Rio, had a clear impact on (re)formulation of the objectives of the DLO-IC programme.

Objectives of the theme 'Rural Development and Sustainable Agriculture'

A major message from UNCED in Rio was the necessity to fully appreciate the interlinkage of environment and development. This insight had a clear impact on the first phase (1998-2001) of the DLO-IC programme which included a strong component on natural resource management and multi-functional land use, in addition to themes such as food security and policy research. The focus on natural resource management and interactions between agriculture and environment became even stronger and, factually, the overarching theme of the second phase (2002-2005). The theme 'Rural Development and Sustainable Agriculture' aimed at integrating research on natural resource management with research on poverty alleviation and evaluation of supportive agro-technology and policy options. Moreover, ample attention was paid to the information requirements of different end users. Stakeholders were involved in the research process.

Even though the MDGs and possible measures to reach these goals were formulated only recently, we will also use the MDGs to evaluate the DLO-IC programme. Of particular relevance to our theme are MDG 1: Eradicate extreme poverty and hunger, and MDG 7: Ensure environmental sustainability; and, more indirectly, MDG 4: Reduce child mortality, MDG 5: Improve maternal health, and MDG 8: Develop a global partnership for development (see Box 1). In that Box, also the specific targets that were dealt with are specified.

In most developing countries, agriculture is the main livelihood for more than 75% of the population. Therefore, the emphasis of DLO-IC on improving land productivity, (agricultural) land use and related policies and its approaches towards implementation of sustainable land use and rural development options, is a core activity and a meaningful entry point in reaching the MDGs.

The theme 'Rural Development and Sustainable Agriculture'

During its first phase, the theme covered 18 multi-annual collaborative projects and several supportive projects. In these projects, innovative scientific-technical methodologies were developed – as reflected in a large number of high-quality scientific publications and new research tools (such as NUTMON and LUPAS) upon which projects of the second phase could build (see below, and De Jager et al. 2007); the dialogue with beneficiaries of the research was initiated, which paved the way for

Box 1. *MDGs. Specific targets are given for MDGs relevant for RSDA (source: www.unmilleniumproject.org)*

MDG 1:	**Eradicate extreme poverty and hunger**
Target 1:	Halve, between 1990 and 2015, the proportion of people whose income is less than 1 US$ a day
Target 2:	Halve, between 1990 and 2015, the proportion of people who suffer from hunger
MDG 2:	**Achieve universal primary education**
MDG 3	**Promote gender equality and empower women**
MDG 4:	**Reduce child mortality**
Target 5:	Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate
MDG 5:	**Improve maternal health**
Target 6:	Reduce by three-quarters, between 1990 and 2015, the maternal mortality rate
MDG 6:	**Combat HIV/AIDS, malaria and other diseases**
MDG 7:	**Ensure environmental sustainability**
Target 9:	Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources
MDG 8:	**Develop a global partnership for development**
Target 18:	In cooperation with the private sector, make available the benefits of new technologies, especially information and communication

demand-oriented interdisciplinary research approaches, and important contributions were made to resolving technical problems and strengthening North-South partnerships. These first steps in modifying the approach to development-oriented research fully unfolded in the formulation of the second phase of the programme (2002-2005), in which participation and inter-disciplinarity, complemented by the required capacity building, became leading principles.

Table 1. *Overview of Theme 2 projects running in DLO-IC 404, period 2002-2005. Summary information on all projects is available at URL: http://www.north-south.nl/index.php/item/340)**

Project acronym	Project leader (current/initial)	Geo- and thematic focus	Period
NUTSAL	André de Jager (LEI)	Kenya, semi-arid lands, nutrient management; NUTMON	1998-2003
EPISODE	Siebe van Wijk (LEI)	Ethiopia, Kenya, China; land degradation and policies	1999-2002
EROCHINA	Coen Ritsema (Alterra)	Loess Plateau, China; soil erosion modelling	1998-2002
EroChinut	Coen Ritsema (Alterra)	Hilly purple region, Sichuan, China; erosion and policy analysis	2001-2004
PIMEA	Mary Mosugu (Alterra) Gerdien Meijerink (LEI)	Ethiopia; land management and policy analysis	2001-2003
INMASP	André de Jager (LEI)	East African Highlands; soil fertility; Farmer Field Schools	2001-2005
MAMAS	Paul van den Brink (Alterra)	Thailand, Sri Lanka; pesticide risk assessment	2000-2004
EROAHI	Rik van den Bosch (Alterra)/ Simone Verzandvoort-van Dijck (Alterra)	Kenya, Tanzania; Soil-water conservation; catchment approach	2000-2004
HIMALAYA	Erik van den Elsen (Alterra)	India, Pakistan, Nepal; deforestation and erosion	2001-2005
IRMLA	Reimund Roetter (Alterra)	China, Philippines, Vietnam; NRM and policy options; land use scenario studies	2001-2005
VEGSYS	Siebe van Wijk (LEI)	China, Vietnam; vegetables; tech-nologies for nutrients and pests	2001-2005
VINVAL	Simone Verzandvoort-van Dijck (Alterra)/ Kees van Diepen (Alterra)	Burkina Faso, Ghana; Inland valleys, land use change and management	2001-2005
RMO-Beijing	Reimund Roetter (Alterra)/ Kees van Diepen (Alterra)	China, Beijing municipality; NRM; water management and policy options	2002-2004
SEARUSYN	Ben Kamphuis (LEI)	China, Vietnam; Rural-urban horticulture (cont. former project China vegetables)	2002-2005
Conservation Agriculture	Ab Wanders (A&F)	South Africa, Zambia; tillage; technology options (cont. former project Sustainable production)	2003-2005

* In the mean-time, many of the project-specific websites have been moved and are, therefore, not given here; it is recommended to trace project information on the web by using a search engine.

During its second phase, under the theme 'Rural Development and Sustainable Agriculture' 15 multi-annual collaborative projects were supported (Table 1), of which three (EROCHINA, EPISODE and NUTSAL) continued from the first phase.

REVIEW OF PHASE 2 PROJECTS AND SPECIFIC LESSONS LEARNED

On the basis of an evaluation of the projects from phase 2, we aim at drawing lessons for future research. The evaluation proceeded in two steps. First, questionnaires (Appendix to this chapter provides a detailed structure) were completed by the project leaders, followed by a workshop, attended by representatives of the Ministry of LNV, project leaders and the project team, to formulate lessons, based on the completed questionnaires.

Evaluation of individual projects

Individual projects were evaluated on the basis of the completed questionnaires (presented in De Jager et al. 2007), and other available project documents and outputs. The four major criteria considered in the evaluation were: (1) scientific innovation, (2) quality of partnership, (3) capacity building and (4) policy relevance.

The completed questionnaires were assessed by two scientists involved in the programme and two external scientists.

(1) Scientific innovation

The DLO-IC projects contributed to scientific innovation in various ways:

- A substantial number of new tools has been produced and evaluated for integrating biophysical and socio-economic analyses in different agro-ecological zones; these form part of analytical frameworks for quantitative analyses of resource use options at farm, village, small watershed and district/provincial scales; examples include the extension of the NUTMON toolbox for nutrient monitoring and technical coefficient generators as developed in PIMEA, VINVAL and IRMLA for different bio-economic settings.
- Novel pathways of involving farmers and extension staff have been explored, making use of local knowledge, combined with formalized knowledge; this has resulted in participatory development of technologies for improved natural resource management (examples include EROAHI, VEGSYS and INMASP).
- Introduction of new approaches and tailoring associated tools to new environments, for instance, by combining farm and regional level analyses of land use options (e.g., IRMLA) or by including risk assessment in the analyses (e.g., MAMAS).

(2) Quality of partnership

In general, the scientific quality of the tasks performed by the research partners was considered very good. However, not in all projects the science networks could be expanded and/or the quality/mode of collaboration improved. This was partly because of limited financial resources and/or restricted project life times, but also donor preferences made it difficult to add or change partners in the course of execution of the projects. During this phase, major improvements have been observed in the quality of collaboration with local partners, both with farmers/farmer organizations and local planners and policymakers.

(3) Capacity building
Formal and informal training received considerable attention with positive results; successes were recorded in the field of institutional capacity building and collective learning (in some cases impressively fast), but these efforts were still too scattered and uncoordinated.

(4) Policy relevance
Work in the DLO-IC programme aims at two policy arenas, on the one hand the Ministry of Agriculture, Nature Management and Food Quality in The Netherlands, on the other hand national and local policymakers in the partner countries.

Tangible successes in this field are difficult to identify, as the programme was designed to aim at and emphasize successes in the science arena rather than in the policy arena. Moreover, the reviewers were scientists, with relatively limited expertise in the area of assessment of policy relevance. However, the tools and methods developed can serve as building blocks in syntheses supporting policy formulation on global issues as framed in the MDGs (see also Box 1) and reflected in global agreements and conventions (Table 2). Most projects generated information relevant for formulating/revising agricultural and environmental policies at sub-national level in the South. Only in a limited number of cases the work focused at the national level in partner countries.

Summarizing, most projects have followed a new integrated style, aiming at a more comprehensive analysis of land use systems at different scales. The research approach followed was to some extent interdisciplinary, characterized by substantial interaction of scientists with land users and policymakers. These developments expanded the role of scientists from knowledge contributors to trainers and facilitators

Table 2. *Examples of relevant international conventions and agreements*

Some relevant international initiatives, conventions and agreements related to RDSA:

- WSSD: World Summit on Sustainable Development
- MDG: Millennium Development Goals
- CBD: Convention on Biological Diversity
- UNFCCC: United Nations Framework Convention on Climate Change
- World Water Forum
- WTO: World Trade Organization
- Various commodity agreements
- International Treaty on Plant Genetic Resources for Food & Agriculture
- MA: Millennium Ecosystem Assessment

of stakeholder workshops. In some way, the extended tasks of scientists and their engagement in providing information at different stages of the land use policy cycle also came at a cost in terms of scientific output.

Evaluation workshop

In the workshop, to assess the projects dealing with rural development and sustainable agriculture in Africa and Asia, 12 scientists and 3 policymakers of the Ministry of Agriculture, Nature Management and Food Quality participated. The main criteria were based on the objectives and expected outputs of the theme 'Rural Development and Sustainable Agriculture' as formulated in the work programme at the start of phase 2 of the DLO-IC programme. The objectives formulated for this theme were:

- To research and develop sustainable intensified agricultural systems;
- To study farmers' decisions and their effects on the environment;
- To formulate promising policy measures that promote adoption of sustainable land use systems, based on local environmental conditions, aims and objectives.

The discussion was structured around the four expected outputs of this theme:

- Multi-stakeholder platforms established for each case study region;
- Biophysical potentials, resource use and environmental risk assessed for alternative technology options;
- Farmers' behaviour analysed and innovative farming systems designed;
- Decision support tools developed for land use scenario analysis to examine impact of technical and policy changes at farm and regional levels.

Multi-stakeholder platforms established for each case study region

Different forms of stakeholder participation were facilitated, i.e., stakeholders were involved at various stages during the research process:

- At the start, to support problem identification and definition of researchable issues;
- During data collection, processing and interpretation via input and exchange of knowledge. Stakeholders often are critical in obtaining relevant data and knowledge to resolve problems or transfer knowledge to farmers and resource managers;
- During the final phase to transfer knowledge and tools developed by the project to end users.

The case study-specific political and socio-cultural settings exerted considerable influence on the way stakeholder participation was realized. In Asia, differences among countries were observed in the intensity of interactions between scientists and stakeholders and in the proportion of non-government interest groups involved. For example, in the Philippines and Malaysia more intensive and more diverse groups were involved than in Vietnam and China. Similar experiences were reported from Africa, where the degree of decentralization appears to determine the availability of the means for and effective participation of different local stakeholder groups in the research process. In Uganda, a high degree of decentralization made effective participation possible, whereas in Kenya interaction between different groups and discussion of results could only be facilitated via policy workshops towards the end of the projects.

Successful participation of and interaction between stakeholders in the research process did, however, result in new research questions. These additional questions, however, were often beyond the scope of the ongoing project's objectives, resources and budget. Hence, fruitful interaction with stakeholders also leads to new and high expectations that often could not be satisfied.

For some projects, tension appeared between the interests of the Dutch Ministry and local stakeholders from the South. Especially in the project definition phase, interests of both stakeholders were not always in line. For instance, a project that initially aimed at analysing the trade-offs between economic and environmental goals for an agricultural region, re-focused its analysis through local stakeholder intervention to concentrate on socio-economic goals (such as production, employment and regional income).

One of the major lessons learned is that stakeholder identification and interaction require special attention. Therefore, in the inception phase of projects, sufficient means should be made available for investments in involvement of stakeholders.

Biophysical potential and environmental risk assessment

Most of the projects dealt with the interactions between agriculture and environment and were successful in creating and/or increasing awareness of farmers and local governments of environmental problems. Many projects examined the prospects for alternative production technologies to reduce soil nutrient depletion, soil loss and sedimentation, or ground- and surface water pollution by agro-chemicals. Economic aspects of implementing knowledge- and labour-intensive technologies were addressed in most studies.

In Asia, the focus was on fertilizer- and water-saving technologies. The projects, in general, concluded that substantial gains in nutrient- and water use efficiencies could be realized, especially through introduction of site-specific crop and soil management systems. A constraint for application of these technologies appears their higher labour requirements, in situations where labour productivity is already low, and farm households try to reduce farm labour to profit from non-farm and off-farm employment opportunities (Hengsdijk et al. 2005; Kuiper et al. 2007).

Very few studies have been conducted on the health risks for consumers associated with (excessive) pesticide application. There is still lack of sound analytical methods and skilled staff for this task. Studies that did look into the health risks for farmers revealed that farmers are often more aware of the risks than local governments and research institutions. The studies on biocide emissions (to soil, water and air) related to agricultural activities require further verification, experimentation and capacity building. Currently, often simple indices are generated and applied for assessments of environmental risks. These approaches need further support by experimentation and monitoring programmes. Lack of knowledge and skilled personnel at local food safety authorities that are responsible for regulating agro-chemical use are major bottle-necks for effectively preventing pollution and ensuring food safety. Policy relevance and enforcement of the projects in this field may be hampered by lack of cooperation with extension services and other agencies responsible for implementation of research findings. This experience indicates the need for a re-orientation of partnerships, as well as for institutional changes (e.g., to strengthen the generally weakened local extension services).

The projects, in general, paid limited attention to quantifying greenhouse gas emissions from agricultural activities and/or to identification of feasible technologies to reduce such emissions.

In Africa, soil nutrient depletion is widespread and a greater threat to sustainability than pollution problems related to excess use of fertilizers and herbicides. A wide range of improved technologies has been developed. Partly, these new technologies were the result of local initiatives that required further scientific support for refinement or infrastructure to become effective. Furthermore, many 'on-the-shelf' technologies, developed at research stations or through on-farm experiments with farmers, are only accessible to a relatively small group of farmers, because of insufficient capacity of local extension services.

Farmers' behaviour analysed and innovative farming systems designed

Analysis of farmers' behaviour shows that farmers are capable of adapting to local biophysical and socio-economic changes, but often lack access to external knowledge, preventing them to react adequately to rapid changes. To utilize both local and international knowledge, projects have increasingly attempted to combine research and extension work. Examples are participatory technology development and analysis of innovative farming practices, based on integration of agro-ecological and economic principles with empirical knowledge.

Again, the socio-political setting has a decisive influence on access to the means required to implement innovations. Such means are more likely available for products that can be traded nationally or internationally. In analysing the decision behaviour of farmers (e.g., whether or not to introduce a new technology), all activities of a household should be taken into account. Such an approach could be in conflict with a possible choice for a sector-specific approach, concentrating on a few sectors. For some regions that are dominated by specific sectors (e.g., horticulture; meat or dairy production) this may not be an important issue.

Linking research, extension and capacity building aimed at increasing the problem solving capacity and impact on society, requires a balanced mix of research and other activities.

Decision support tools developed and evaluated with stakeholders

The projects generated a variety of new software tools for analysing land use options at different scales (farm, village, district and province). Targeted end users of these tools are, in most cases, local research teams, planners or extension workers. In some cases, tools developed for scientists (e.g., an expert system for quantifying nutrient balances and optimizing fertilizer management; or regional land use optimization models) have been converted into simpler tools for use by extension workers (such as field guides) or have been supplemented by well-structured user interfaces that allow interactive use by planners and/or facilitate communication between scientists and other stakeholders.

The spectrum of applications has been wide. On the one hand, tools have been applied to illustrate resource requirements for realization of different sets of regional development goals and targets, conflicts between targets and resource availability, identification of technical constraints, trade-offs between different development goals and promising directions for interventions at farm or regional level. These applications have contributed to widening the perspectives of the different stakeholders on sustainable development. On the other hand, for scientists, these analyses, including their documentation, have improved skills to deal with complex problems in an interdisciplinary manner, and to identify knowledge gaps. For farmers, planners and other stakeholders it has increased insight into the economic and environmental consequences of different land use strategies and stimulated informed discussions on land use options among different interest groups. Introduction of new techniques (such as expert systems and GIS) and capacity building of National Agricultural Research Systems in using these tools have increased the demands of local planning authorities for their application in the local context. A very positive development has been the ample spill-over effects, reflected in the use of the tools in many national programmes.

Evaluation of expert systems and farm and regional land use analysis models and discussion of results with and by stakeholders has also resulted in a demand for a multi-scale approach to identify better and more feasible solutions. One of the gaps identified was insufficient attention for capacity building in understanding the concepts of new techniques and interpretation of results. Development of skills in these areas should be well-balanced with capacity building directed at transfer of technical skills. Furthermore, projects engaged in developing tools to support land use decisions require that a broad spectrum of expertise is represented to clearly delimit and communicate the capabilities of the tools and their limitations.

CONCLUSIONS

The following eight lessons for future research were extracted.

Lesson 1: Disciplinary science provides the basis

Initially, most activities were science-driven with a mono-disciplinary orientation. This was necessary to increase insight into underlying processes. It provided the basis for the various improved interdisciplinary research methods and tools needed for and useful in the design and evaluation of higher-scale systems in a considerable number of agro-ecological zones and for (future-oriented) scenario studies. It is important to continue strengthening the bases of disciplinary knowledge, while giving special attention to socio-economic research and its links with biophysical and technology-oriented research.

Lesson 2: Solutions and new insights require multi-disciplinary and multi-scale approaches

Multi-disciplinary, multi-scale research and integrated assessments that combine insights and knowledge from different disciplines and scales are needed to deal with the complexity of rural development and to support decision-making processes. This approach allows application of new insights in targeted problem-solving and has the potential to deliver solutions acceptable to the end user. Understanding scale-dependencies and linkages is essential for identifying successful policy and farm management strategies. Further development of both, up-scaling and down-scaling methodologies in the biophysical and socio-economic domains is urgently needed.

Lesson 3: Re-inforce focus on resource use efficiency

Substantial resource use efficiency gains are possible, especially for nutrients and water and to a less extent for labour, energy and capital. Efficiency gains have the potential to alleviate pressure on scarce resources, contribute positively to economic development and reduce the environmental impacts of agriculture, including emissions and loss of biodiversity. Possible trade-offs should be identified and analysed explicitly – such as the socio-cultural factors that constrain the adoption of new, more resource use-efficient technologies.

Lesson 4: Rural development is not equal to agricultural development

The importance of non-farm activities for the rural economy has largely been ignored. Non-farm income-generating activities are, however, key elements in the livelihood strategies of rural dwellers and are strongly linked to food security and the environmental impacts of agriculture. In addition to research on agricultural production, the research agenda for rural development should also consider non-farm activities, institutional arrangements that constrain or facilitate rural development and environmental services related to water, carbon and biodiversity.

Lesson 5: Crucial decision level: the farm household

Policies or technologies that are not consistent with the context in which farm households operate will have little impact. Farm households weigh competing claims on their land, labour and capital of different (agricultural and non-agricultural) activities in the light of their household objectives. These objectives and the portfolio of possible household activities need to be taken into account when designing policies or technologies.

Lesson 6: Agriculture and on-farm and off-farm biodiversity are tightly linked

Agronomists and environmentalists need to collaborate in taking local perspectives as the starting point for development of new biodiversity management programmes. Until now, lack of common understanding and lack of an operational framework have strongly hampered successful implementation of such programmes. Local improvement of germplasm can integrate and complement breeding activities in the public sector and contribute to conservation of agrobiodiversity and to rural development.

Lesson 7: Interaction is needed to increase impact

In addition to increasing interaction and integration between the different scientific disciplines, attention must also be given to strengthening interaction with stakeholder groups. Over time, participation and multi-disciplinarity, complemented by capacity building, have become leading principles in research projects, reflecting the insight that interaction with relevant stakeholders is an essential element in translating insight into impact. Multi-disciplinarity that evolves into inter-disciplinary research, thus, implies building upon the knowledge and experience of all relevant stakeholders (including young and old, men and women, rich and poor, etc.). This entails a joint learning process, in which the different groups of rural communities such as farmers, researchers, policymakers, traders, NGOs, and other local resource managers learn from and with each other within the context of the research project.

Lesson 8: Invest in involvement of stakeholders

Stakeholders' capacities, involvement and relevance depend on cultural, institutional and financial factors. Accurate identification and involvement of stakeholder groups is essential for effective research and policy implementation. Communication is a key element in this process. The identification and involvement of relevant stakeholders is not always easy, as the same cultural, institutional and financial factors may constrain some groups from actively participating (such as women, landless, minority ethnic or religious groups). Additional care and effort must be put into facilitating the involvement of these less vocal and powerful stakeholders.

THE WAY AHEAD

There are many challenges ahead for any research programme that aims at supporting rural development and sustainable agriculture. This is perhaps best underlined by the display of the world population clock, currently (May 2007) counting 6.59 billion people and the counter that shows the area of arable land (currently some 8.57 billion hectares[1]). About every 7 seconds, 1 ha of arable land is lost, and it is just six years ago that the world population clock surpassed the 6 billion.

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[1] www.irri.org (May 2007)

In the face of such huge challenges, commitment to tasks and concerted actions that aim at achieving the Millennium Development Goals on all fronts would be essential, but will depend, first of all, on the political will and support of governments.

With respect to food security, environmental issues and rural livelihood (Roetter and Van Keulen 2007; Verhagen et al. 2007; Kuiper et al. 2007), we have identified some specific knowledge gaps that have to be tackled in new research programmes on RDSA. Based on our review, we argue that agriculture plays three specific roles in future rural development strategies:

- A solid base for changing livelihoods;
- A producer of high quality affordable food; and
- A provider of environmental services.

Each of these roles has its own specific research requirements. Clearly, the three different roles for agriculture identified here are not mutually exclusive neither are they *per se* in conflict. They do, however, call for a clear identification of the dominant role of agriculture under local biophysical and socio-economic conditions and the tailoring of research to meet the associated specific requirements.

Agriculture as a solid base for a changing livelihood

In terms of agricultural research, one could focus on ensuring stable production, by providing technologies tailored to female-dominated agricultural households (since males tend to migrate first to urban areas), where possible generating surpluses that allow households to invest in profitable enterprises either within or outside the agricultural sector.

It will also be necessary to look at 'exit strategies' to enable households living in adverse biophysical and/or socio-economic settings to move out of agriculture. This may involve investments in education and infrastructure, allowing households access to alternative sources of income.

Agriculture as a sector producing high-quality affordable food

Biophysical improvements, particularly in the field of plant breeding and best agricultural practices, are required to increase crop yield potentials, close yield gaps, and increase resource-use efficiencies. That should be complemented by farmer-based strategies exploiting local capabilities to increase and diversify production and contribute to environmental sustainability. Land and labour productivity will be increased in this way and farm households will receive an economic incentive to produce food in an environmentally friendly way (conserving resource quality and protecting biodiversity) that is consistent with consumer demands, including local diversity.

Overcoming constraints that emanate from globalization and adverse economic environments requires additional policy research. Research on the scope for agricultural growth needs to be placed in the larger context of increasingly open economies, affecting local food markets, on the influence of the macro-economic environment as reflected in taxes and relative prices and on the impact that the internationalization of agricultural enterprises can be expected to have on 'rural economic structures'.

Possible implications of expected population growth and dietary changes for increased food and fodder production and associated claims on resources (such as arable land) should be assessed in relation to claims for non-food or non-agricultural use of resources. The demand for biofuels may in the near future become an important factor leading to fiercer competition for scarce resources.

Agriculture as a provider of environmental services

Most interesting perhaps, are the emerging opportunities to provide clean water and sequester carbon as environmental services through creating markets for such services (Perez et al. 2007). These new options go beyond the traditional approaches of conservation and the environmentally sound use of natural resources. Whereas the price of clean water can be negotiated between various stakeholders, specific institutional arrangements as well as political will are needed to turn a public good into a private, tradable good – such as in the case of creating a carbon market. Whether and how other services, such as soil protection, the conservation of biodiversity and landscapes and the encouragement of tourism can contribute to sustainable development pathways under different settings needs to be further investigated. Not much research has been done so far into the topic of which specific institutional arrangements are required to establish markets for environmental services. This also suggests that the scope of research needs to be widened to include important rural development issues rather than being restricted to agriculture.

Integrated rural development as the main stake

Research should aim to assess the future roles and potential of agriculture, forestry and other rural activities, as well as human capital in the sustainable development of rural areas. Such analyses should cover representative rural areas of the focal regions of the policy-support international research programme of the Ministry of LNV (BO Cluster International): in Sub-Saharan Africa, East and South-east Asia.

Relations between rural activities and ways to promote diversification, innovation and production of value-added products and (other industrial/urban) services should be explored.

Eventually, results from science for agriculture and development need to be integrated with those from non-agricultural disciplines. It is necessary to look at the role of health standards, educational standards by age and gender, and vocational training systems which are all important to the development of rural areas.

CONTOURS OF A NEW PROGRAMME ON RDSA

In the course of the review process of the second phase (2001-2005) of DLO-IC, various elements and contours for a new programme came to the fore. The Ministry of Agriculture, Nature Management and Food Quality has formulated a vision on such a new programme (LNV 2005). Suggested major shifts in priorities as compared to the previous programme include:

- Full integration of research and capacity building activities to better utilize and create synergies between main fields of expertise within Wageningen UR;
- A clearer indication of preferences and choices for those issues and sectors where the Netherlands can play a leading or pioneering role (such as the dairy, meat, horticulture and aquaculture sub-sectors);
- Expressing preferences clearer than in the past also implies that LNV will focus more on a few research areas – whereby choices are made more independently of other international fora/multi-lateral donors. This also has distinct implications in terms of co-financing (e.g., EU projects).

This vision focuses on impacts and links strongly related to national interests. Combining this policy-oriented vision with the science agenda is a challenge, but successful integration will strengthen both agendas.

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APPENDIX: STRUCTURE OF QUESTIONNAIRE

A) Project setting

1. What was the background and motivation of the project?
2. What was the institutional context (partners with which cooperated?)

B) Project objectives

1. What were the initial project objectives?

C) Project activities

1. Which activities were employed to meet the objectives?

D) General project outputs

1. What are the scientific contributions of the project (to RDSA methodology or more general scientific contributions)?
2. What are policy-relevant findings of the project for Dutch and for Southern policy-makers?
3. What are the outputs in terms of capacity-building and partnerships?

E) Tangible outputs, dissemination and impact

Can you describe for the (max. 10) key outputs of your project:

1. Type of output
2. Dissemination of output/results (examples of dissemination: papers + articles; policy briefs; policy workshops; scientific conferences and workshops; website)
3. Have your results been used, and if yes by whom, where and how?
4. What has been the benefit or impact (indicate evidence of impact, e.g. page hit count)?

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

1. Future research on Rural Development and Sustainable Agriculture
2. The role of research in generating policy-relevant information in support of LNV and other policy institutions
3. Partnerships and development efforts in the South
4. Interactions between research and decision makers, both in The Netherlands and the South

and:

5. Which insights were gained by employing a multi-disciplinary methodology that would have been missed by disciplinary research?

G) Unfinished business and future challenges

6. Which important things remain to be done that could not be achieved by the project?
7. Which important challenges in the area of RDSA in the tropics are there in the near future (say 5 to 10 years)?
8. What type of research could contribute to addressing these challenges?

H) For completed projects

1. What has happened since your DLO-IC project was completed?
2. Are there follow-up proposals developed and to whom are they submitted?

I) Additional information/remarks etc.

Please feel free to share with us any additional information, ideas and suggestions for the book.

CHAPTER 7

PROJECT ASSESSMENTS

A. DE JAGER[1], C. RITSEMA[2], M. MOSUGU[2], G. MEIJERINK[1], P. VAN DEN BRINK[2], H. VAN DEN BOSCH[2], E. VAN DEN ELSEN[2], R.P. ROETTER[2], S. VAN WIJK[1], S. VERZANDVOORT-VAN DIJCK[2], C.A. VAN DIEPEN[2] AND B. KAMPHUIS[1]

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During 2002-2005, 15 multi-annual collaborative projects under the theme 'Rural Development and Sustainable Agriculture' (Theme 2 of DLO-IC) were supported (see Chapter 6 of this volume). Out of these projects, 12 participated in a comprehensive assessment (Table 1). Individual projects were evaluated on the basis of the completed questionnaires presented in this chapter, and other available project documents and outputs. The four major criteria considered in the evaluation were: (1) scientific innovation, (2) quality of partnership, (3) capacity building and (4) policy relevance. The structure of the questionnaire is presented in the Appendix to Chapter 6 of this volume.

R.P. Roetter, H. Van Keulen, M. Kuiper, J. Verhagen and H.H. Van Laar (eds.), Science for Agriculture and Rural Development in Low-income Countries, 115–215.

Table 1. *Overview of the 12 'Theme 2' projects that participated in the project assessments. Summary information on all projects is available at URL: http://www.north-south.nl/index.php/item/340)**

Project acronym	Project leader (current/initial)	Geo- and thematic focus	Period
NUTSAL	André de Jager (LEI)	Kenya, semi-arid lands, nutrient management; NUTMON	1998-2003
EroChinut	Coen Ritsema (Alterra)	Hilly purple region, Sichuan, China; erosion and policy analysis	2001-2004
PIMEA	Mary Mosugu (Alterra) Gerdien Meijerink (LEI)	Ethiopia; land management and policy analysis	2001-2003
INMASP	André de Jager (LEI)	East African Highlands; soil fertility; Farmer Field Schools	2001-2005
MAMAS	Paul van den Brink (Alterra)	Thailand, Sri Lanka; pesticide risk assessment	2000-2004
EROAHI	Rik van den Bosch (Alterra)/Simone Verzandvoort-van Dijck (Alterra)	Kenya, Tanzania; soil-water conservation; catchment approach	2000-2004
HIMALAYA	Erik van den Elsen (Alterra)	India, Pakistan, Nepal; deforestation and erosion	2001-2005
IRMLA	Reimund Roetter (Alterra)	China, Philippines, Vietnam; NRM and policy options; land use scenario studies	2001-2005
VEGSYS	Siebe van Wijk (LEI)	China, Vietnam; vegetables; technologies for nutrients and pests	2001-2005
VINVAL	Simone Verzandvoort-van Dijck (Alterra)/ Kees Van Diepen (Alterra)	Burkina Faso, Ghana; Inland valleys, land use change and management	2001-2005
RMO-Beijing	Reimund Roetter (Alterra)/ Kees Van Diepen (Alterra)	China, Beijing municipality; NRM; water management and policy options	2002-2004
SEARUSYN	Ben Kamphuis (LEI)	China, Vietnam; Rural-urban horticulture (cont. former project China vegetables)	2002-2005

* In the mean-time, many of the project-specific websites have been moved and are, therefore, not given here; it is recommended to trace project information on the web by using a search engine.

NUTSAL*

Assessment and monitoring of nutrient flows and stocks and development of appropriate nutrient management strategies for arid and semi-arid areas in Kenya

A) Project setting

The rapid increase in Kenya's population has resulted in rural-urban migration and out-migration from the high potential to arid and semi-arid areas (ASAL) in search of new farmlands. The associated introduction of crop production technologies from high potential areas, including continuous cultivation of favourite crops, has proven unsuitable as it often results in low yields or complete crop failure, mainly because of unreliable rainfall, both in quantity and distribution. Moreover, the increased pressure on land necessitated intensification of land use, often without the necessary external inputs to sustain its productivity. Since soils in ASAL are fragile and low in fertility, and because of their sandy texture, susceptible to erosion and leaching, these developments have led to serious decline in soil fertility status and declining crop yields.

To address the problems in the ASAL the Kenyan Agricultural Research Institute (KARI) formulated the project 'Assessment and monitoring of nutrient flows and stocks to determine appropriate integrated nutrient management strategies for arid and semi-arid lands in Kenya'. This project was implemented in the period 1998-2003 and Wageningen UR was requested by KARI to participate.

B) Project objectives

The objective of the project was to design, test and implement, demonstrate and disseminate improved, integrated soil fertility and water management techniques and improved inorganic fertilizer and organic input recommendations for various land use zones, soil types, farming systems and farm types in ASAL through participatory efforts of scientists with all relevant stakeholders.

C) Project activities

The participatory NUTMON-methodology was applied. In the study, three major phases were distinguished (i) diagnosis and analysis of existing farm and nutrient management systems, (ii) participatory learning and action research, and (iii) stakeholder workshops. In the first two phases, six farmer groups, comprising 110 farm households in total, participated intensively in the research activities during the period 1999-2002. Based on earlier farming system research activities in the area,

* Questionnaire received 2006; Project leader A. De Jager (LEI)

six representative clusters were selected to cover the variation within the semi-arid areas in Kenya in terms of agro-ecological characteristics, population density and farming system. Within each cluster one representative village was selected and the participating farm households were selected during a participatory village ‘baraza’ (meeting) in each village.

The diagnostic phase was conducted in the period 2000-2001 and aimed at analysing current nutrient management, determining the magnitude and major sources of nutrient depletion, analysing financial performance, creating farm household awareness of nutrient management aspects and jointly with the farm household, arriving at a research and development agenda.

The participatory learning and action research was implemented in the period 2001-2002, covered on average two cropping seasons and combined various elements of participatory research methodologies. This included the following steps:

- Group formation
- Sensitization of farmers on soil fertility status
  Based on the results of the activities in the diagnostic phase, farmers’ meetings were organized to synthesize the information obtained (soil analysis results, nutrient flows and balances, financial results) and prioritize the major problems to be addressed.
- Identification and selection of technology options
  In a farmers’ meeting, technology options to address the prioritized problems were identified. The research teams adopted various modes of discussion: plenary, sub-groups, separate groups for men and women. The researchers also presented potential technology options during the meeting. All options were pooled without any order or priority. In a plenary discussion a priority ranking was made by the farmers through consensus or voting.
- Implementation of on-farm experiments
  Jointly with the farmers a research protocol was formulated, comprising a hypothesis, test crop, exact description of treatments, experimental layout, aspects to be monitored and/or measured, division of responsibilities between farmers and researchers. In general, a simple experimental layout was designed with 1 replicate per farm (with other group members implementing similar experiments serving as replicates), plot size varying between 25 and 100 m^2 and at most 4 treatments per experiment.
- Monitoring and data analysis
  Records were kept in accordance with the research protocol. Researchers measured aspects such as nutrient contents of manure, plant density and yield. Farmers monitored a variety of factors such as date of planting, date of manure application, emergence date, plant vigour, colour, weed, pest and disease incidence, prices of inputs and outputs, etc. In many cases farmers were given record books to monitor their observations. Unfortunately, no structured recording and analysis of these farmers’ observations through techniques such as matrix ranking or scoring was conducted.

- Joint researchers and farmers evaluation
  During implementation of the experiments, field days were organized, attended by farmers participating in the project, neighbouring farmers, extension staff and local leaders, enabling farmers to share their results and experiences with the community. In a joint meeting of farmers and researchers the experimental results were discussed and evaluated, using criteria such as crop yields, partial plot-level nutrient balances, nutrient use efficiencies, partial gross margins and value cost ratios.

Two consultative stakeholder' workshops were organized in 2002 and 2003 to brief major stakeholders and policymakers on project activities and results, and to formulate recommendations and action plans to address the problems in the ASAL in Kenya.

The study area comprised parts of Machakos, Mwingi, Makueni and Kajiado Districts. The region is characterized by low, temporally highly variable rainfall, varying on average from 600 to 800 mm annually, bi-modally distributed, and resulting in two distinct growing seasons.

The soils are variable in depth, depending on parent material and slope, and are generally low in organic matter and deficient in nitrogen and phosphorus, whereas potassium levels are generally adequate except in Makueni. Low infiltration rates and susceptibility to surface sealing make the soils vulnerable to erosion at the beginning of the season when the land is bare. Major characteristics of the clusters are summarized in Table 1.

D) General project outputs

Soil characteristics

Most farms show soil-N values below and soil-P values above an adequate soil fertility threshold level. Moreover, the variability among farms is much higher for P than for N. Soil potassium levels are, with the exception of those in Kasikeu, well above the threshold on most farms in the research clusters. Organic carbon levels in the soil are again variable and on the majority of the farms well below the level considered 'adequate' from an agronomic point of view.

Soil nutrient management

Current soil fertility management practices in the farming systems in the semi-arid areas in Kenya result in slightly negative nutrient balances (Table 2). The losses, however, represent only a very small proportion of the total soil nutrient stocks, especially for phosphorus and potassium.

Nutrient flows into and out of the farm are generally low (all clusters represent low external input agricultural systems), but considerable variability exists among the studied research clusters. Use of mineral fertilizers and import of organic materials (animal feeds) correlated positively and significantly with crop yields, financial returns and degree of market-orientation of the farm (marketed proportion of crop products and distance to market). This indicates that because of the relatively high

Table 1. *Major characteristics of the farming systems in the research clusters*

	Matuu	Kasikeu	Kibwezi	Kionyweni	Kiomo	Enchorica
Farm households selected (no.)	28	19	17	26	13	8
Farming system characterization	rainfed + irrigated farming local cattle, maize, beans, sorghum	rainfed farming maize, pigeon pea, beans, cowpea	rainfed + irrigated farming, pigeon pea, cowpea, sorghum	rainfed farming cross-bred cattle, maize, beans, fruit trees	rainfed farming maize, beans, sorghum, millet, pigeon pea	rainfed farming free ranging cattle, maize, beans
Average annual rainfall (mm)	600	700	560	600	600	500
Population density	High	High	High	High	Low	Low
Soils	Alfisols Acrisols	Ferralsols	Alfisols	Alfisols Acrisols	Alfisols	Vertisols Alfisols
Average area per farm (ha)	1.5	2.8	3.5	2.3	6.7	51.6
Cultivated area per farm (ha)	1.3	1.6	1.7	1.7	3.4	1.0
Livestock per farm (TLU[1])	6.1	5.2	0.8	6.2	6.8	28.4
Distance to market (km)	8.4	1.2	1.5	5.4	3.5	35.6
Female-headed households (%)	0	16	6	19	15	13

1 TLU is a Tropical Livestock Unit, a hypothetical animal of 250 kg live weight, used to bring different animal types under the same denominator.

Table 2. *Average farm level soil nutrient stocks (topsoil 30 cm) and flows in the research clusters in the period 2000-2001*

	Matuu	Kasikeu	Kibwezi	Kionyweni	Kiomo	Enchorica
N-stock (kg ha^{-1})	3016	6857	4077	1828	3596	2770
Net N-flow (kg ha^{-1} yr^{-1})	–14	–15	–7	–1	–4	–8
N-flow (% stock yr^{-1})	–0.5	–0.2	–0.2	–0.1	–0.1	–0.3
P-stock (kg ha^{-1})	3825	449	1797	7211	1403	5865
Net P-flow (kg ha^{-1} yr^{-1})	–1	2	0	–4	0	–2
P-flow (% stock yr^{-1})	0.0	+0.4	0.0	–0.1	0.0	0.0
K-stock (kg ha^{-1})	6931	6115	11866	15563	9151	15709
Net K-flow (kg ha^{-1} yr^{-1})	–14	0	–4	–1	–1	–3
K-flow (% stock yr^{-1})	–0.2	0.0	0.0	0.0	0.0	0.0

price of fertilizers and the high risks of crop failure in the rainfed systems, use of mineral fertilizers is restricted to the market-oriented farms with access to irrigation facilities.

Financial performance

Average net farm income levels were low, resulting in 35-85% of the farm households living below the poverty line, depending on research location. Labour productivity is low, especially in the subsistence-oriented farming systems. Off-farm income played an important role in the total family earnings in Kasikeu, Kibwezi and Kiomo with contributions to family income of over 60%. In the more remote locations, opportunities for off-farm income were very limited. Net farm income levels were higher in the partially intensive, more market-oriented farming systems in Matuu and Kasikeu.

Participatory learning and action research

The farmers' groups decided to focus the experiments on various application levels and combinations of farmyard manure and types of mineral fertilizers on the most common crop in the area (Table 3).

The results show that the erratic rainfall conditions in these semi-arid areas seriously hamper design and implementation of appropriate soil fertility management techniques at farm level. The results in Matuu, comparing irrigated and rainfed maize, show that incentives, in terms of financial returns, for application of manures and fertilizers dramatically increase when water availability is not constraining. The experimental results also show that the negative nutrient balances, prevailing in the rainfed farming systems can be remedied by application of higher levels of FYM and/or mineral fertilizers. Combinations of FYM and fertilizer tend to give better yield responses than application of FYM or fertilizers alone.

The financial returns to fertilizer and manure application are low and almost all treatments in the rainfed crops show Value-Costs Ratios (VCRs) below 2. Thus, under the prevailing conditions in semi-arid Kenya, it is financially unattractive and risky to apply these higher levels of nutrients, despite the positive impact on yields and nutrient balances. The combinations of FYM and fertilizers appear to give better financial returns than either of the two alone. The most appropriate strategy in terms of application of fertilizers and FYM for a farmer in a given situation depends among others on cash and manure availability. However, FYM application levels as in the experimentation are not feasible, because of lack of good quality manure. Labour may also be a serious constraint, especially when alternative (for instance off-farm) activities provide higher returns. The unfavourable price ratio between inputs and outputs also seriously constrains the adoption of nutrient adding technologies in the semi-arid areas. Even moderate reductions in fertilizer prices, for instance through reduced transaction costs and/or increased chain efficiency could result in significantly higher VCRs, rendering application of fertilizers much more attractive to farmers in semi-arid areas.

Table 3. *Impact of application of various combinations of organic and mineral fertilizers to different crops on yield, gross margin, partial N-balance, N-use efficiency (Nout/Nin) and Value-Cost Ratio (VCR) in five research clusters (average of two growing seasons in the period 2001-2002)*

Research site, test crop (number of plots)	Technology tested	Yield (kg ha^{-1})	Gross margin (KSh × 1000 ha^{-1})	Partial N-balance (kg ha^{-1} season^{-1})	Nout/ Nin	VCR
Matuu, irrigated, maize (n=11)	Farmers' practice	2416	24.1	–144	-	-
	5 t/ha FYM *	1978	17.3	–98	3.96	–1.75
	130 kg/ha DAP + 135 kg/ha CAN	2988	23.3	–93	2.55	0.87
	5 t/ha FYM + 135 kg/ha CAN	2634	20.9	–72	2.00	0.40
	5 t/ha FYM + 135kg/ha DAP + 135 kg/ha CAN	3500	25.9	–60	1.64	1.19
Matuu, rainfed, maize, (n=7)	Farmers' practice	813	8.1	–49	-	-
	5 t/ha FYM	613	3.6	–27	3.96	–0.80
	130 kg/ha DAP + 135 kg/ha CAN	1263	6.0	–7	2.55	0.68
	5 t/ha FYM + 135 kg/ha CAN	943	4.0	7	2.00	0.24
	5 t/ha FYM + 135kg/ha DAP + 135 kg/ha CAN	1475	5.6	23	1.64	0.73
Kionyweni, rainfed, maize/ cowpea (n=11)	Farmers'practice	1173	14.3	–48	-	-
	No inputs	1340	16.3	–54	-	-
	5 t/ha FYM + 42 kg/ha CAN	1807	18.6	–27	1.63	1.68
	20 t/ha FYM	1900	13.4	57	0.57	0.72
	40 t/ha FYM	2352	8.4	175	0.35	0.61
Kasikeu, rainfed, maize (n=5)	Farmers' practice (0 input)	1260	12.6	–27	-	-
	20 ton/ha FYM	1909	14.1	27	0.61	1.29
	40 ton/ha FYM	2736	17.3	153	0.43	1.48
Kiomo, rainfed, maize (n=5)	Farmers' practice (0 input)	500	5.0	–10	-	-
	100 kg/ha 20/20/0	450	1.5	11	0.45	–0.16
	200 kg/ha 20/20/0	502	–1.0	29	0.28	0.00
	Farmers practice (6 ton/ha FYM)	489	3.4	10	0.50	-
	20 ton/ha FYM	663	1.7	53	0.19	0.45
	40 ton/ha FYM	880	–2.5	116	0.13	0.45
Kibwezi, irrigated, onions (n=3)	Farmers' practice (5 ton/ha FYM)	813	–25.0	10	n.a.	-
	5 ton/ha FYM + 100 kg/ha 20/20/0	1027	–23.7	23		1.43
	5 ton/ha FYM + 200 kg/ha 20/20/0	1345	–20.3	32		1.78
	5 ton/ha FYM + 300 kg/ha 20/20/0	3046	10.6	–6		4.96

* FYM = Farm yard manure; DAP = Di-ammonium phosphate; CAN = Calcium ammonium nitrate; Ksh = Kenyan shilling.

Stakeholders' consultations

During the two stakeholders' consultations, the results of the diagnostic and PLAR activities in the project were combined with the experiences, goals and aspirations of the major stakeholders in the ASAL to arrive at a set of research and development orientations (Table 4).

Table 4. *Research and development priorities, identified during stakeholders' consultations*

System characterization	Rainfed; Low population density	Rainfed; High population density	Irrigated systems
Clusters	Enchorica, Kiomo	Kionyweni, Kasikeu	Kibwezi, Matuu
Short-term measures	• Control livestock numbers • Improve animal health care • Increase local food production through water harvesting, use of manure and rotation	• Breeding and using improved cattle • Mono-cropping maize and dual purpose legumes • Application of Rock Phosphate • Efficient nutrient recycling through crop residues and manure	• Maintenance and management of small-scale irrigation systems • Reduce transaction costs: market information, physical infrastructure, marketing channels, cooperatives, micro-finance
Long-term measures	• Design of development plan for livestock-wildlife-tourist industry • Establishment of feed-lots for high intensity beef production • Establishment of manure processing facilities • Infrastructure: feed grains and processed manure transport, marketing infrastructure for meat • Ecological niche market development	• Introduction dairy breeds • Import of feed grains from high potential areas • Cultivation of mono-cultures of maize and grain legumes • Cultivation of forage legumes • Efficient manure management • Establishment milk marketing system • Infrastructure for transport of feed grains	• Establishment of effective production-marketing chain in public-private partnership • Development of skills for all links in chain (production, quality control, transport, marketing)

Conclusions

Following some adaptations to deal with the specific characteristics of farming systems in the ASALs, the NUTMON methodology appeared an efficient tool for quantification of nutrient balances and financial performance at both farm and activity (plot) level in the arid and semi-arid areas of Kenya. An advantage is its ability to estimate hard-to-quantify flows of nutrients, which contribute to high nutrient losses from the farms. The participatory approach followed increased awareness and insight among farm households with respect to soil nutrient flows, nutrient deficiencies and nutrient depletion. On this basis, the constraints and potentials for improving the situation were identified.

Results indicate that in general the soils in the region are of poor quality and low in total nitrogen (N) and organic carbon (C). Monitoring for two seasons indicated that low and erratic rainfall in the semi-arid zone of Kenya is a major constraint to crop production. The natural resources are degrading as a result of slightly negative soil nutrient balances, associated with soil erosion, volatilization and leaching, resulting in declining soil fertility status and reduced vegetative cover. Smallholder farming families are under increasing pressure, due to low and declining incomes from agricultural activities, requiring income supplementation from off-farm activities, which leads to labour scarcity on the farm. Introduction of more sustainable production technologies, including soil and water conservation practices and more efficient crop residue and manure management practices, is labour-demanding and conflicts therefore with income-generation.

The experimental results show that in the common rainfed farming systems the problems of low yields and negative nutrient balances could be addressed by application of higher doses of FYM and/or fertilizers. However, the financial returns to fertilizer and manure application are low, which makes application of these higher doses unattractive and risky under these conditions, despite the positive impact on yields and nutrient balances.

Combinations of FYM and chemical fertilizers appear to give better financial returns than either component alone. Where conditions are better, as in the case of irrigated vegetable production, where water and marketing constraints are alleviated, farmers immediately respond by changing farm management practices, including higher doses of mineral and organic fertilizers, resulting in higher and more stable yields and higher financial returns. It is, therefore, obvious that water harvesting techniques and increase in and improvement of simple small-scale irrigation systems are key issues in effectively addressing soil fertility management in the semi-arid areas.

The farming community in this area is at a high risk to become trapped in a downward poverty cycle that may force them eventually to out-migrate from these marginal rural areas, leaving a degraded and without interventions, further deteriorating landscape and increasing pressure on other already densely populated rural and urban areas. To break this negative spiral a number of specific policy measures are suggested to be put in place:

- an active and coherent national agricultural policy is required, aiming at protection of the weak agricultural sector in the semi-arid areas of Kenya from the world market (price policies, import tariffs, export subsidies, etc.);
- local and national policymakers should initiate and support development of production chains for a number of potentially commercially attractive products (horticultural products, beef, milk, legume grains);
- private sector investment should be stimulated through premiums and tax incentives;
- targeted research, development and extension activities should be supported;
- micro-financing institutions should be established, preferably linked to chain- and community-based organizations and initiatives.

Such measures will lead to a much wider range of financially attractive technology options for implementation by smallholders. This is expected to result in more sustainable natural resource management practices and improved livelihoods in the semi-arid areas.

E) Tangible outputs, dissemination and impact

Can you describe for the (max. 10) key outputs of your project:

The project resulted in a policy-brief which was presented to a group of member of parliament, a KARI technical bulletin to be used by the extension service, 5 papers published and submitted to regional and international scientific journals and 7 presentations at national and international conferences.

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

This is an example of a project which is formulated entirely by the research and policymakers in Kenya. Wageningen UR was hired for its expertise and experience in natural resources management. Compared to most other projects influence of Wageningen UR research staff on the research planning and process was limited. This has resulted in some problems concerning the quality of the research process, but the high level of ownership guaranteed a wide dissemination and use of the project results. Researchers and policymakers evaluated the North-South cooperation in the project in general very positively.

The technical orientation of the majority of the KARI staff and management, limited the impact of the results at policy levels. In first instance KARI refused to issue an extension bulletin since no concrete potential technical solutions were presented for the semi-arid lands.

The project builds upon a long-standing relationship between KARI and Wageningen UR (see Box 2 in Roetter and Van Keulen, this volume). This facilitated a smooth implementation of the project at implementation and management level. A number of joint follow-up projects were initiated as a result of this project.

EROCHINUT*

An interdisciplinary approach to reduce water, soil and nutrient losses by erosion in the agricultural hilly purple area, Sichuan province, China by combined use of participatory and modelling techniques

A) Project setting

1) What was the background and motivation of the project?

China's agricultural policy formulated in the ninth Five Year Plan (1996-2000) and the 2010 long-term planning goals aimed at a steady annual growth of agricultural production and farmer income (Ministry of Agriculture, 1996). The commitment of the Chinese government to maintain over 95% self-sufficiency in grain production, to avoid dependency on international markets for their long-term food security, puts even more emphasis on the increase of production. The Hilly Purple area of the Sichuan Basin, in which the project is situated, is one of the most important agricultural areas in Western China. This area has been degraded by constant soil erosion, which has reached 3.035 t km^{-2} in 2004. Soil erosion has direct negative effects on the productivity of the land by loss of nutrients, water and soil. This loss of productivity directly affects the farmers' income, because more inputs are necessary to counteract these processes and to maintain long-term food production. Another adverse effect is that the soil and nutrient losses are transported to the Yangtze river, upstream of the newly build Three Gorges dam. At present, China faces a transition from organic fertilizers to mineral ones. The replacement of the organic fertilizers will lead to a further deterioration of the physical soil structure, and erosion and runoff are expected to increase during the coming years. With the strong emphasis in China on the increase of production and the efforts of the government to keep the market prices of fertilizers as low as possible, fertilizer use is expected to grow continuously. This might lead to even higher losses of nutrients by runoff and erosion. The government of the P.R. of China recognizes the problem of soil erosion and promotes a comprehensive approach to control erosion. However, there is no proper tool to plan and evaluate the effects of changed management practices.

2) What was the institutional context (partners with which cooperated?)

The research partners were IIED, England; SUAS, Sweden; SFI, Chengdu, China; ISWC, Yangling, China; ISSAS, Nanjing, China. The project was coordinated by Alterra. The project is funded by the EU through the INCO-dev programme and the

* Questionnaire received 2006, revised May 2007; Project leader C. Ritsema (Alterra)

Dutch Ministry of Agriculture, Nature and Food Quality through the 'North-South' programme.

B) Project objectives

1) What were the initial project objectives?

- Standardization of the methods of collection, storage and conservation of runoff and sediment samples to obtain reliable and reproducible data.
- Comparison of the quality of nutrient measurement data of a national laboratory with international standards, to guarantee a sufficient degree of accurateness.
- Quantification of the loss of soil, water and nutrients at the watershed level and collection of the necessary soil, meteorological, topographical and land use variables, which will form the basic input of the model.
- Extension of an existing state of the art soil erosion model with a submodel capable of predicting the transport of nutrients at the watershed level.
- Calibration and validation of the extended model for the conditions met in the Hilly Purple Area of the Sichuan province in China.
- Description of institutions, regulations, policies and factors influencing farm management practices related to soil, water and nutrient management at the farm and watershed level.
- Development of a methodology to combine participatory approaches with the use of the extended model.
- To arrive at acceptable solutions to reduce soil, water and nutrient losses using the developed work plan.

2) Have there been any (major) changes to these objectives and for what reason?

No

C) Project activities

1) Which activities were employed to meet the objectives?

- Standardization of nutrient erosion measurements in the study area in China and development of a methodology to measure nutrient losses at the watershed level.
- Field survey to measure relevant watershed variables needed for model input and to quantify the current soil, water and nutrient losses in the selected watershed in the Hilly Purple area.
- Extension of the physically-based soil erosion and hydrological model LISEM with a robust nutrient routine.
- Determination of management constraints on both farm and watershed level and development of possible alternative land use and soil and water conservation measures, including preparation of LISEM input parameters.

- Calibration and validation of the extended LISEM model for the conditions met in the Sichuan province, China.
- Integrated farm and watershed management process to optimize land use and soil and water conservation measures via an iterative use of the validated model and participation of all actors involved in the watershed.

2) Can you identify disciplinary and multi-disciplinary activities?

The experiences of large-scale participatory watershed development programs in Asia and elsewhere have shown clear and positive economic, environmental and social effects. Economic impacts include increased demand for rural labour, as well as substantial increases in crop and livestock production and diversity. Among the environmental impacts are reduced land degradation (e.g., erosion, salinity, water-logging, etc.) and increased surface and groundwater supplies for domestic and agricultural uses impacts. Social impacts include increased capacity and cohesion of local organizations and communities and the transformation of inflexible bureaucracies into more people-centred learning organizations. Physically-based erosion models can be used to evaluate the combined effect of different conservation measures and changes in land use on soil erosion at the catchment level. Most of the nutrient and erosion studies in China have been mainly limited to field scale experiments and descriptions. The main focus of the EroChinut project was to develop a new methodology to improve land and water management on farm and watershed level in the current socio-economic situation by integrated use of participatory and soil erosion and nutrient modelling techniques. The major goal of the participatory work was to develop a methodology to combine participatory approaches with the use of the adapted model and derive acceptable solutions to reduce soil, water and nutrient losses in the area under consideration. The determination of the management constraints was done with a participatory rural appraisal, with special attention to soil, water and soil fertility management. This included labour, financial situation, knowledge level and off farm factors, which influence the decision-making processes of the farm households. Stakeholder Analysis techniques were identified and assisted in understanding relationships between key stakeholders and other interest groups. In this way a complete picture of all actors in a watershed was accomplished, which formed the boundary conditions for the decision-making processes. With this information, different land use scenarios were developed.

D) General project outputs

1) What are the scientific contributions of the project (to RDSA methodology or more general scientific contributions)?

The major output of the project is the exchange of knowledge, methodology and expertise between the different partners. This close co-operation stimulated the input of each partner, reflecting in the scientific valuable results and the socio-economic guidelines in how to achieve this result. Other outputs are:

- Farming system analysis of the Hilly Purple Area, Sichuan Province.
- Socio-economic facts of farmer communities in small agricultural catchments.
- An extension of the LISEM model with a nutrient module, and calibration for comparable areas.
- A number of land use scenarios defined by different target groups all with their own interests.
- Cost analysis of the alternative land uses.
- Several MSc students who were able to finish their thesis due to the EroChinut project.

Land use alternatives were derived by taking into account: (i) the current land use, (ii) farmers view on future land use, (iii) politicians view on future land use, (iv) management optimization of the current land use and (v) biophysical optimization of the area. The farmers identified a land use pattern for 2005 they think is profitable. The policymakers, i.e., the county level policymakers, defined an expected land use pattern in 2005 based on the economical effects for the county. Finally, the researchers in the project defined a land use pattern with most expected effects on reduction of discharge and soil and nutrient losses. The latter was split in two, one scenario used the current land use as the starting point and introduced land management aspects as the use of ridges, contour ploughing etc. The other scenario was a change of land use based on slope classes. Here, cropland was allowed on slopes between 0°-15°, on slopes between 15°-25° orchard was used and on the slopes >25° forest. The alternatives were compared on their effect on water, soil and nutrient losses using the extended, calibrated LISEM model, and on their effects on the regional economical situation. It proved that the biophysical optimization reduced discharge, soil loss and nutrient losses most effectively. However, this scenario also reduced the economical situation of the area considerable.

2) What are the outputs in terms of capacity-building and partnerships?

Capacity building

- The overall project included the exchange of students between Wageningen University and the Chinese partners.
- The extended LISEM model (software), data and results were shared between the partners.
- Workshops with policymakers, farmers association and other key stakeholders were held throughout the project. In these workshops, results from the project were discussed, which enhanced learning by all parties.

Partnerships

An ongoing collaboration between ISWC, SUAS, SFI and ISSAS is established. This has resulted in defining and conducting new projects (e.g., VEGSYS) and publishing joint papers.

E) Tangible outputs, dissemination and impact

Can you describe for the (max. 10) key outputs of your project:

1) Type of output

- Reports (MSc Thesis, annual reports, final project report)
- Scientific papers

2) Dissemination of output/results (examples of dissemination: papers + articles; policy briefs; policy workshops; scientific conferences and workshops; website)

- Website of the project (www.erochinut.alterra.nl)
- Final workshop held in Beijing at the ISCO conference
- List of articles, partly foreseen in a special issue of the project.

Li, X.W., X.Z. Shi, Z.H. Cao, K. Blombäck and C.J. Ritsema, 2002. Precise survey and mapping of soil properties for a catchment of purple soils in Sichuan Province, China. Soil Science, *In Chinese.*

Li, X.W., X.Z. Shi, Z.H. Cao, K. Blombäck and C.J. Ritsema, 2002. Measurement and modeling of soil water holding features curves of purple soils in Sichuan Province, China. Bulletin of Soil Science, *In Chinese.*

Wang, H.J., J.L. Yang, X.W. Li, X.Z. Shi, Z.H. Cao, K. Blombäck and C.J. Ritsema, 2002. Soil nutrients loss in three catchments of purple soil region in Sichuan Province, China. Bulletin of Soil Science, *In Chinese.*

Chen, Y. and C. Lin, 2001. Study on the methodology of crop parameter measurement for soil erosion modeling. Southwest Journal of Agricultural Sciences 14.

Blombäck, K., V. Jetten, J. Stolte, A. Lindahl and S. Ledin. Discharge, sediment and nutrients losses from the Ziyang catchment. I: Extension of the erosion model LISEM to include multiple textural classes and transport of N and P.

Stolte, J., K. Blombäck, V. Jetten, H.G.M. van den Elsen, X. Shi and Y. Chen. Discharge, sediment and nutrients losses from the Ziyang Catchment. II: Application of the extended LISEM model.

Chen, Y., C. Lin and J. Zhang. The Xiangshui watershed, an upstream area of the Yangtze river: Biophysical characteristics, land use and management, and hydrological implications.

Cui, L., Z. Li, B. Wang and Y. Chen. The dynamic variation character of soil moisture of different land use types in Purple Hilly area.

Niu, D., S. Zhang and Z. Nancy, 2001. Study on Sichuan water and soil management Agencies.

Van Wijk, M.S., J. Vlaming, J. Thompson, C. Yibing and L. Choawen, 2002. Participative land use scenario development and impact analysis, EroChinut mission report.

3) Have your results been used, and if yes by whom, where and how?

The extended LISEM model is in use by many projects, and is made available through the LISEM website.

4) What has been the benefit or impact (indicate evidence of impact, e.g., page hit count)?

The project website got so far 1357 hits (May 2007), with last 10 visits from USA, Germany, China and Finland.

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

1) Future research on Rural Development and Sustainable Agriculture

To develop optimal conservation measures, aiming at reducing soil, water and nutrient losses, technical as well as socio-economic information is needed. By involving farmers and policymakers in the process of future land use planning, optimal solution can be found.

2) The role of research in generating policy-relevant information in support of LNV and other policy institutions

Research questions should closely be aligned to the priorities and interests of policymakers. Research results can, if presented correctly, be a good reflection of the impact of foreseen policy by policymakers. There must be a good interaction between policy and research in planning studies.

3) Partnerships and development efforts in the South

The major benefit of this specific project is the exchange of knowledge, methodology and expertise between the different partners. This close cooperation stimulated the input of each partner, reflecting in the scientific valuable results and the socio-economic guidelines in how to achieve this result. Such cooperation between institutions and organizations in target countries and European institutions, and Wageningen UR in specific, is essential to come to a sound project result.

4) Interactions between research and decision makers, both in The Netherlands and the South

As stated before, research results can, if presented correctly, be a good reflection of the impact of foreseen policy by policymakers.

5) Which insights were gained by employing a multi-disciplinary methodology that would have been missed by disciplinary research?

Solutions for combating the erosion problem in the Hilly Purple area can be found by changing, amongst others, the current land use in dependence of slope steepness (disciplinary result). This has negative consequences for the income of the farmers (multi-disciplinary result). These negative consequences must be solved before implementation of land use strategies can be successful.

G) Unfinished business and future challenges

1) Which important things remain to be done that could not be achieved by the project?

The main issue still to be done is presenting the project results for a scientific audience. For this purpose, a special issue of the journal Soil and Tillage research has been prepared, and will be released soon.

H) For completed projects

1) What has happened since your DLO-IC project was completed?

Manuscripts are prepared to be incorporated in a special issue.

2) Are there follow-up proposals developed and to whom are they submitted?

A follow-up of the project was established, concentrating on vegetable production in peri-urban areas, funded by EU (INCO).

PIMEA-ETHIOPIA*

Policies for sustainable land management in the east African highlands

A) Project setting

1) What was the background and motivation of the project?

The project built upon and complemented research by IFPRI, ILRI, and Mekelle University (MU) in 1997 on 'Policies for Sustainable Land Management in the East African Highlands'. This project aimed to help policymakers in the East African Highlands region identify and implement policies to contribute to improved land management, in order to increase agricultural productivity, reduce poverty and ensure sustainable use of natural resources.

The new phase of the project focused on the sustainability of land management practices in more detail in communities and households already surveyed; and to develop bio-economic models of additional household and community situations that could not be included in the first phase of the work. This phase was led by IFPRI and Wageningen University Research centre (Wageningen UR), in collaboration with ILRI, MU, and other Ethiopian collaborators. Additionally IFPRI conducted a study to assess market development in the Ethiopian highlands and its relationship to development and land management.

2) What was the institutional context (partners with which cooperated?)

The project was funded by the Ministry of Foreign Affairs (DGIS) and in part by the Ministry if Agriculture and Nature Management (LNV). LNV co-funded the agro-ecological work packages of the project. The research partners were IFPRI, Mekelle University and Wageningen University and Research. Within Wageningen UR, researchers from Alterra, PRI and LEI collaborated with the Department of Development Economics.

B) Project objectives

1) What were the initial project objectives?

- To identify the key factors influencing land management in the Ethiopian highlands and their implications for agricultural productivity, sustainability and poverty;

* Questionnaire received 2006, revised May 2007; Project leaders M. Mosugu (Alterra) and G. Meijerink (LEI)

- To identify and assess policy, institutional and technological strategies to promote more productive, sustainable, and poverty reducing land management;
- To strengthen the capacity of collaborators in the Ethiopian highlands to develop and implement such strategies, based upon policy research; and
- To increase awareness of the underlying causes of land degradation problems in the Ethiopian highlands and promising strategies for solving the problems.

2) Have there been any (major) changes to these objectives and for what reason?

No

C) Project activities

1) Which activities were employed to meet the objectives?

The overall project consisted of several activities that were executed by the different partners, which will not be reviewed here. The focus of the agro-ecological analyses that were carried out by the Wageningen UR partners (Alterra, PRI and LEI) were as follows.

Assessment of current land use

- Analysis of collected data on nutrient management at farm level and cross landscape elements, including constraint analysis (nutrient balances versus stocks, farmers revenue/income, financial opportunities to invest).
- Formulation guidelines for problem solving.

Identification of existing alternative technologies

- Estimation of technical input-output coefficients for the identified land management alternatives using secondary data, biophysical models and expert opinions.

Formulation of potential technologies

- Generate coefficients using the concepts incorporated in the Technical Coefficient Generator (TCG).

Dynamics of natural resources

- Develop a dynamic description of soil quality indicators to 'fully' describe the situation and the possible consequences of changes in agricultural practices.
- Combine the simplified descriptions ('models') that have been developed in the framework of the 'Wageningen-SOW' activities (for nitrogen and phosphorus, separately) and add a description (at the same level of detail) for carbon.

Up-scaling aspects

- Develop a dynamic landscape model for assessing soil erosion and nutrient depletion rates and the consequences of these for the quality of natural resources in the Tigray region.
- Evaluate the impact of present and alternative scenarios of landuse/technology, and policy interventions on soil erosion and nutrient losses in the region.

Policy dialogue

- Workshop with farmers and policymakers to validate, discuss and review the assessment of current land and soil fertility management practices.
- A number of working sessions with representatives of farmers and policymakers to review the identified technology/policy options and model results using an iterative procedure.

2) Can you identify disciplinary and multi-disciplinary activities?

The overall project had a multi-disciplinary focus with researchers from different backgrounds (economics, production ecology, soil science) working together. The agro-ecological analysis component, which was co-funded by LNV, was a close collaborative effort involving an economist from LEI, a production ecologist from PRI and a soil scientist from Alterra. Each had a distinct (disciplinary) work package, which was later integrated into the other work packages. A joint article was published afterwards, combining the work done by the different disciplines.

D) General project outputs

1) What are the scientific contributions of the project (to RDSA methodology or more general scientific contributions)?

- The results from the project were used to publish a scientific article in Agriculture, Ecosystems and Environment.
- Several project reports were written and made available internationally through the internet.
- The data that was collected in the field, the project results and programmes that were used (e.g., NUTMON) were made available to all project partners, including the Mekelle University.

2) What are policy-relevant findings of the project for Dutch and for Southern policymakers?

Northern Ethiopia (Tigray) is one of the poorest regions in the world. It was the scene of one of the worst famine disasters in the past decades (1984), and the region is still at risk.

Finding ways to improve the agricultural setting and livelihoods of the people is therefore a top priority for the Ethiopian Government. The project has looked into several possible “development pathways”. Several conclusions could be drawn by the research on sustainable agriculture:

Firstly, it showed that the variable onset of rains is crucial to crop growth. The issue is not so much the amount of rain, which is on average sufficient, but unpredictable start of the rains. If farmers sow their crops too early or too late (i.e., the rains unexpectedly start too late or too early), then the risk of crop failure, and famine are very high. Stone or soil bunds can conserve the moisture content and, therefore, are a way to reduce this risk to some extent.

Secondly, although nutrient losses are high, replenishing the soil with organic materials is not a feasible option, because of the scarcity of plant resources. Crop residues are important sources of livestock feed and fuel and cannot be used as green manure, or mulching. External resources are key to maintaining soil nutrient balances. However, markets are often far away, there are few roads and farmers have no money to buy fertilizer.

Thirdly, a widespread reforestation of erosion-prone catchments leads to a relatively minor decrease in soil erosion and may not be worth the opportunity costs of losing agricultural land. However, when taking into account other benefits of trees (for fodder, food, fuel), reforestation may be a viable option.

Finally, non-agricultural areas or fallow areas where there is bush growth, are a valuable resource for livestock feed. The farming system does not produce sufficient feed resources and the amount of feed livestock can get from (communal) grazing areas is limited.

There were very little opportunities for improved land management in Northern Tigray, one of the poorest areas in the world.

3) What are the outputs in terms of capacity-building and partnerships?

Capacity building

- The overall project included 3 PhD students from Mekelle University who started their PhD programme at Wageningen University. The researchers from Alterra, PRI and LEI collaborated with these students in the project.
- After the project ended, the models (software), data used and results were given to Mekelle University.
- Workshops with policymakers, NGOs and other key stakeholders in defining policy in Tigray were held throughout the project. In these workshops, results from the project were discussed, which enhanced learning by all parties.

Partnerships

Memorandums of Understanding (MoUs) were signed with IFPRI and Mekelle University, and partnerships were built from that.

E) Tangible outputs, dissemination and impact

Can you describe for the (max. 10) key outputs of your project:

1) Type of output

Report on description of current production activities including nutrient balances on plot level calculated by NUTMON for two sites in the highlands of the Tigray region.

Report on alternative production activities possible in the Tigray region including I/O coefficients related to these.

Report on potential production activities including TCG specific for farming systems in the Tigray Region.

Report on the dynamic and spatial aspects of nutrient flows, based on LISEM modelling on watershed level specifically for the Tigray Region.

Policy workshop where results of the biophysical part of the research are presented and discussed with the relevant policymakers for the Tigray region.

Databases and models:

NUTMON database for Teghane and Gobo Deguat (LEI)
LISEM model for Gobo Deguat (Alterra)
TCG for Gobo Deguat (PRI)

2) Dissemination of output/results (examples of dissemination: papers + articles; policy briefs; policy workshops; scientific conferences and workshops; website)

- Website (on the North-South portal).
- Policy workshop held in Mekelle at the end of the workshop.
- Article in in Agriculture, Ecosystems and Environment (H. Hengsdijk, G.W. Meijerink and M.E. Mosugu (2005). Modeling the effect of three soil and water conservation practices in Tigray, Ethiopia. Agriculture, Ecosystems & Environment, 105, 29-40).

3) Have your results been used, and if yes by whom, where and how?

- Response PhD students from Ethiopia have used and are building on the results of the project.
- Follow-up project by Wageningen University and IFPRI is being formulated.

4) What has been the benefit or impact (indicate evidence of impact, e.g., page hit count)?

- Scientific publication cited 5 times.
- North-South website does not register hits (!).

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

1) Future research on Rural Development and Sustainable Agriculture

An integrated, multi-disciplined approach is crucial to analysing sustainable land use issues in poor regions. The problems in these regions are usually multi-dimensional and technical solutions should always be combined with an analysis of the socio-economic settings and conditions.

2) The role of research in generating policy-relevant information in support of LNV and other policy institutions

Research questions should closely be aligned to the priorities and interests of policymakers. But research that does not answer a very specific, short term policy question because it is more long-term and general in nature, can still be valuable to policymakers.

3) Partnerships and development efforts in the South

Good partnerships with (research) institutions in the South are crucial to the success of an international research project. Establishing and developing networks with partners in the South are important to Wageningen UR. Vice versa, research institutions have a benefit in collaborating with Wageningen UR institutes with respect to extending their research agenda into new areas or working with new models (and software), obtaining funds and receiving training.

4) Interactions between research and decision makers, both in The Netherlands and the South

One cannot expect policymakers to read research reports. Discussions with policymakers, giving them information on research results (orally or in policy paper) are more effective. Targeting of policymakers is also crucial (knowing which person within which department to interact with).

5) Which insights were gained by employing a multi-disciplinary methodology that would have been missed by disciplinary research?

The fact that certain technological options (integrated nutrient management) for sustainable agriculture were not feasible, once other factors (and disciplines) were taken into account. The multi-disciplinary nature also expanded the scope of the project, enabling answering various issues at once.

G) For completed projects

1) What has happened since your DLO-IC project was completed?

The extended project (with IFPRI, Wageningen UR, Mekelle University) has continued.

2) Are there follow-up proposals developed and to whom are they submitted?

The Department of Development Economics and IFPRI are developing a follow-up proposal.

INMASP*

Integrated nutrient management to attain sustainable productivity increases in east African farming systems

A) Project setting

In Africa soil fertility degradation is considered to be one of the major long-term constraints to food security and environmental degradation. While formal agricultural research has in the past generated a vast amount of knowledge and fundamental insights in soil fertility aspects and ways to enhance it, application of these results by farmers in the field have been below expectations, among others because the prevailing extension approach did not allow farmers to assess them critically, adapt them where necessary, and learn how to further develop them. Given the diversity and variability of the environments of rainfed farming in Africa, farmers have already a wide body of knowledge in addressing soil fertility. Research and development should build upon these experiences and turn farmers into experts, capable of decision making and undertaking actions which are (a) informed by principles and methods and (b) aided by equipment and tools, which have been developed through linkage to practice. To address similar shortcomings in extension work on Integrated Pest Management (IPM) the Farmer Field School (FFS) approach was successfully developed in Indonesia by FAO's IPM programme in South East Asia. Whereas IPM is about bugs, INM is about nutrients. But that is only half the story. As much as the bugs in IPM are an entry point for a totally different approach to innovation in small-scale irrigated rice production, INM is an entry point for a totally different approach to innovation and development in African rainfed smallholder production. It combines (a) a technical focus on a locally feasible sustainable mix of nutrient management strategies, and (b) a developmental and institutional focus on using farmer creativity in capturing local opportunity for improving the productivity of farming.

The INMASP project embodies a multi-institutional and multi-disciplinary approach based on a network of nine partner institutions from Kenya, Uganda, Ethiopia and Europe. The partners are drawn from local NGOs, national research institutions, universities and farming communities of the three East African

* Questionnaire received 2006; Project leader A. De Jager (LEI)

communities. African team members include Debub University and SoS Sahel from Ethiopia; Makerere University and Environmental Alert from Uganda; and ETC-East Africa and Kenya Agricultural Research Institute (KARI) from Kenya. European partners include Wageningen University and Research Centre in The Netherlands and the National Agricultural Research Foundation from Greece.

B) Project objectives

The project has the following objectives:

- To develop an institutional sustainable approach of identifying, testing, monitoring and evaluation of farm or catchment-level technologies addressing soil nutrient management constraints using principles and institutional aspects of the Farmer Field School (FFS) approach;
- To generate appropriate and effective technologies to address problems of soil nutrient depletion aimed at a long-term increase of productivity and profitability of farming systems in East Africa; and
- To develop a participative policy formulation process involving researchers, extensionists and district policymakers aiming at formulating appropriate district policy recommendations and policy instruments to address soil nutrient depletion leading to a sustainable increase in productivity of farming systems in East Africa.

C) Project activities

A literature review on FFS experiences was conducted, followed by a field visit to the major FFS programmes in Kenya. This revealed the following major issues to be addressed in the methodology:

- Learning activities have a cycle of 1 cropping season, which is insufficient to appraise full range of impacts of nutrient management technologies;
- Relatively little attention is paid to developing farmers learning and research capacity in soil fertility issues, apart from central-plot experimentation, on-farm experimentation is required to capture diversity and individual adaptation of technologies;
- Issuing of initial grants jeopardizes the sustainability and up-scaling of the FFS approach;
- Systematic in-built monitoring and impact assessments are inadequate;
- Policy and institutional support at national level is necessary for a successful up-scaling of the approach.

In order to address these observed shortcomings, the project decided to initiate a pilot FFS programme with a focus on long-term group sustainability and developing learning and research capacities. It is aimed to contribute to the on-going search for the most appropriate and effective model of farmers' platforms.

Kiambu and Mbeere District were selected to implement the activities. Both districts face serious soil fertility decline, have experiences with the FFS approach, and represent major contrasting agro-ecological zones and farming systems. A representative catchment was selected and community workshops organized to introduce the project, assess interest and willingness to participate, identify existing groups or willingness to form new groups. In total four FFS groups were formed: Kamugi FFS (30 farmers; 50% women) and Munyaka FFS (31 farmers; 74% women) in Mbeere; Kibichoi FFS (30 members; 40% women) and Ngaita FFS (26 members; 56% women).

An overview of the trends and challenges in the agricultural sector in both districts was conducted. This was followed by base-line surveys at the 4 sites to diagnose and describe the current farming system practices, to create an understanding of farmer's soil fertility management practices, challenges and possibilities and capture farmer's dynamics of farm management. Consequently all FFS members participated in a participatory diagnostic activity using the NUTMON approach and covering the farm management activities in the period March – August 2000. Results of the NUTMON activity were discussed at FFS level and individual farm households were supplied with a diagnostic report covering soil fertility management and economic performance indicators.

These activities formed the initial steps of the learning cycle of the FFS and were followed by a curriculum programme conducted for five seasons consisting of: experimental design session, central plot and individual experiments, Agro-Eco Systems Analysis (AESA), monitoring and observations, special topics sessions and group dynamics implemented in FFS meetings every two weeks. The experimental design was an integrated process whereby farmers, research, extension staff where sharing views on options to address the identified constraints and whereby the FFS finally decided about the options for learning and experimentation. Much attention was paid in the FFS session to the process of experimentation and aspects such as having a control, the location of experimental plots, the design, the advantages of repetitions, and the formulation of simple hypotheses. Monitoring, observations and evaluation of the experiments was conducted by the FFS using earlier documented AESA, various pictorial and scoring tools. The FFS agreed upon the various indicators for qualitative observations such as yields, pest and diseases, leaf colour, plant health, soil moisture, weeds incidence, plant vigour and labour. FFS members were encouraged to make quantitative measurements on yields, inputs, costs and benefits. Based upon the observations and results of the seasons experiment a new cycle of experimental design is started for the following season. Furthermore the FFS determined the curriculum for special topics during the season and jointly with the facilitators, resource persons were identified.

Soon after the start of the FFS, members explored the possibilities of implementing commercial activities to generate income for the group and its individual members. Where necessary the facilitators assisted the group members in planning and connecting to external resource persons or inputs suppliers. A graduation ceremony marked the end of the involvement of the facilitators, but the starting point of the continuation of the farmer-led FFS.

A one-day policy workshop was organized in each District to share the results of the FFS approach with stakeholders and District level policymakers, resulting in an action plan to facilitate implementation of the FFS approach.

About 6 months after the graduation ceremony, an impact assessment was conducted by the facilitators to evaluate the contributions of the FFS approach and the conducted activities in the FFS towards a sustainable improvement of livelihoods of small-scale farmers in target areas in general and towards sustainable soil fertility management practices in particular. The assessment included both a longitudinal (comparison before and after joining the FFS) and latitudinal comparison (comparison between farmers of FFS and farmers not members of an FFS). The impact levels, target areas, target groups and tools used are summarized in Table 1. Discussions with all FFS members were organized individually and during a FFS meeting. A sample of 30% of the number of the FFS farm households is selected of which half from within the village and the other half from the immediate surrounding villages. Purposive sampling is being done with similar average resources (land size, no. animals) as the FFS group.

Table 1. *Characteristics of FFS (standard deviation in parentheses)*

	Kiambu		*Mbeere*	
	Kibichoi	Ngaita	Munyaka	Kamugi
Number of farm households in FFS	30	12	30	29
Number of household members	6.3 (2.4)	5.4 (2.1)	6.5 (1.8)	6.6 (2.1)
Average area cultivated (ha)	0.8 (0.5)	0.5 (0.2)	1.2 (0.8)	2.1 (3.1)
Tropical livestock units (TLU)	4.0 (5.1)	3.0 (4.5)	1.1 (1.7)	1.8 (1.8)
Family earnings ($ farm^{-1} halfyear^{-1})	395 (569)	156 (517)	189 (150)	48 (220)
Off-farm income ($ farm^{-1} halfyear^{-1})	241 (352)	128 (261)	96 (147)	39 (68)
Off-farm income (% of family earnings)	61	82	51	81
HH below poverty line (%)	80	67	100	97
Market orientation (% of produce sold)	52	46	22	31
Distance to market (km)	6	5	11	9

1 US$ = Ksh 75
Poverty line = 1 US$ person^{-1} d^{-1}

D) General project outputs

The project has implemented 11 Farmer Field Schools in Kenya, Uganda and Ethiopia reaching about 310 farming households who represents the larger farming communities. An FFS curriculum on INM was developed in each of the participating countries. The project has made extensive reviews of the FFS methodology and how it could be adapted to INM in east African region to provide insight into opportunities and constraints for implementing similar methodologies elsewhere. Analysis of sustainability of East African farming systems using NUTMON methodology has revealed that soils are degraded and that crop yields and farm income are low. For example the characteristics of the farm household members of the FFS in Kenya show that income levels, both on-farm and of-farm, are considerably low in Mbeere District, resulting in almost all households living below the poverty line of 1 US$ per day (Table 1). But also in the Kiambu District 60-80% of the households are below the poverty line.

The farms in Kiambu district import considerable amounts of nutrients both through fertilizers, organic fertilizers and animal feeds (Table 2). On the other hand unproductive losses through leaching (N,K), gaseous losses (N) and erosion are high. When the import of external inputs is slightly lower, as is the case in the farms in Ngaita FFS, a considerable negative balance for N and K is observed. A focus on reduction of nutrient losses appears to be the most appropriate in these farms.

The extensive system in Mbeere is characterized by low import levels of nutrients, only grazing and nitrogen fixation bring nutrients in the system, and low crop production levels. It is obvious that the input from communal grazing has its limitations and that in order to achieve necessary increase in crop productivity appropriate ways have to be found to import nutrients in the system.

The project has engaged the FFS members in a process of technology development based on a combination of local farmer's knowledge and science linkages.

***Table 2**. Average farm-level N-flows per flow type in kg ha^{-1} half year^{-1}*

	Kiambu		*Mbeere*	
	Kibichoi	Ngaita	Munyaka	Kamugi
IN 1 Mineral fertilizer	31.7	26.2	1.5	5.2
IN 1 Mineral animal feeds	32.5	15.0	0.2	0.1
IN 2 Organic fertilizers	14.6	13.9	0.7	0.3
IN 2 Organic animal feeds	10.6	4.9	0.0	0.0
IN 2 Grazing animals	0.0	0.0	12.7	20.0
IN 3 Atmospheric deposition	8.0	3.4	6.7	4.0
IN 4 Biological N fixation	3.6	3.1	11.3	4.2
OUT 1 Crop products	–12.5	–10.7	–5.4	–0.8
OUT 1 Animal products	–6.8	–5.0	0.0	–0.0
OUT 2 Crop residues	–2.3	–7.6	–0.2	–4.5
OUT 2 Animal manure	0.0	0.0	–5.3	–8.2
OUT 3 Leaching	–33.7	–37.0	–4.3	–4.7
OUT 4 Gaseous losses	v20.8	–22.8	–1.2	–1.0
OUT 5 Erosion	–18.5	–21.7	–8.2	–0.1
OUT 6 Human excreta	–9.0	–11.7	–7.3	–12.0
Total balance	**–2.6**	**–50.0**	**1.1**	**2.5**

Table 3. *Summary of results of experiments on central plot in Munyaka FFS, Mbeere District in period 2002-2005*

Treatments and crops	Yield kg ha^{-1}	GM \$ ha^{-1}	B/C ratio	VCR	N-bal kg ha^{-1}	Nout / Nin	FFS score
Maize: 2002 SR + 2003 LR							
FYM (16 t ha^{-1})	2530	28	1.1	-	–22	1.6	4.0
DAP (216 kg ha^{-1})	2960	185	1.7	–0.4	–22	1.6	4.5
FYM (16 t ha^{-1})+ DAP (216 kg ha^{-1})	3741	114	1.3	2.2	–2	1.0	5.2
FYM(16 t ha^{-1})+ DAP (216 kg ha^{-1})+Tith (3.6 t ha^{-1})	4350	203	1.4	2.7	1	1.0	6.3
Beans: 2003 SR (Crop failure)							
Control							
TSP (100 kg ha^{-1})							
Rhizobium (0.27 kg ha^{-1})							
TSP (100 kg ha^{-1}) + Rhizobium (0.27 kg ha^{-1})							
Cowpeas: 2004 LR + 2004 SR							
Control	1100	131	1.8	-			4.8
Rhizobium (0.17 kg ha^{-1})	1175	149	1.9	9.6			4.8
TSP (104 kg ha^{-1})	1387	171	1.9	2.1			4.8
TSP (0.17 kg ha^{-1}) + Rhizobium (104 kg ha^{-1})	1700	253	2.3	4.2			5.6

SR = Short Rains from October – February;
LR = Long Rains from March – August
N-bal = Partial N-balance (IN1 + IN2 – OUT1 – OUT2)
FFS-score = 20 points divided over treatments on preference of technology
VCR = (GrossValue Treatment – GrossValue Control)/(VariableCosts Treatment – VariableCost Control);
FYM = Farm yard manure.

This has resulted in the development and testing of technologies such as green manuring technologies (tithonia, green manure legumes etc.); manure and composting; Rhizobium inoculation of beans; tillage practices in Napier production; livestock feeding; and organic and inorganic combinations for crop production. Examples of experiments and its results in one of the FFS in Kenya are presented in Table 3.

The project has trained FFS facilitators drawn from national agricultural extension systems and the private sector for running FFS and up-scaling the same. A number of workshops and meetings have also been organized for policymakers to discuss FFS and Integrated Nutrient Management in the target countries of Kenya, Uganda and Ethiopia. To further enhance sharing of the project outputs, a website was created to give opportunities for persons and organizations working in the area of soil fertility management and Farmer Field Schools access to various project reports and outputs (www.inmasp.nl). Jointly with FAO a FFS manual for implementing INM with FFS in East Africa is published.

E) Tangible outputs, impact and experiences of the project

Joint problem diagnosis during the FFS platforms brought Government and non-governmental organizations together to define priority problems and opportunities for research & extension. It has provided a strong foundation for on-going co-operation and learning for change. Through the FFS platforms, farmers and the consortium organizations have had opportunity to better understand and appreciate the Indigenous Knowledge available with the farmers and build upon it as a knowledge base for continuing future innovative work. Initial results of the impact assessment exercise show that although 50% of the farmers were already experimenting prior to joining the FFS, one year after all members engaged in experimentation and had significantly improved the process (using control comparisons, detailed observation, more structured evaluation on multiple aspects etc.) The FFS platforms have bridged the gap between agricultural extensionists, and the farmers as it has provided a forum and the means by which agricultural extension agents have been more closely in contact with farmers on a fortnightly basis. The FFS process has fostered cohesiveness and sustainability of the groups and for future activities. At the FFS platform level, community structures were created to facilitate the ongoing project activities, but also resulted in a number of commercial activities such as vegetable production and marketing and milk processing. One year after the closing of the FFS facilitation process all FFS groups were still active, but the focus shifted to joint implementation of commercial activities. The FFS appears to be an excellent approach to link smallholders to national, regional and even international markets. The FFS approach is gaining momentum in East Africa in a broad range of research and development organizations and is already implemented to address a wide array of rural livelihood challenges.

The project resulted in a series of publications and seminar presentations, 4 students (2 MSc and 2 PhD in Uganda and Kenya) participated in the projects and through national and regional networks the projects actively contributed to the upscaling and institutionalization debate around FFS in the East African region.

Summary

The Integrated Nutrient Management Project (INMASP) was initiated in December 2001 to reverse declining trends of soil fertility and to make a sustainable contribution to the livelihoods of small-scale farmers in East Africa (Kenya, Uganda and Ethiopia). Stakeholders recognized that in the face of increasing population pressure and shrinking land sizes, approaches and remedies are required that may not only address the biophysical constraints to food production, but also to build up social, economic and human capital for sustaining the production process among smallholder farmers. The project has worked with 310 farming households in 11 Farmer Field Schools (FFS) in East Africa, analysed productivity constraints in low to high agricultural production areas, trained extension workers on FFS methodology, developed and tested technologies with farmers and engaged policymakers in formulating FFS-INM friendly policies. The success of this methodology is that it brings all the stakeholders together in a learning process that leads to effective decision-making and action. The approach proved to bridge the gap between research and extension in addition to building community capital and to stimulate the improvement of gender relations and good governance at the local level.

MAMAS*

Managing Agrochemicals in Multi-Use Aquatic Systems

A) Project setting

1) What was the background and motivation of the project?

Agriculture in Asian countries has undergone significant intensification within the last 30 years. Traditional crop varieties and agricultural techniques have been changed to increase productivity; however, modern high yield varieties tend to require great inputs of agrochemicals, and of particular concern, pesticides. In Asian countries, the water resource is often used for land crop irrigation, watering of livestock, catch fisheries, and communal bathing. The impact of agrochemicals on the sustainability of such a multi-use water management system may be complex in terms of both the fate and effects of contamination. Very few studies regarding the environmental distribution, toxic effects on aquatic organisms, or general impact on aquatic ecosystems of agrochemicals have been undertaken in Asian countries.

Understanding and mitigating negative impacts of agrochemicals on the ecosystem will involve the active participation of a range of stakeholders and a systems approach to research. Furthermore if information derived from research is to lead to decision-making and action, policy development must be integral to the process.

2) What was the institutional context (partners with which cooperated?)

- Institute of Aquaculture, University of Stirling, Scotland, UK (Coordinator)
- Alterra, Wageningen University and Research centre, Wageningen, The Netherlands
- Departamento de Biologia, Universidade de Aveiro, Aveiro, Portugal
- National Aquatic Resources Research and Development Agency, Colombo, Sri Lanka
- Agribusiness Centre, University of Peradeniya, Peradeniya, Sri Lanka
- School of Environment Resources and Development, Asian Institute of Technology, Thailand
- Department of Fishery Biology, Faculty of Fisheries, Kasetsart University, Thailand

* Questionnaire received 2006; Project leader P. Van den Brink (Alterra)

B) Project objectives

1) What were the initial project objectives?

The overall objective of the MAMAS project was to develop tools and techniques to be integrated into a risk assessment model for the use of agrochemicals in aquatic systems in Asian countries. Specifically, the project aimed to identify realistic worst-case scenarios & impacts through a situation appraisal and preliminary risk assessment. Batteries of simple, low cost and environmentally relevant diagnostic bioassays have been developed. Local researchers have also been trained in the use of these techniques, and protocols disseminated in local languages. Land management practices have been monitored, and bioassays deployed in field sites to investigate the applicability of fate and effects models. Pesticide residue sampling has also been conducted. Monitoring data is used to develop a decision support system (DSS) for the evaluation of local risks and possible mitigation methods. Policy guidelines for sustainable management of agro-ecosystems in the region will be developed through a participatory approach.

2) Have there been any (major) changes to these objectives and for what reason?

No

C) Project activities

1) Which activities were employed to meet the objectives?

Year 1 Data collected from the situation appraisal (Work package 1) undertaken in year 1, was reported back to primary and secondary stakeholders through workshops held in Thailand and Sri Lanka. The State of the System Reports (SOS) for Thailand and Sri Lanka, can be found on the MAMAS website (www.mamas.org), together with all other output listed below. These reports were created initially through participatory activities with key informants and focus groups as well as household interviews in selected communities.

This information was then presented to and discussed with key stakeholder groups. A preliminary risk assessment (PRA) was carried out and published in a report entitled “Environmental and human risks of pesticide use in Thailand and Sri Lanka: Results of a preliminary risk assessment”. The preliminary risk assessment aimed to build on the initial situation analysis by using information on the environmental characteristics of the study sites, to estimate the potential risks (environmental and human) through pesticide exposure. Techniques used in European risk assessment of agrochemicals were applied. Both the environmental and the human health assessment indicated large potential risks.

Year 2 Environment and land use monitoring (Work packages 5 and 6) was carried out at sites identified in the PRA in both Thailand and Sri Lanka. This involved collecting information on hydrological characteristics of the systems of concern, farming practices, land use and the type and quantity of pesticides applied throughout the year. Work packages 5 and 6 were due to be completed during the third year of the project. Preliminary methods were also developed for the analysis of pesticide residues in environmental media (Work packages 7 and 8). Target pesticides were identified from the PRA in year 1. Laboratory toxicity bioassays were also developed and tested using local species.

Year 3 Individual partners from Thailand and Sri Lanka initiated a programme of chemical effects monitoring using a combination of chemical analysis and *in situ* bioassays (Work packages 7 and 8). This was facilitated with a series of three workshops organized during year 3. This programme is nearing completion as of August 2005 and will be reported in full in the final technical report. Environment and land use monitoring (Work packages 5 and 6) also continued during year 3 for both Thailand and Sri Lanka.

Year 4 All activity in the environment and land use (WP5 and 6) and chemical and effects monitoring (WP7 and 8) work packages will be completed and reported on during the early part of year 4. Monitoring data will then be available for the risk assessment procedure. The first version of the decision support system (PRIMET) is already available for carrying out the risk assessments (WP9). Training on the use of PRIMET will then be provided by Partner 2 during the last MAMAS workshop. The outputs from the risk assessment process will then be used in the training and implementation of pesticide administration and risk mitigation procedures (WP 9). Policy bulletins for the administration and management of pesticides in multi-use aquatic systems will also be developed (WP10).

2) Can you identify disciplinary and multi-disciplinary activities?

The project was a combination of social, economic and natural sciences. The situation appraisal comprised of performing interviews, quantitative economic assessments, workshops, which results feed into the preliminary risk assessment which makes use of natural sciences. The results of this situation appraisal and risk assessments was communicated back to all stakeholders by means of state of the system workshops. The same approach was used at the end of the project.

D) General project outputs

1) What are the scientific contributions of the project (to RDSA methodology or more general scientific contributions)?

Development of Risk Assessment methodology for tropical countries

Pesticide exposure via for instance spray drift or runoff to surface water, accumulation in the topsoil, and leaching to groundwater potentially affects organisms in water and soil and might also pose risks to humans via dietary exposure, in case they consume contaminated aquatic products like groundwater, macrophytes and fish. Tropical risk assessment is, however, only a young field of science that lacks the wealth of data as present for temperate regions. The uncertainty associated with the use of temperate data on pesticide properties and species sensitivity for tropical situations is, however, largely unknown. In order to estimate these risks in the tropics at the household level the PRIMET Decision Support System was developed. PRIMET runs with a minimum of input data (www.primet.wur.nl).

Development of bioassay techniques using local species

To improve the representativeness of standard biological methods to assess effects of pesticides under field conditions in the tropics, within the project a battery of simple, cost effective and relevant environmental diagnostic bioassays was developed. The selected local species were used in tests to compare their sensitivity and response to key contaminants in comparison to tests conducted with standard species. In addition to lethal toxicity tests, tests were also conducted using non-lethal endpoints, incorporating both standard (e.g., reproduction, growth) and non standard (e.g., feeding rate) endpoints.

2) What are policy-relevant findings of the project for Dutch and for Southern policymakers?

Participatory and integrated policy (PIP) formulation towards improved measures for risk assessment and mitigation of the impacts of agrochemicals in fish production systems is a major objective of the work package 10. During multi-stakeholder workshops questions like “Do you agree with our research findings?”, “Why do farmers overuse” “What are the constraints to more efficient use of pesticides” and “Is this work beneficial to policymakers” are answered. Policymakers indicated that the MAMAS project will help in the development of policies and research in Thailand and Sri Lanka. The results of the risk assessment will be used by the departments of agriculture to impose bans or tighten the manufacture and distribution of pesticides that are harmful. It was also mentioned that this work will help to strengthen extension services to help farmers to recognize risks to human and environmental health.

3) What are the outputs in terms of capacity-building and partnerships?

Eight PhD and two MSc students are involved in this project. Five scientists were exchanged longer than 3 months and 3 visiting scientists were present.

E) Tangible outputs, dissemination and impact

Can you describe for the (max. 10) key outputs of your project:

1) Type of output

- Situation appraisal report
- Preliminary Risk Assessment report
- Standard Operation Procedure for in-situ tests with local species
- Report on local environmental conditions, agricultural practices and pesticide use
- Decision Support System

2) Dissemination of output/results (examples of dissemination: papers + articles; policy briefs; policy workshops; scientific conferences and workshops; website)

All outputs are downloadable from the MAMAS website (www.mamasproject.org). Many presentations have been given at several scientific conferences (SETAC Europe conferences in Hamburg, Germany (2003), Prague, Czech Republic (2004), Lille, France (2005), SETAC ASE Asia Pacific meeting. Christchurch, New Zealand (2003), SETAC World meeting, Portland, USA (2004), WAS World Conference, Bali, Indonesia (2005). Research findings are published in an article in a major newspaper of Sri Lanka, in reports and peer reviewed papers (see references below). Four SOS workshops have been organized to communicate the results back to all stakeholders. Workshop results also have been published in English and local language.

Little, D.C., A. Yakupitiyage, K. Satapornvanit, K. Kaewpaitoon, T. Ungsethaphand, G.K. Milwain, D.J. Baird, P.J. Van den Brink, G.J. Taylor and A.J.A. Nogueira (2003). Managing Agrochemicals in Multi-use Aquatic Systems (MAMAS). State-of-the-system report: Thailand. MAMAS report Series no. 1/2003. Asian Institute of Technology and Kasetsart University, Bangkok, Thailand.

Van den Brink, P.J., M.M.S. Ter Horst, W.H.J. Beltman, J. Vlaming and H. Van den Bosch (2005). PRIMET version 1.0, manual and technical description. A Decision Support System for assessing Pesticide RIsks in the tropics to Man, Environment and Trade. Alterra-Report 1185, Wageningen, The Netherlands.

Van den Brink, P.J., N. Sureshkumar, M.A. Daam, I. Domingues, G.K. Milwain, W.H.J. Beltman, M. Perera, P. Warnajith and K. Satapornvanit. (2003). Environmental and human risks of pesticide use in Thailand and Sri Lanka. Results of a preliminary risk assessment. Alterra-Report 789, Wageningen, The Netherlands.

Satapornvanit, K., D.J. Baird, D.C. Little, G.K. Milwain, P.J. Van den Brink, W.H.J. Beltman, A.J.A. Nogueira, M.A. Daam, I. Domingues, S.S. Kodithuwakku, M.W.P. Perera, A. Yakupitiyage, S.N. Sureshkumar and G.J. Taylor (2004). Risks of pesticide use in aquatic ecosystems adjacent to mixed vegetable and monocrop fruit growing areas in Thailand. Australasian Journal of Ecotoxicology 10: 85-95.

3) Have your results been used, and if yes by whom, where and how?

The risk assessment methodology is now also used in a SANPAD project with Rand Afrikaans University in South Africa entitled: “Environmental and Human Risk in Pesticide Use in Southern Africa”. The experience gathered on risk assessment has been used in the MAPET and VEGSYS project. At the end of the project (December

2005) a training of local researchers in the risk assessment methodology of PRIMET was held.

4) What has been the benefit or impact (indicate evidence of impact, e.g., page hit count)?

The MAMAS website is frequently visited by Thai and Sri Lankan people. The State of the System workshops initiated much discussion among stakeholders (farmers, extension service, pesticide industry and registration people) so awareness on the problem is growing. Since most dissemination activities are planned at the end of the project (end 2005), much of this (like policy briefs) still has to be done.

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

1) Future research on Rural Development and Sustainable Agriculture

Future research should be focussed on the validation of the risk assessment methodologies used in the PRIMET decision support system. Tropical risk assessment is only a young field of science that lacks the wealth of data as present for temperate regions. The uncertainty associated with the use of temperate data on pesticide properties and species sensitivity for tropical situations is, however, largely unknown.

2) The role of research in generating policy-relevant information in support of LNV and other policy institutions

Future projects should include a capacity building component for local pesticide regulators. This group is often very small (often 1 person per country) and works quite isolated and lacks the capacity to perform a state of the art risk assessment. Within current projects courses are developed but these are aimed at training local researchers.

3) Partnerships and development efforts in the South

For the MAMAS project we invited two people from each participant to Wageningen to perform the preliminary risk assessment. This visit was started with a 4 day course after which all relevant data was gathered and the risk assessments performed. This event proved to be very successful to transfer knowledge, build bridges between partners, perform a risk assessment and make a fast start of the project. After this initial visit it is very important that a person from The Netherlands spends a vast amount of time in the South in order to make sure that the projects keeps its focus and all relevant information is transferred and optimally used.

4) Interactions between research and decision makers, both in The Netherlands and the South

It has been planned to organize a State of the System workshop in The Netherlands to improve the interaction between researchers and policymakers in The Hague. In the morning the research findings can be disseminated to all relevant Dutch stakeholders who are invited for these workshops, while in the afternoon the stakeholders can discuss the relevance and implications of these results among themselves and report back their findings to the whole group which can be followed by a general discussion to distil the general consensus.

5) Which insights were gained by employing a multi-disciplinary methodology that would have been missed by disciplinary research?

To my opinion it is impossible to assess the risks of pesticides not using a multi-disciplinary approach. Interviewing techniques are needed to obtain data on pesticide usage and an assessment of pesticide marketing and registration is needed to obtain drivers for transition towards rational pesticide use. The questionnaire on attitude towards pesticide usage and importance of pesticides in terms of costs and information is needed to focus dissemination strategies.

G) Unfinished business and future challenges

1) Which important things remain to be done that could not be achieved by the project?

Validation of the PRIMET risk assessments by field measurements and capacity building of local pesticide regulators.

2) Which important challenges in the area of RDSA in the tropics are there in the near future (say 5 to 10 years)?

See F1 and G1. In terms of pesticide risk assessment the up-scaling of these risks to a watershed level is a real challenge. This is needed because now it is not known to what extent the use of pesticides on one farm influences other farms. In Thailand for instance we visited a biological farm in which many pesticide residues were measured in the water.

3) What type of research could contribute to addressing these challenges?

A combination of experimental research, modelling and development of training programs. The advantage being that much can be learned from the research programme 416 ‘Environmental risks and emission reduction of pesticides’ of the Dutch Ministry of Agriculture, Nature and Food Quality.

EROAHI*

Development of an improved method for soil and water conservation planning at catchment scale in the East African Highlands

A) Project setting

1) What was the background and motivation of the project?

In the East African Highlands soil and water conservation programs have proved expensive to implement and rarely succeed in having any lasting impact on the problem. Often farmers are accused of being conservative land users. However, more and more people realize that not the farmers but the planning approach, which is basically a top-down approach, is wrong. Experts from outside usually exclude the farmers from the planning process. This results often in recommendations for mitigating problems that are not perceived as immediate priorities by the farmers. For most farmers the main concern is how to sustain and improve production, and therefore soil conservation programs should focus on combating productivity losses, rather than preventing soil loss.

For this reason in Kenya and Tanzania extension services use the Catchment Approach. This is a methodology for participatory soil and water conservation planning at catchment scale. The approach is currently applied at different locations in the East African Highlands. The method has been reviewed in 1996 and the EROAHI project developed tools to assist the local extension services to improve the methodology based on this review. Main improvements are:

- To make better use of farmers' knowledge on soil and water conservation.
- To provide a simple tool for economic cost-benefit analysis of proposed conservation measures.
- To improve the planning method. Currently anti-erosion plans are developed for each individual farm (farm-by-farm), whereas it is more efficient to start with a plan for the entire catchments, because of the nature of the erosion problem.

The results are combined into one methodology that can be applicable for other locations within the African Highland ecoregion, e.g., in Madagascar, Ethiopia and Uganda.

* Questionnaire received 2006; Project leaders H. Van den Bosch (Alterra) and S. Verzandvoort-Van Dijck (Alterra)

2) What was the institutional context (partners with which cooperated?)

The project aimed at improving an approach that is actively used and institutionalized by the extension services in Kenya and Tanzania. Therefore both services were partner and client in this project. In each country an experienced research partner participated. The project was scientifically supervised by Wageningen University and managed by Alterra. The African Highlands Programme was regularly consulted in order to ensure compliance with their regional activities.

Partners:

- Kenyan Ministry of Agriculture, Soil and Water Conservation Branch, Kenya
- Lushoto District Agriculture and Food Security Office, Tanzania
- Kenya Agricultural Research Institute, Regional Centre Embu, Kenya
- Agricultural Research Institute Mlingano, Tanzania
- Wageningen University, Department of Environmental Sciences
- Alterra Green World Research

B) Project objectives

Goal of the project was (i) to make better use of farmers' knowledge in SWC planning, (ii) to include cost-benefit analysis to facilitate informed decisions by farmers and increase adoption (iii) to improve the planning and bring it to the level of a catchment, rather than farm by farm. This resulted in 5 objectives

- To develop field scale indicators of erosion and sedimentation based on indigenous knowledge of soil and vegetation characteristics.
- To attach quantitative values of erosion, sedimentation and/or productivity to the developed indicators, based on field scale measurements.
- To quantify erosion, sedimentation and soil productivity at catchment scale using the developed indicators and compare the estimates with a detailed model study to develop simple 'rules of thumb' for erosion assessment.
- To develop a methodology for economic impact assessment of planned soil and water conservation measures at farm level.
- To further develop a specific methodology for catchment scale soil and water conservation planning in the East African highlands using a participatory approach.

C) Project activities

Description

Figure 1 gives the various clusters of activities and their interrelations. Three types of activities are distinguished:

- Activities that contributed to the development of the tool for participatory soil erosion mapping, relating to farmers' indicators and how they can be used for SWC planning;

- Activities that contributed to the development of the tool for financial analysis of SWC measures, relating to the effectiveness of SWC measures and how this can be used in SWC planning; and
- Supporting modelling activities, scientific surveys and research of physical processes of soil erosion. One of the main objectives of this work was to understand how farmers' knowledge and scientific knowledge can support each other in SWC planning. As indicated in Figure 1 the scientific work on modelling and surveys and (physical processes) supported the development of the tool for participatory soil erosion mapping as well as the development of the tool for financial analysis of SWC measures.

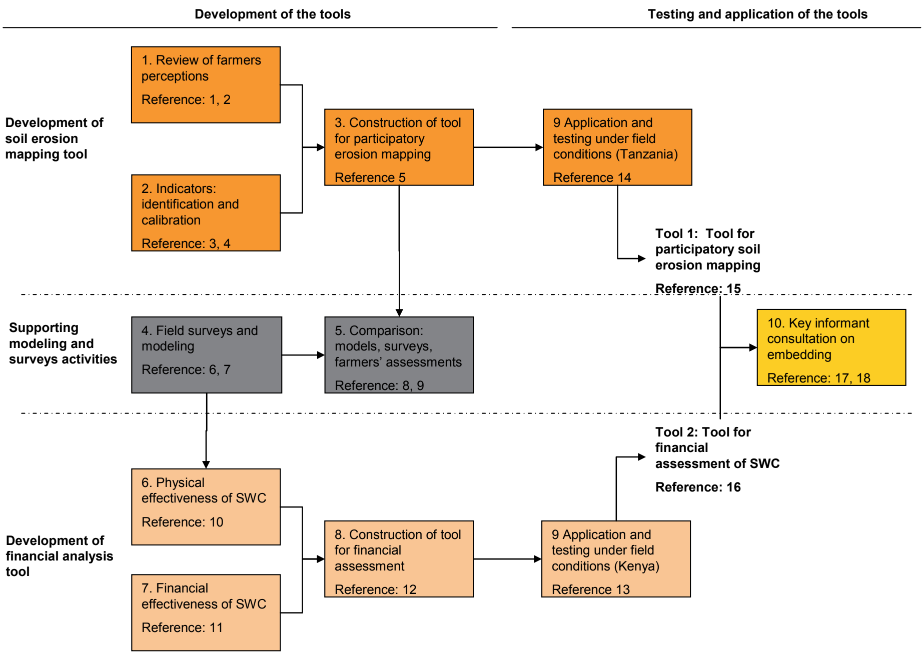

Figure 1. *Clusters of activities and their relations*

Cluster 1: Review of farmers' perceptions on erosion, SWC measures and adoption, to understand farmers' perception on soil erosion, to determine the social and economic factors that influence adoption of SWC-measures, and to establish relationship with the farmers for further activities. Two reviews were carried out, one in each research site. The review in the Kenyan site aimed to evaluate knowledge and perceptions of soil erosion and existing soil and water conservation measures. Community meetings and semi-structured household surveys were carried out in the catchment with 120 households. The review in the Tanzanian site consisted of group discussions and transect walks. A total of 104 households were interviewed and several fields were visited during the transect walks.

Cluster 2: Identification and calibration of indicators, to (i) identify the main indicators that farmers use to quantify erosion and to (ii) attach semi-quantitative values to the erosion indicators, using scientific measurements. In group meetings, in semi-structured interviews with 120 households, discussions with key-informants and during transect walks farmers listed known erosion indicators and assessed the indicators in their fields and their causes. Indicators were categorized into current indicators (those that are observable immediately after a rainfall event) and past indicators (resulting from long-term erosion) leading to a consensus list of erosion indicators for the study area. Field measurements were done to link measured soil loss and yield loss to the presence of the most important indicators. On 9 combinations of soil type and slope class runoff plots were installed to relate the sheet-rill erosion indicators to actual soil loss. Five erosion indicators were identified within about 25 farmers' fields to estimate crop yield gaps.

Cluster 3: Construction of a tool for participatory soil erosion mapping. In this cluster farmers were assisted to produce a soil erosion map based on the indicators identified before. A participatory mapping exercise was facilitated resulting in a detailed topographic map of the area (with property delineation, and infrastructure). A field-by-field survey of soil erosion and crop production levels was carried out during 2 seasons using the previously compiled consensus list of indicators, resulting in a soil erosion map for the catchment, according to farmers' knowledge and perceptions. The method was evaluated and described.

Cluster 4: Field surveys and modelling exercises to assess the degree of soil erosion using scientific methods. The actual erosion was assessed in the field following the guidelines of the Assessment of Current Erosion Damage method (ACED). The method was applied along transects (Kenya case) and on field level (Tanzania case), and resulted in both cases in an erosion map for the catchment, indicating the spatial distribution of erosion in a (semi-) quantitative way.

Two different models were used to estimate spatial patterns of soil erosion. The Morgan, Morgan and Finney (MMF) model is an empirical model developed to estimate mean annual soil loss from field-sized areas on hill slopes. The model was selected for its simplicity and relative low data requirements. The second model used is the LISEM model, a model based on physical-chemical laws and equations that predict erosion patters within a catchment for a single rainfall event. The LISEM model was calibrated and validated with data on soil and water loss at the outlet of the study catchments. For this purpose spatial data on climate, soils and crops were collected as well as data on runoff and soil loss at the outlets of the catchments. Flumes were constructed and equipped with automatic sampler equipment for discharge and sediment load.

Cluster 5: Comparison of farmer assessments with scientific methods in order to assess the validity and employability of farmers' maps in SWC planning. For the Gikuuri catchment in Kenya the previously developed farmers' map was compared with the ACED maps. In the Tanzanian site the results of a survey using farmers' indicators was compared to the ACED maps. The spatial erosion patterns between the two approaches were compared using cross tabulation and the degree of agreement was evaluated using kappa coefficient analysis in the SPSS program. The predictions with the LISEM model (Kenyan site) and the MMF model (both sites) were compared to the ACED maps and the farmers' maps.

Cluster 6: Physical effectiveness of soil and water conservation, to assess the physical effectiveness of the most important SWC measures used in the East African Highlands (bench terraces, grass strips and fanya juu. Gerlach troughs, trench ditches and runoff plots were used to assess the physical effectiveness. Besides, farmers were interviewed and group discussions were used to obtain farmer's reasons for preferences of certain SWC measures.

Cluster 7: Financial effectiveness of soil and water conservation, to assess the costs and benefits of most frequently implemented SWC measures. In the Tanzanian research site a study was carried out to assess the costs and benefits of bench terraces, grass strips and fanya juu which are important SWC measures. Cost Benefit Analysis (CBA) was undertaken to farmers with low, moderate and high opportunity costs of labour at different slopes and soil types.

Cluster 8: Development of a tool for financial analysis of SWC measures. Based on the results of the clusters 6 and 7 a tool was made and described that helps extension workers to make ex-ante estimates of the financial impacts of the implementation of SWC measures in a participatory way. The method was evaluated and described.

Cluster 9: Testing of the tools under field circumstances. The 2 tools developed in cluster 3 and 8 respectively were tested in the field. The financial tool was developed in Tanzania and tested in Kenya, and the soil erosion mapping tool was developed in Kenya and tested in Tanzania. The experiences of these exercises helped to fine-tune the methods.

Cluster 10: Key informants consultation on embedding of the tools in current approaches. The team consulted key informants of the extension services of the Ministries of Agriculture in Kenya and Tanzania to determine in which stages of the currently applied catchment approaches in Kenya and Tanzania the developed tools best fit and have optimal effect. Interviews, workshops and field visits were organized. Conclusions were summarized and feed-back workshops were organized with key-informants and farmers.

D) General project outputs

1) What are the scientific contributions of the project (to RDSA methodology or more general scientific contributions)?

The project delivered two new methods to be employed within the daily context of the extension services. *The first method* is a method for participatory soil and water conservation planning at catchment scale. The method makes use of farmers' indicators for soil erosion and results in a catchment erosion risk map, made by farmers. For each unit on the map expected yield loss due to erosion is assessed by farmers and experts, relating erosion to yield loss. Since farmers can relate to the map it is a good basis for further negotiations on soil and water conservation planning at catchment scale. *The second method* developed by the project is a method for financial analysis of soil and water conservation measures before the actual implementation. The analysis is done for and with farmers and shows farmers when they can expect financial returns from their investments in land management activities. The method takes into account the socio-economic situation of the farmer family as well as the bio-physical situation, such as slopes, soils and climate.

Advantages of using the tools in soil and water conservation planning

- Better quantification of current soil erosion
- Linking soil loss to yield loss
- Economics of soil and water conservation
- Catchment level planning rather than farm level planning
- Ownership and adoption

2) What are policy-relevant findings of the project for Dutch and for Southern policymakers?

3) What are the outputs in terms of capacity-building and partnerships?

The project resulted in three PhD degrees; two of them with affiliation to the NARS of Kenya and Tanzania.

The project resulted in a much closer relationship between the NARS and the national extension services in the field of national resources management, since they all closely worked together in this 5 year project.

E) Tangible outputs, dissemination and impact

Can you describe for the (max. 10) key outputs of your project:

1) Type of output

Reports, theses and papers

- EROAHI Report 1: Tools Description: describes in detail the developed tools and the potential use of the tools in the current extension approaches.
- EROAHI Reports 2, 3 and 4: PhD theses.
- Okoba, BO., 2005. Farmers’ indicators for soil erosion mapping and crop yield estimation in central highlands of Kenya. Doctoral Thesis Wageningen University.
- Tenge, A.J.M., 2005. Participatory appraisal for farm level soil and water conservation planning in West Usambara highlands, Tanzania. Doctoral Thesis Wageningen University.
- Vigiak, O., 2005. Modelling spatial patterns of erosion in the West Usambara Mountains of Tanzania. Doctoral Thesis Wageningen University.
- Five additional papers were presented at international scientific conferences.

2) Dissemination of output/results (examples of dissemination: papers + articles; policy briefs; policy workshops; scientific conferences and workshops; website)

The methods were developed not only together with the farmers but also together with representatives of the extension services in Kenya and Tanzania, since they are the end-users of the methods. In other words: the project worked with the clients from start to end. The extension services and the researchers developed a strategic vision on how the tools can be used in the current approaches for natural resource management in Kenya and Tanzania

A four day final workshop was held at the end of the project were farmers and extension services explained the problems and questions they had when starting the project, the project team presented the results of the project and the extension service developed the strategic plan for effective utilization. This was generally perceived as a very effective dissemination strategy. Both extension services are currently using the methods in their daily work with the farmers to combat soil and water erosion.

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

Address a real need

This project addressed a real need of the extension services. Their method to plan SWC measures was evaluated and drastic improvements were proposed. These improvements required scientific input, which was provided by the project.

Lesson learned: know what the needs of the stakeholders are, reason from their perspective while designing a project. This also requires a long term presence of a research organization in a specific area, in order to have the insight, overview and contacts.

Work with the client

The fact that the project worked together from the start with the client (the national extension services) has to proven rewarding and very effective. It was also not easy. Extension workers and scientists have different priorities, different daily experiences, different goals and different languages. It takes commitment, energy, and perseverance to set common goals and, above all, to keep on working together over a relatively long period of time.

Especially the simple fact that daily practice and procedures of the extension workers were changing drastically over the project period cause problems and asked for flexibility of the group, in order to answer today's rather than last year's questions.

The lesson learned: work with the client (i.e., local resource manager and national extension services) from the very beginning, that means from designing the project to delivering the results. Work on a strategic implementation plan as part of the project.

Partnership DLO and Wageningen University

In this project, Alterra was overall coordinator of the project and especially responsible for the tangibility and applicability of the results. The Wageningen University was responsible for the scientific quality of the work and the education of PhD students. This resulted in a good balance between science and applicability. The project was locally managed by the PhD candidates (both experienced researchers) which guaranteed continuous presence, focus and dedication by the local partners.

Multi-disciplinary methodology and participatory approach

The tools developed in this project could only be developed in a multi-disciplinary team and in a participatory way. Farmers and extension were consulted continuously and they were setting the agenda. Questions were both of a technical and a socio-economic nature.

G) Unfinished business and future challenges

Planning and implementation at a catchment level

Because water flows from high to low, erosion has to be studied and combated at a catchment scale. Treating fields separately and independently can easily be a waste of resources, because of run-off damage form up-stream untreated fields. Also, and maybe even more important, farmers who live and farm downstream of treated fields may benefit from this more than the farmers that own the treated fields. Therefore a truly catchment level approach for soil and water conservation planning and implementation is required. This approach should:

- Identify hotspots, were activities should start and concentrate (can be done with EROAHI tools);

- Estimate ex-ante costs and benefits per treated field (EROAHI tools).
- Estimate downstream effects of implementation and value in monetary terms (who else is going to gain or loose from the implementation?).
- Start a negotiation process with all land users in the catchment in order to share costs and benefits in an equal way. This means that people may have to invest in other's land (cash or kind). This requires a solid negotiation process.

The type of research required for this is twofold:

- A method for quick but reliable *spatial* assessment of erosion. Interconnection of fields, roads, commons.
- A financial translation of this: investment and benefits per field or land unit.
- Development of a negotiation method in order to persuade farmers to collectively invest in their catchment rather than individually invest in fields. This can only be achieved if the assessments tools mentioned before are understandable and excepted by the farmers (ingredients available from EROAHI).

HIMALAYA-INDIA, NEPAL, PAKISTAN*

Himalayan degradation: An interdisciplinary approach do analyse the dynamics of forest and soil degradation and to develop sustainable agro-ecological strategies for fragile Himalayan watersheds

A) Project setting

1) What was the background and motivation of the project?

Soil and forest degradation in the Himalayan region is a serious threat to agricultural sustainability. Increased anthropogenic activities in an inherently fragile ecosystem with steep slopes and intense monsoon rains have accelerated the various processes of soil and ecosystem degradation. The soil and forest degradation problems in the Himalayan region are caused primarily by human induced marginalized agriculture, livestock grazing, fodder and fuel wood collection, and timber cutting. The high rate of population growth in the region and associated socio-economic development such as rapid urbanization and infrastructure development accelerated and intensified the degradation process. Deeper insights into such a complex and inter-related phenomena are still lacking. The present levels of understanding and systematic analysis of forest and soil degradation are very poor and databases for Himalayan region are non-existent. No monitoring activities are carried out even in cases where such monitoring can be of direct benefit to project-related management activities. The motivation of the project was to gather data that would help increase this level of understanding, and to come up with practical guidelines for managing the fragile ecosystems in the Himalayan region.

2) What was the institutional context (partners with which cooperated?)

The project was funded in part by EU under '5th framework programme: Confirming the International Role of Community, Research, INCO-DEV, Region Asia', and in part by LNV. The research partners were the Agricultural University of Norway (AUN), Alterra, the University of Wales at Swansea, Forest Research Institute (FRI), Pakistan Forest Institute (PFI) and Tribhuvan University.

B) Project objectives

1) What were the initial project objectives?

- The overall objective of the project was to analyse the dynamics of forest and soil degradation processes at the watershed level in the Himalayan region by

* Questionnaire received 2006, revised May 2007; Project leader E. Van den Elsen (Alterra)

incorporating biophysical and socio-economic factors, and to come up with recommendations to combat degradation in this region. The specific objectives of the project were to:

- Review the extent and severity of forest and soil degradation processes and the role of ecological and socio-economic factors responsible for them in the Himalayan region.
- Analyse the ecological and socio-economic impacts of forest and soil degradation for the selected watersheds by using field and laboratory techniques and participatory research methods.
- Develop and apply biophysical and bio-economic models to quantify the forest and soil degradation processes under existing and alternate ecological, technological, and economic regimes.
- Suggest integrated participatory conservation strategies to optimize land use in terms of conservation of forests and soils in the selected watersheds.

2) Have there been any (major) changes to these objectives and for what reason?

No

C) Project activities

1) Which activities were employed to meet the objectives?

The focus was on studying the systems behaviour in its entirety and to develop sustainable management strategies, which are technically feasible, economically viable, and socially acceptable. One catchment was selected in each study country. Within the catchments, field experiments, household surveys and participatory research techniques were used. The collected data were used for GIS-based soil erosion and bio-economic models for the selected watersheds. Data generated by earlier studies was used for estimating temporal change. The emphasis was on capturing the changes in the stock of forests and soil resources, both actual and simulated under alternate policy scenarios. The results of the bio-economic model provided a theoretical basis for identifying the relative importance of different factors that contribute to the degradation processes in the region. These results will enable authorities, farming organizations etc. to define sound policies and regulations aiming at achieving sustainable management of the natural resources in this ecologically fragile region of the world.

The overall project consisted of several activities that were executed by the different partners, which will not be reviewed here. Alterra was responsible for erosion modelling. The focus of the work done by Alterra was as follows.

Installation of equipment

- Equipment to measure rainfall, soil moisture content and discharge was installed in all 3 countries.
- Manuals were written to allow the local partners to collect the data and to maintain the equipment.

Training

- The local partners were trained to use the equipment and to collect the other input data that are necessary for the erosion model.
- A training course was given in Wageningen, in which the partners learned to use the erosion model itself (AUN gave a similar course on the bio-economic model in Delhi).

Data analysis

- Data received from the local partners were analysed, and input datasets for the erosion model were created. Processed data were shared with the partners.
- Maps of land use and elevation were made based on Remote Sensing imagery.

Erosion simulations

- An erosion model was applied to catchments in India and Nepal, but could not be applied in Pakistan because of lack of data.
- Some land use scenarios were also simulated with the erosion model to predict the effect land use change would have on soil erosion.

2) Can you identify disciplinary and multi-disciplinary activities?

The overall project had a multi-disciplinary character, with researchers with different backgrounds (economics, social sciences, remote sensing, soil science) working together. Maps were made in close collaboration with Swansea. Land use scenarios were discussed with AUN. AUN also worked closely together with the partners in the Himalayan Region to apply a bio-economic model, which for its input data was dependent on participatory interviews with local stakeholders. Each partner had a distinct (disciplinary) work package, the results of which were integrated into the other work packages.

D) General project outputs

1) What are the scientific contributions of the project (to RDSA methodology or more general scientific contributions)?

- Several scientific articles.
- Several project reports were written and made available internationally through the internet.
- The data that was collected in the field, the project results and programmes that were used (e.g., the soil erosion model LISEM) were made available to all project partners.

2) What are policy-relevant findings of the project for Dutch and for Southern policymakers?

The results showed the importance of an integrated approach to sustainable resource management. Sustainable development is only possible if physical degradation is prevented, if ecosystems are preserved, if production is maintained and if the development directions proposed are acceptable to the local stakeholders.

3) What are the outputs in terms of capacity-building and partnerships?

Capacity building

- Partners were trained in the use of equipment for measuring rainfall, soil moisture and discharge. They also learned how to apply the erosion model LISEM, and how to collect the input data necessary for this model. Local people were also involved in the measurements.
- Several students did their internship in the framework of the project.
- After the project ended, the models (software), data used, results and equipment were given to the partners in India, Nepal and Pakistan.
- The final workshop of the project (held in 2006, in Shimla, India) presented the results of the project to a wider audience, including policymakers.

Partnerships

Several partners collaborated closely in the project.

E) Tangible outputs, dissemination and impact

Can you describe for the (max. 10) key outputs of your project:

1) Type of output

Research reports, papers and databases

2) Dissemination of output/results (examples of dissemination: papers + articles; policy briefs; policy workshops; scientific conferences and workshops; website)

- Website (on the North-South portal) and on the AUN server.
- Several papers have been submitted to, e.g., Remote sensing of the Environment and the International Journal of Ecology and Environmental Sciences. One of these was published in 2007, and the others are still in the process of being published.

3) Have your results been used, and if yes by whom, where and how?

Most publications have not appeared yet, and those that have were published only recently. It is, however, expected that the results will find their way to both local scientists, and local policymakers, as the International Journal of Ecology and Environmental Sciences is published in India, and is, therefore, well accessible in the region.

4) What has been the benefit or impact (indicate evidence of impact, e.g., page hit count)?

Scientific publications are still in the process of being published.

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

1) Future research on Rural Development and Sustainable Agriculture

An integrated, multi-disciplined approach is crucial to analysing sustainable land use issues in poor regions. The problems in these regions are usually multi-dimensional and technical solutions should always be combined with an analysis of the socio-economic settings and conditions.

2) The role of research in generating policy-relevant information in support of LNV and other policy institutions

Research questions should closely be aligned to the priorities and interests of policymakers and local stakeholders.

3) Partnerships and development efforts in the South

Good partnerships with (research) institutions in the South are crucial to the success of an international research project. Establishing and developing networks with partners in the South is important to Wageningen UR. Vice versa, research institutions have a benefit in collaborating with Wageningen UR institutes with respect to extending their research agenda into new areas or working with new models (and software), obtaining funds and receiving training.

G) Unfinished business and future challenges

1) Which important things remain to be done that could not be achieved by the project?

Not enough data could be made available to run the erosion model and the bio-economic model for all study areas. The reason was political instability, which made it dangerous for local scientists to collect data in the field (Nepal) and which prevented scientists from western institutes from visiting Pakistan. Had enough data been available, insights might have been gained from comparing the model results from the different study areas with each other.

2) Which important challenges in the area of RDSA in the tropics are there in the near future (say 5 to 10 years)?

The main challenge in the Himalayan region is to achieve sustainable development given pressures created by increasing population.

3) What type of research could contribute to addressing these challenges?

Multi-disciplinary research is needed, because sustainable development is only possible if physical degradation is prevented, if ecosystems are preserved, if production is maintained and if the directions proposed are acceptable to the local stakeholders.

IRMLA*

Integrated resource management and land use analysis in East and South-east Asia

A) Project setting

1) What was the background and motivation of the project?

IRMLA is a follow-up to the SysNet project, a research collaboration between IRRI, Wageningen UR and four NARS in South and South-east Asia, operating between 1996 and 2000. The aim of SysNet was to develop systems approaches and applications to regional land use scenario analyses. Main donor was the Ecoregional Fund (www.ecoregionalfund.com). Co-sponsors included IRRI and DLO International Cooperation Programme (330).

IRMLA was set up to bridge the gap between ongoing work on Natural Resource Management (NRM) problems at plot/field/farm level and regional land use explorations, and, henceforth, develop a multi-scale approach to land use analysis and associated tools; these were supposed to be evaluated under different biophysical and socio-economic settings in Asia. This set-up responded to earlier specific requests made by local stakeholders (planners, local government officials, mayors) during the final SysNet stakeholder meetings. Summarizing, the overall goal of IRMLA was to expand the SysNet land use analysis methodology in width, in length and in depth:

- In width (stronger incorporation of environmental impacts)
- In length (incorporation of long term effects)
- In depth (incorporation of farmers' decisions)

Context: Growing populations, expanding economies and urbanization in South, East and South-east Asia have brought issues concerning competing claims on natural resources to the fore. As agricultural systems intensify and diversify in order to meet the multiple objectives of rural societies (food security, higher income and increased employment) they must do so by optimizing resource use efficiency. Research on resource-use efficient technologies at field or farm level alone will not suffice to solve the problems, but needs to be combined with resource use and policy analyses at different higher or 'regional' (district, provincial) decision levels.

To this end, IRMLA project aimed at development and application of research tools to enable the identification of potential conflicts among resource uses and support the search for land-use options that best would match the various rural development objectives. Evaluation and application was performed in four case

* Questionnaire received 2006, revised May 2007; Project leader R. Roetter (Alterra)

study regions at sub-national levels, including, at least, two levels of analysis (e.g., farm and district).

2) What was the institutional context (partners with which cooperated?)

The EU-INCO-dev project consortium was composed of eight research institutes from five countries:

- Alterra Green World Research Institute (Alterra), Plant Research International (PRI) and Group Plant Production Systems (PPS), Wageningen UR, The Netherlands
- Zhejiang University (ZU), P.R. China
- National Institute for Soils and Fertilizers (NISF), and Cuu Long Delta Rice Research Institute (CLRRI), Vietnam;
- Mariano Marcos State University (MMSU), Philippines
- Institute for Meteorology and Climate Research (IMK-IFU), Forschungszentrum Karlsruhe, Germany

Four regional studies were carried out together with different stakeholders (policy-makers, planners, farmers) from: (i) Omon district, Cantho province, Vietnam (ii) Tam Duong district, Vinh Phuc province, Vietnam (iii) Dingras/Batac municipality, Ilocos Norte, Philippines and (iv) Pujiang county, Zhejiang province, P.R. China.

B) Project objectives

1) What were the initial project objectives?

The main objectives of IRMLA were:

- to develop scientific-technical approaches that support development of sustainable land use systems through informed decision-making on resource use at various hierarchical levels, and policy design
- to develop operational tools integrated in a decision support system for multi-scale analysis of land use systems and appropriate policy interventions, and
- to design innovative production systems that produce sufficient food and that are resource-use efficient and tailored to sustainable land use.

2) Have there been any (major) changes to these objectives and for what reason?

Objectives have not been changed.

C) Project activities

1) Which activities were employed to meet the objectives?

The work concentrated on effective farm level integration of recent research results from field level on natural resource management (NRM) and regional policy evaluation. Five major activities can be distinguished:

- Examination of the broad scope for technology and policy changes and identification of technically feasible, short (2001-2005) and long term (2010-15) development scenarios for (four) selected regions in E and SE Asia.
- Further development of the multiple-goal linear programming technique (IMGLP) and its operationalization in the form of the land use planning and analysis system (LUPAS) for land use explorations at the regional level – making use of most recent GAMS commercial software components.
- Development of farm household models (FHM) for analysing the options for optimizing resource-use (e.g., intensification of cropping systems or growing new crops) within the constraints (e.g., the availability of labour and capital and the product prices) at the farm level.
- Development of Technical Coefficient Generators (TCG) that describe the input-output relationships of all relevant production activities (i.e., yields and costs for feed, fertilizers and other inputs for the main cropping and animal production systems) for present and possibly future production techniques; these relationships are used in IMGLP and FHM.
- The integration of results from farm household modelling with the regional policy analysis framework, and the analysis of effects of policy interventions on the adoption of improved (knowledge-intensive) management practices and assessment of their contribution to regional development goals for the various case studies.

2) Can you identify disciplinary and multi-disciplinary activities?

Most of the activities are multi-disciplinary. For example, agricultural intensification and diversification, technology changes and changing socio-economic conditions strongly interact in the four case study regions characterized by rice-based production systems that are under rapid transition. A major goal is to develop methods and tools that integrate the various biophysical and socio-economic dimensions of alternative land use options. Depending on the assumptions made in future scenarios about technology and policy changes, agricultural production systems, employment and environmental pollution will vary in the study regions (in the Mekong Delta, Red River Basin (Vietnam), Northern Luzon (Philippines) and Zhejiang Province (China)). In general, the changes currently observed cause increasing shortage of scarce natural resources such as water, land and clean air. Agriculture has to compete with other land uses /sectors for the scarce land and water resources. Multi-disciplinary and interdisciplinary approaches are required to be able to make these complex problems transparent and identify technically feasible and socially acceptable solutions.

D) General project outputs

1) What are the scientific contributions of the project?

A major innovation is the development of a multi-scale framework for land use policy analysis (a combination of farm household and regional land use optimization models, and other component models (e.g., expert systems to quantify input-output relations of various current and future alternative production activities)). A related innovation is, that the design and evaluation of this framework has been carried out jointly with local stakeholder platforms in four different regions.

IRMLA has put emphasis on communication of results to both the scientific community and to regional stakeholders (including provincial and national planners and policymakers).

A considerable number of international journal /peer-reviewed papers have been published and many more are in press (a special issue of Agricultural Systems is in the making), submitted or completed; moreover, the project produced several technical reports, six project reports, international workshop proceedings, posters and newsletters – most of these are available from the project site: www.irmla.alterra.nl Operational tools (Linear Programming (LP) models and technical coefficient generators) have been made available via internet.

2) What are policy-relevant findings of the project for Dutch and for Southern policymakers?

Example: Pujiang, Zhejiang Province

Scenarios

Recently, FAO proposed five main strategies to reduce hunger and poverty and to improve the livelihoods of farm households: (i) intensification of existing production systems, i.e., increasing factor productivity through greater use of external inputs per unit area or per animal, (ii) diversification of production and processing, i.e., the allocation of production resources among different income-generating activities, (iii) expansion of land holding or herd size, (iv) increasing off-farm income, both agricultural and non-agricultural, and (v) complete exit from the agricultural sector. For Pujiang, we have defined four scenarios, in addition to a reference scenario representing the current situation that is used as a benchmark for the results of the other scenarios. The four scenarios refer to the first three poverty reduction strategies, while the fourth scenario combines the last two poverty reduction strategies. The strategies to increase off-farm income and to exit from agriculture are to a certain extent interrelated as both depend on the generation of employment opportunities outside the agricultural sector.

Results

Results of the reference and the four alternative future scenarios for Pujiang are presented in Table 1. Similar scenario analyses, tailored to the goals and aspirations of stakeholders have been performed for the three other case studies (Omon and Tam Duong in Vietnam and Dingras in the Philippines).

Intensification Land use allocation in this scenario is not different from the reference scenario (Table 1). However, land use activities with improved nutrient recoveries are selected resulting in a reduction in nitrogen surplus of 130 kg N ha^{-1} compared to the reference situation, caused by lower nitrogen inputs in cropping systems. The manure nitrogen surplus increased by about 20% due to increased feed intake with a higher nitrogen content and the associated higher animal productivity. Land use activities with mechanized field operations are selected on 34% of the area under the rice-vegetables systems in this scenario, but not for other systems. These labour-saving activities are sufficiently remunerative and contribute to solving the labour constraints that limit a further increase in economic returns. Labour bottlenecks in this scenario are associated with harvesting of vegetables and fruits, and operations in woody ornamentals for which no mechanized alternatives were defined. Although the costs of production in cropping activities are lower than in the reference scenario, the major share of the 6% increase in per capita income and land productivity is derived from higher returns from livestock activities.

Table 1. *Results (in units per year) of the reference, intensification, diversification, land expansion and exit scenarios*

Indicator	Unit	Ref.	Intensi-fication	Diversification		Land expansion	Exit
				D1	D2		
Labour income	CNY/pers	12,850	13,610	15,920	16,050	14,772	15,540
Land productivity	CNY/ha	62,250	65,920	77,110	77,720	58,716	60,180
Share active agri-cultural population	%	32	32	35	63	33	35
N surplus	kg N/ha	425	296	412	237	251	283
Biocide index	-	756	758	747	747	632	664
Ratio agricultural area per forest area	-	0.46	0.46	0.46	0.46	0.56	0.46
Land use:							
Rice	ha	6,805	6,804	6,521	6,521	6,701	6,660
Vegetables	ha	3,745	3,745	3,584	3,584	3,685	2,896
Rice-vegetables	ha	3,309	3,210	3,654	3,653	3,373	3,436
Fruits	ha	8,107	8,107	8,162	8,162	13,183	9,146
Woody ornamentals	ha	1,395	1,395	1,340	1,340	1,396	1,105
Animal population	%	100	100	200	200	100	100
Labour force	%	100	100	100	100	100	80
Share unused manure in N surplus	%	22	39	57	0	38	41
Cropping intensity	%	1.75	1.75			1.62	
Mechanized activities	%	0	5	11	11	12	15

Diversification First, Table 1 shows the scenario results for D1 and D2 – i.e., when the number of animals in Pujiang is doubled. In scenario D1, manure is not used in cropping systems, while in scenario D2 it contributes to the nutrient requirements of cropping systems. The slightly higher per capita income and land productivity in D2 compared to D1 is a consequence of the lower costs for fertilizers, while manure is available at no costs and only requires labour for transport and distribution in the field. Manure application in cropping systems increases the participation in the active agricultural labour force (from 35% to 63%), indicating the labour-intensity of transport and distribution of manure. Concurrently, it results in a much lower nitrogen surplus in scenario D2 than in D1 and in the previous scenarios, as witnessed by the share of unused manure in the nitrogen surplus. In scenario D1 the opposite trend is observed, i.e., the share of unused manure in the regional nitrogen surplus increases to 57% due to the larger number of manure producing animals.

Agricultural land expansion The less fertile soils that become available in the land expansion scenario, are only used for fruit production (Table 1), the most profitable and least labour-demanding activity. Although average land productivity is 11% lower than in the intensification scenario, per capita income is 8% higher.

Exit from agriculture We show in Table 1 the consequences of a 20% reduction in the agricultural labour force of Pujiang. Total regional economic surplus decreases less than the agricultural labour force, so that overall per capita income is 14% higher than in the intensification scenario. In contrast, land productivity is about 9% lower, due to the change from vegetable production to the less labour-demanding, but also less profitable fruit production.

Conclusions

Location-specific socio-economic conditions, such as access to labour and product markets, and biophysical conditions, determine the potentials for and constraints to diversification, adoption of technological innovations and productivity increase in rice-based cropping systems. Furthermore, in many parts of E and SE Asia the current production structure, i.e., small land holdings with high labour/land ratios, limits the choice portfolio of farmers for applying new farming activities and technologies. Here, we have explored the consequences of four major poverty reduction strategies at the regional level.

Diversification towards livestock production seems the most promising strategy to increase per capita income. However, to avoid environmental problems (N-surplus) that might interfere with environmental protection, manure should be applied efficiently in cropping systems. In that respect, the scope for expansion of animal husbandry seems limited in Pujiang, as the cropping systems can accommodate only a restricted quantity of manure nitrogen, and manure produced in excess of that level negatively affects the environment. It is remarkable that the N surplus in the reference scenario and in D1 is identical, despite a doubling of the number of animals in the last scenario.

The increased N surplus due to more animals in D1 is completely compensated by the more efficient nutrient utilization in the cropping systems through site specific nutrient management. This illustrates the impact of improved nutrient management in cropping systems and the derived environmental benefits, as also is shown in the intensification scenario. In contrast, the effects of improved nutrient management on per capita income seem to be only slightly positive which may hamper their adoption by farmers.

Incorporation of manure in cropping systems is very labour-demanding and thus significantly increases regional labour participation, although it may be questioned whether this would represent ‘gainful’ employment. More important is its favourable effect on the N surplus. The share of manure nitrogen in the N surplus ranges from 20 to 60% across scenarios and when animal husbandry further expands and/or intensifies policy measures and new technologies should be designed to guarantee application of manure in cropping systems in an efficient way to avoid environmental problems.

The exit strategy contributes to a reduction in rural poverty, but this scenario is only realistic under sufficient availability of non-agricultural employment opportunities. For Pujiang, located near industrialized zones and given the impressive economic growth in China, this would seem a feasible development from an economic point of view. However, in the present situation in China such a development may have serious social consequences. For most rural inhabitants, land serves as an old-age insurance, and they will, therefore, be reluctant to give up their land rights.

Underemployment in the agricultural sector is difficult to tackle within the current structure, as certain peak periods (beside possible market constraints) prevent further expansion of labour-demanding crops (vegetables and woody ornamentals) and thus a larger participation of the available labour force in the regional production. This can only be solved through import of temporary labourers from outside Pujiang or the mechanization of operations in these peak periods, such as harvesting of vegetables and fruits. Machinery for this type of operations is underdeveloped, which calls for research and development in the field of agricultural mechanization. Such mechanization will alleviate labour constraints in peak periods and will further increase labour and land productivity.

The results from this study illustrate some of the trade-offs at stake between per capita income and environmental quality objectives in Pujiang.

3) What are the outputs in terms of capacity-building and partnerships?

IRMLA has invested considerably in capacity building of local NARS with respect to new research methods (through specific and formal training) and through initiating and maintaining multi-stakeholder processes in the four study regions. The project has strengthened partnerships between European and Asian research organizations and local stakeholder platforms – and among Asian NARS and, in particular, between NARS and local governments. Continuation of research partnerships is warranted through exchange of students (PhD and MSc) between Asian and European partners (a.o. three PhD projects); some follow-up projects are being formulated; possibilities for new partnerships have been opened by inviting a number of other research groups to an international conference (SUMAPOL 2005) that was organized by the project.

E) Tangible outputs, dissemination and impact

- For the scientific output, see point D1 (and section Output at the end);
- Other scientific output and project activities are described under points C1, D2 and D3;

- Within four years, numerous presentations have been made on project results to the local governments and stakeholder platforms in the four regions (at least twice per year) – moreover, final results for the Chinese case study have been presented to policymakers (representatives from three Chinese national ministries and provincial governments, and the agricultural counsellor of the Dutch Embassy in China). Results have also been presented in three international conferences and at national workshops and seminars. (many presentations and papers are available via the project website (12500 hits so far);

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

1) Future research on Rural Development and Sustainable Agriculture

First, while bio-economic models (i.e., simplified representations of reality) are useful for exploring the consequences for agricultural production and resource use for different (plausible) scenarios on technology and policy change, such modelling studies need to be complemented by empirical studies into 'real-world' constraints to technology adoption and implementation of policy measures. Such combination appears to be fruitful but is still very rare.

Secondly, integrated studies and the associated methodology development and evaluation as conducted in IRMLA require considerable and continued financial investments – the more so since the research process is dependent on frequent interaction with stakeholder platforms; this requires time for establishing trust and flexibility and continuity to respond to changing information needs; moreover, time and funding needed for capacity-building for such integrated methodologies are generally high; this seems a weak point in times of declining investments in agricultural research with a tendency to shorter funding periods; strategic partnerships should be emphasized; means have to be found to maintain long-term research collaboration.

2) The role of research in generating policy-relevant information in support of LNV and other policy institutions

Integrated scenario studies (combining farm and regional analyses) are effective in producing policy-relevant information. Such studies are able to show the integrated results from different policies, the interaction between different factors (e.g., changes in land use, agricultural intensification, environmental protection, changing consumption patterns, etc.), and the trade-offs between factors (e.g., income and environmental effects) at farm and regional level. The constraints and opportunities identified for the farm level can be taken into account in the formulation of regional interventions to arrive at feasible and meaningful management strategies and policy options.

3) Partnerships and development efforts in low-income countries

IRMLA project illustrates that long term investment in capacity building of NARS pays off for all parties involved. For NARS by enabling them to respond to requests from local governments and other organizations for policy-relevant information; for Wageningen UR by creating a platform for exchange of students and for local governments and other stakeholders by receiving more tailor-made information.

4) Interactions between research and decision makers, both in The Netherlands and in the low-income countries

In The Netherlands, the work in IRMLA has stimulated and intensified collaboration and dialogue between Wageningen researchers and officials from LNV on the future role of agricultural science for rural development and sustainable land use. IRMLA has fostered fruitful South-South research collaborations and has led to a number of similar policy-oriented studies carried out independently by NARS in Asia on request of local governments or international organizations.

5) Which insights were gained by employing a multi-disciplinary methodology that would have been missed by disciplinary research?

   See point F2 above.

G) Unfinished business and future challenges

1) Which important things remain to be done that could not be achieved by the project?

Still, efforts should be made to translate more of the numerous and valuable research findings into policy briefs for decision makers in The Netherlands and for the partner countries in the South.

2) Which important challenges in the area of RDSA in the tropics are there in the near future (say 5 to 10 years)?

To develop a holistic approach to generation and dissemination of knowledge on efficient and sustainable agricultural production systems; to gain more insight into factors facilitating implementation of sustainable land use and rural development options.

3) What type of research could contribute to addressing these challenges?

- Integrated agricultural systems analyses – combining scenario analyses and empirical studies;
- Integrated studies in representative case study areas.

H) For completed projects

1) What has happened since your DLO-IC project was completed?

Project is just completed; most efforts aim at communicating research results; much less is done for the dissemination of results to local stakeholders/a broader audience.

2) Are there follow-up proposals developed and to whom are they submitted?

See H1; follow-up proposals have been developed by NARS (e.g., application of the methodology by CLRRI to another province in the Mekong delta) and in the framework of the 'Kennisbasis' of Wageningen UR to further develop the multi-scale land use analysis methodology.

Output

International journal/doubly reviewed proceedings papers

Published:

Van Ittersum, M.K. Roetter, R.P., Van Keulen, H., De Ridder, N., Hoanh, C.T., Laborte, A.G., Aggarwal, P.K., Ismail, A.B. and Tawang, A. (2004). A systems network (SysNet) approach for interactively evaluating strategic land use options at subnational scale in South and South-east Asia. *Land Use Policy*, 21, 101-113.

Roetter, R.P., Van den Berg, M.M., Hengsdijk, H., Wolf, J., Van Ittersum, M.K.,Van Keulen, H., Agustin, E.O., Tran Thuc Son, Nguyen Xuan Lai, Wang Guanghuo, and Laborte, A.G (2004). A dual-scale approach to integrated resource management in East and South-east Asia. CD-ROM proceedings (June 2004) In: C. Pahl-Wostl, Schmidt, S., Rizzoli, A.E. and Jakeman, A.J. (eds.), Complexity and Integrated Resources Management, Transactions of the 2nd Biennal Meeting of the International Environmental Modelling and Software Society, Manno, Switzerland, Volume 2, pp. 612-618. iEMSs, June 2004.

Hengsdijk, H., Van den Berg, M.M., Roetter, R.P., Wang, G., Wolf, J., Lu, C.H. and Van Keulen, H. (2005). Consequences of technologies and production diversification for the economic and environmental performance of rice-based farming systems in East and South-east Asia. In: K. Toriyama, K.L. Heong and B. Hardy (eds.), Rice is life: scientific perspectives for the 21st century. World Rice Research Conference, Tsukuba 4-7 November 2004, Japan, (WRRC 2004 Proceedings, Session 14, pp. 422-425).

Roetter, R.P., Hoanh, C.T., Laborte, A.G., Van Keulen, H., Van Ittersum, M.K., Dreiser, C., Van Diepen, C.A., De Ridder, N. and Van Laar, H.H. (2005). Integration of Systems Network (SysNet) tools for regional land use scenario analysis in Asia. *Environmental Modelling & Software*, 20, 291-307.

Fang, B, Van den Berg, M.M., Wang, G. and Roetter, R.P. (2005). Identification of technology options for reducing nitrogen pollution in cropping systems of Pujiang. *Journal of Zhejiang University Science*, 6B, 981-990.

Mai van Trinh, Leopold, U., Van Keulen, H., Nguyen Dinh Dong and Roetter, R.P. (2005). Mapping uncertain nitrogen concentration in shallow ground water under intensive farming. Proceedings, ACRS 2005, The 26th Asian Conference on Remote Sensing, 7-11 November 2005, Hanoi, Vietnam. (CD-ROM Proceedings).

Ewert, F., Van Keulen, H., Van Ittersum, M.K., Giller, K., Leffelaar, P. and Roetter, R.P. (2006). Multi-scale analysis and modelling of natural resource management options. In: A. Voinov, A.J. Jakeman and A.E. Rizzoli (eds.), Proceedings of the iEMSs Third Biennial Meeting "Summit on Environmental Modelling and Software. International Modelling and Software Society, Burlington, USA, July 2006. CD ROM. Internet: http://www.iemss.org/iemss2006/sessions/all.html

Ponsioen, T.C., Hengsdijk, H. Wolf, J., Van Ittersum, M.K., Roetter, R.P., Son, T.T. and Laborte, A.G. (2006). TechnoGIN, a tool for exploring and evaluating resource use efficiency of cropping systems in East and Southeast Asia. *Agricultural Systems*, 87(1), 80-100.

Roetter, R.P., Van den Berg, M.M., Hengsdijk, H., Wolf, J., Van Ittersum, M.K., Van Keulen, H., Agustin, E.O., Tran Thuc Son, Nguyen Xuan Lai, Wang Guanghuo and Laborte, A.G. (2007). Combining farm and regional level modelling for integrated resource management in East and South-east Asia. Special Issue, *Environmental Modelling & Software*, 22, 149-157.

Special Session of *Agricultural Systems* (Volume 94, June 2007) on technology and policy options for rice ecosystems in Asia (SUMAPOL 2005):

Roetter, R.P., H. Van Keulen, H. Hengsdijk, M.M. Van den Berg and H.H. Van Laar (Eds) (2007). Sustainable resource management and policy options for rice ecosystems. Special Session, *Agricultural Systems*, 94(3), 763-887.

Roetter, R.P., H. Van Keulen, H. Hengsdijk, M.M. Van den Berg and H.H. Van Laar (2007). Editorial: Sustainable resource management and policy options for rice ecosystems. Special Session, *Agricultural Systems*, 94, 763-765.

Van den Berg, M.M., Hengsdijk, H., Wolf, J., Van Ittersum, M.K., Wang, G. and Roetter, R.P. (2007). The impact of increasing farm size and mechanization on rural income and rice production in Zhejiang province, China. Special Session, *Agricultural Systems*, 94, 841-850.

Hengsdijk, H., Wang, G., Van den Berg, M.M., Wang, J., Wolf, J., Lu Changhe, Roetter, R.P. and Van Keulen, H. (2007). Poverty and biodiversity trade-offs in rural development: A case study for Pujiang county, China. Special Session, *Agricultural Systems*, 94, 851-861.

Van Paassen, A., Roetter R.P., Van Keulen, H. and Hoanh, C.T. (2007). Can computer models stimulate learning about sustainable land use? Experience with LUPAS in the humid (sub-)tropics of Asia. Special Session, *Agricultural Systems*, 94, 874-887.

Submitted/completed manuscripts:

Mai, V.T., Van Keulen, H., Roetter, R.P., Bui, H.H. and Nguyen, V.B. Nitrogen leaching in intensive cropping systems in Tam Duong district, Red River Delta of Vietnam. Submitted to Nutrient Cycling in Agroecosystems.

Mai, V.T., Van Keulen, H. and Roetter, R.P. Nitrogen leaching and nitrogen losses in rice-rice-maize systems on sandy loam soil in Tam Duong district, Red River Delta, Vietnam. (to be submitted to Nutrient Cycling in Agroecosystems)

Mai, V.T., Van Keulen, H., Hessel, R., Ritsema, C., Roetter, R.P. and Thai, P. Soil erosion in Quan Dinh watershed, a hilly area in Tam Duong district, north Vietnam. (to be submitted)

Mai, V.T., Hessel, R., Van Keulen, H., Ritsema, C. and Roetter, R.P. Simulation of soil erosion in Quan Dinh watershed in Tam Duong district, north Vietnam. (to be submitted).

Education (MSc and PhD studies completed at Wageningen and abroad)

PhD

(1) A.G. Laborte, IRRI, Philippines (May 2006, Wageningen University)
(2) Fan Bin, Zheijiang University, China (June 2006, Zhejiang University)
(3) V.T. Mai, NISF, Vietnam (April 2007, Wageningen University)

MSc

(4) N. Suijkerbuijk, Netherlands (June 2005, Wageningen University)
(5) C. van der Heide, Netherlands (July 2005, Wageningen University)
(6) J. Paalhaar, Netherlands (April 2006, Wageningen University)

VEGSYS*

Sustainable technologies for pest, disease and soil fertility management in smallholder vegetable production in China and Vietnam

A) Project setting

1) What was the background and motivation of the project?

How the idea for the proposal developed:

In the field site of the EroChinut project (http://www.erochinut.alterra.nl/) many of the farmers approached the researchers with questions about vegetables. They complained about all their problems in cultivation, marketing and lack of any extension. After checking the status of vegetable research and extension in Sichuan Province this confirmed what the farmers were complaining about. In addition the observed high doses of agro-chemicals and wide use of forbidden products, made it even more important to develop a project which would deal with this. As LEI was also involved in peri-urban project in Vietnam (funded by an earlier phase of the LNV IC programme) with similar problems, it was decided to submit a proposal to deal with these problems in the two countries. With almost 18 million hectares of harvested vegetable area per year in China and 600,000 hectares in Vietnam it was clear that there is a large need for applied research and extension in the horticulture sector.

As phrased in project proposal:

In many areas of Asia, smallholder farmers are increasingly investing their limited resources in vegetable cultivation as cash crops as they see this as the most promising income generating activity. Vegetable farming is often combined with other market-oriented activities, such as pig raising and fruit trees. However, farmers face problems of poor seeds, increasing crop damage by pests and diseases, and low fertilizer efficiency. More and more agrochemical inputs are used to overcome these problems (fertilizers and synthetic pesticides), with increasing environmental pressure on the local environment. A further problem is the considerable fluctuation in market prices for vegetables from one season to the next. The combination of low fertilizer efficiency and high use of synthetic pesticides means that this activity is rapidly becoming *environmentally* unsustainable. The high requirements for agrochemical inputs in combination with fluctuating market prices make this new activity *economically* unsustainable.

* Questionnaire received 2006; Project leader S. Van Wijk (Alterra)

2) What was the institutional context (partners with which cooperated?)

Institutes	Country
Agricultural Economics Research Institute (LEI)	The Netherlands
Alterra Green World Research	The Netherlands
Applied Plant Research (PPO)	The Netherlands
Soil and Fertilizer Institute (SFI)	China
College of Agricultural Economics and Trade (CAET), Sichuan Agricultural University	China
Universität Hannover (UHANN)	Germany
Consejo Superior de Investigaciones Científicas (CSIC)	Spain
Hanoi Agricultural University (HAU)	Vietnam

Cooperation with other organizations/institutes (non project partners):

CIRAD, IFPRI, FAO Vegetable IPM programme, RIFAV, private sector (Fresh Partners, Metro, East West Seeds and Syngenta)

B) Project objectives

1) What were the initial project objectives?

1. To identify and analyse the key biophysical and economic constraints to productivity, profitability and sustainability of smallholder vegetable farming systems.
2. To develop and test in a participatory manner improved pest and disease management techniques in vegetable farming systems with increased efficiency of use, effectiveness and reduced impact on the environment.
3. To develop and test in a participatory manner improved soil fertility management techniques in vegetable farming systems that improve both productivity and long-term sustainability.
4. To identify marketing strategies that increase the profitability of vegetable production.
5. To make information on developed technologies widely available to farmers and to formulate complimentary policy and programme options at the local or regional level to promote adoption of the improved production techniques.

2) Have there been any (major) changes to these objectives and for what reason?

In addition to Objective 4 ‘Identifying Marketing Strategies’, the project team also took the step to apply these strategies in Vietnam. It became an important objective in the project to ‘Link smallholders to high-end consumer markets’.

C) Project activities

1) Which activities were employed to meet the objectives?

Identification of key constraints to productivity, profitability and sustainability

- Participatory tools and techniques were used to characterize the vegetable production systems in the study regions, including key constraints to pest and disease management, soil fertility and marketing.
- A detailed quantitative survey (n = 124) of the production systems covering an entire production year were carried out using the NUTMON methodology (see www.nutmon.org).

Improved plant protection and soil fertility management strategies

- Participatory Technology Development.
- Based on the qualitative and quantitative diagnosis farmers and researchers screened and tested a wide range of promising environmentally friendly plant protection techniques and improved in farmers' fields. In addition, biological monitoring of pest populations and disease epidemics were recorded through the whole production cycle. After this first round of screening, the most promising techniques were selected to combine testing with soil fertility management practices.

Pesticide leaching

- The project addressed the off-site environmental issue of synthetic pesticide use by using a simulation model for pesticide leaching and accumulation. This resulted in recommendations on dose rates and methods for specific crops, soil types and local topographical conditions.
- Adoption of the PEARL model to local circumstances in China and Vietnam.

Marketing strategies

- The third key element is the marketing system for vegetables in the study areas. A standard marketing analysis framework was applied to examine market structure and performance (SCP framework).
- Value chain research with large quantitative surveys among all chain actors (collectors, traders, wholesalers, traditional retailers and modern retailers).

Dissemination and recommendations

- Organization of feedback meetings with farmers, traders, extension and other stakeholders.
- Dissemination of results through the popular media (TV and Newspapers).
- Policy level workshops were organized in both countries.
- Presentation of results in national and international conferences.
- Publication of results in scientific journals.

2) Can you identify disciplinary and multi-disciplinary activities?

The following disciplines were actively involved in the project:

- Marketing researchers
- Agriculture economists
- Soil scientists
- Entomologists
- Pathologists
- Agronomists
- Hydrologists
- Environmental scientists

For the identification of key constraints to productivity, profitability and sustainability a multi-disciplinary approach was needed. This was also needed for the design of the improved production practices experiments.

D) General project outputs

1) What are the scientific contributions of the project (to RDSA methodology or more general scientific contributions)?

- The individual disciplinary scientific contribution for developed countries was not innovative, but both the multi-disciplinary approach and farmer participatory research approach has been very innovative, especially in the context of horticulture in developing countries.
- Farmer participatory research was introduced by the VEGSYS project for the first time in Sichuan province. In Northern Vietnam this was also a relatively new concept.
- The pesticide leaching studies in China and Vietnam where the first of its kind. The in depth quantitative and qualitative studies of vegetable marketing in Sichuan Province were the first which had ever taken place.
- The expansion of the NUTMON tool to monitor:
  - Individual farmer marketing strategies;
  - Pests and diseases; and
  - Active ingredients of pesticides.
- The development of NUTMON into a Participatory Learning Tool for farming through its production of individual farm reports, in which farmers are benchmarked for various financial, agronomic and environmental indicators.

2) What are policy-relevant findings of the project for Dutch and for Southern policymakers?

- The Rapid Diagnostic Appraisals clearly demonstrated the needs of farmers for improved services by local and national governments. These needs were:

- Access to knowledge and applied technologies for horticulture.
- The lack of suitable locally available improved vegetable varieties.
- The need of a certification system for safe vegetables. Farmers were not rewarded by the market if they produced safe vegetables, because people do not believe them. In Vietnam the current certification system is not functioning and consumers have no faith in it.

- Quantification of the low performance of the local horticulture systems. With small changes large improvements can be achieved both in financial, agronomic and environmental performance.
- The results of the monitoring studies demonstrate how much officially forbidden pesticides are used by the farmers and how easily they were to get.
- The application of the pesticide leaching model in China predicts high concentration of pesticide residues in groundwater, upon which many farmers depend for their drinking water.
- In Vietnam, the transformation of old style cooperatives into new style cooperatives does not result in better functioning cooperatives. The approach remains top down. Although very small, farmer producer groups are much more successful.
- Our study of vegetable retailing in Hanoi shows how important the traditional retail sector is as an income generating activity for the poor. The current strengths of the traditional retail sector are expected to maintain its dominant position in the total retail sector. Supermarkets now have a share of 2% of vegetables sold to consumers in Hanoi, this share is expected to grow slowly, but at a slower pace than the total growth in demand for vegetables. But based on experiences in neighbouring countries, it is important for the traditional sector to innovate as on the long run supermarkets will become more important. Most important: innovation is needed in guaranteeing consumers vegetables which are safe to consume. Through cooperation with farmer groups, a few wholesalers and a group of traditional retailers, this should become feasible.
- Our study of sourcing practices by supermarkets in Chengdu (Sichuan province, China) shows that small scale farmers are not necessarily excluded from the supermarket procurement system. Innovative institutions (such as associations and co-operatives) and local governments could facilitate this transition.

3) What are the outputs in terms of capacity-building and partnerships?

Farmers

- 124 farmers were trained in record keeping. All of them received reports in Vietnamese/Chinese with an analysis of their farm, benchmarked with the average of the whole sample. Several training sessions were given to train the farmers in understanding the reports.
- 15 farmers were selected for the Participatory Technology Development process. On farm trials were executed with them. At the start, halfway and at the end of the trial, field days were organized to invite all other farmers in the village to monitor the trials and understand the results.

- One small farmer producer group was selected to benchmark their current production and processing practices with international standards. Based on this an extensive GAP checklist was made, after which the group was trained in understanding what they had to change to meet these standards.

Researchers

- 25 researchers in Vietnam and 16 researchers in China were trained in Farmer Participatory Research.
- 15 researchers in Vietnam and 10 researchers in China were trained in using the NUTMON toolbox.
- 3 researchers in Vietnam and 3 researchers in China were trained in pest and disease monitoring and data analysis.
- 5 researchers in Vietnam and 5 researchers in China were trained in designing, implementing and analysing field experiments.
- 3 researchers in Vietnam and 3 researchers in China have received training in marketing research.
- 2 researchers in China and 2 researchers in Vietnam received training in the PEARL model.
- In China:
  - 2 Chinese researchers obtained their PhD based on work in the project.
  - 2 Chinese researchers obtained their MSc.
  - 1 Dutch student carried out their MSc thesis in the VEGSYS project.
- In Vietnam:
  - 5 Dutch students carried out an MSc thesis in the VEGSYS project.
  - 1 Vietnamese researcher started with his PhD at Wageningen University based upon VEGSYS methodology and data (WOTRO scholarship).

Partnerships

- A partnership with the VEGSYS farmers in one of the research villages in Vietnam was established with a Dutch company. Since its establishment in May 2005 the following milestones have been achieved:
  - A post harvest centre with cold storage facilities was built in the village.
  - Ten farmers (mostly female) are now supplying about 1 ton of fresh herbs per week. About six women from the village are employed by the company to sort, grade and package the fresh herbs.
- A partnership with METRO Cash & Carry has been established. A joint proposal has been developed and plans for sourcing vegetables from VEGSYS farmers are currently worked out.
- A partnership has been established with Syngenta for a project about safe use of pesticides.
- In China cooperation with:
  - Bureau of Agriculture in Pengzhou;
  - Vegetable office of Pengzhou; and

- Horticulture farmer union in Pengzhou
- In Vietnam research cooperation with:
  - CIRAD;
  - RIFAV (Research institute for fruits and vegetables);
  - Farmer Field Schools projects of the Hanoi Farmers Union, a Danish NGO (ADDA);
  - FAO IPM Community programme, and
  - Ministry of Agriculture and Rural Development.

E) Tangible outputs, dissemination and impact

Can you describe for the (max. 10) key outputs of your project:

1) Type of output

- Improved production technologies for four key vegetable crops (garlic, eggplant, wax gourd and wrapped heart mustard) developed and tested with farmers
- 30 project reports have been produced and published on the project website: www.vegsys.nl
- New NUTMON Toolbox version 3.0 with new functions:
  - Monitoring marketing strategies of farmers
  - Monitoring active ingredients of pesticides
  - Monitoring occurrence of pests, diseases and weeds
- New software tool for producing individual farm reports in local languages named Word Access Reporting Tool (WART).
- Linking of NUTMON to PEARL and development of PRIMET: tool for environmental risk assessment.
- Establishment of export integrated quality chain with small farmers in Vietnam.
- Development of GAP checklist with Phuc Thinh cooperative in Vietnam.

2) Dissemination of output/results (examples of dissemination: papers + articles; policy briefs; policy workshops; scientific conferences and workshops; website)

Workshops

- Organization of the seminar “Development of sustainable horticulture in Hanoi province”, March 28th, 2003. 30 different stakeholders ranging from farmer extension, researchers, district level and provincial level government officials.
- Organization of the seminar “Development of sustainable horticulture in Penghzou county”, February 21st, 2004, Penghzou, Sichuan province, China. Participation of 60 different stakeholders ranging from farmer union, traders, county level and provincial level government officials. The meeting was covered by a television station in Sichuan province.
- Organization of two farmer feedback workshops with results of farm monitoring, one in Penghzou (China) and one in Dong Anh (Vietnam).

- Organization of two crop solution development workshops with farmers, one in China and one in Vietnam.
- Organization of two mid-term review workshops with researchers and farmers in Vietnam.
- Organization of trial result workshops in Vietnam with farmers, researchers, extension, farmer union and agriculture district officials. The meeting was covered by a national news paper.

Conferences

Authors	Title paper	Conference
Xiaoyong Zhang, Xinhong Fu and Jinxiu Yang	The Evolution of Chinese Vegetable Supply Chain	International conference of the International Food and Agribusiness Management Association (IAMA), 9-11 June 2004, Montreux, Switserland
Pham Van Hoi, Lin Chaowen and Rik van den Bosch	Leaching potential of pesticides used in peri-urban vegetable farming in Hanoi (Vietnam) and Chengdu (China)	The 4th World Conference of the "Society of Environmental Toxicology and Chemistry (SETAC)", 14-18 November 2004, Portland, USA.
Rik van den Bosch, Lin Chaowen and Pham van Hoi	Inventory of pesticide use and farmers' perception in peri-urban vegetable production in Hanoi (Vietnam) and Chengdu (China)	The 4th World Conference of the "Society of Environmental Toxicology and Chemistry (SETAC)", 14-18 November 2004, Portland, USA.
*M.S. van Wijk, Cuong Trahuu, Bu Thi Gia, Nguyen An Thru and Pham Van Hoi	The traditional vegetable retail marketing system of Hanoi and possible impacts of supermarkets	International conference on Supply Chain Management in Transitional Countries, International Society of Horticulture Science (ISHS), 19-23 July 2005, Chiang Mai, Thailand
*Xiaoyong Zhang, Xinhong Fu, Jinxiu Yang and M.S. van Wijk	Vegetable Supply Chains of Supermarkets in Sichuan, China and their Implication for Supply Chain Management	International conference on Supply Chain Management in Transitional Countries, International Society of Horticulture Science (ISHS), 19-23 July 2005, Chiang Mai, Thailand
*A.P. Everaarts, Nguyen Thi Thu Ha and Pham Van Hoi	Agronomy of a rice-based vegetable cultivation system in Vietnam. Constraints and recommendations for commercial market integration	International conference on Supply Chain Management in Transitional Countries, International Society of Horticulture Science (ISHS), 19-23 July 2005, Chiang Mai, Thailand

*All three papers presented in the ISHS conference will be published in *Acta Horticultura.*

Publications

Xiaoyong Zhang, Jinxiu Yang, Xinfong Fu, 2005. The Vegetable Supply Chain of Supermarkets in Sichuan, China and its Implication for Supply Chain Economics. Forthcoming in *Food Policy*.

M.S. van Wijk, R. Engels, Tran Huu Cuong, Nguyen Anh Tru and Pham Van Hoi, 2005. Opportunities for farmers: 'safe' vegetables for Hanoi. LEISA Magazine, June 2006.

Website

Website available since November 2002: www.vegsys.nl. In the table below the total number of hits till date are presented and from which continent people looked at the VEGSYS website

1.	Europe	2339	64.6 %
2.	Asia	927	25.6 %
3.	North America	157	4.3 %
4.	Africa	41	1.1 %
5.	Latin America	37	1.0 %
6.	Australia	33	0.9 %
7.	Central America	5	0.1 %
	Unknown	81	2.2 %
	Total	**3620**	**100.0 %**

3) Have your results been used, and if yes by whom, where and how?

- As the technologies where developed with farmers the chance of uptake is large. It would probably be the best to have a monitoring and evaluation study to see how many farmers are now using the newly developed technologies.
- Our farm recording, monitoring and feedback system was an important reason for the Dutch company to work with the VEGSYS farmers. Input record keeping is an important requirement for international markets.
- The insight we provided into how farmers manage pest and diseases and why, is important information which is used to design the pesticide safe use programme for Syngenta.
- The insight in marketing and working with farmers formed the basis for the development of a domestic supply chain with a large international supermarket chain in 2006.

4) What has been the benefit or impact (indicate evidence of impact, e.g., page hit count)?

- The full analysis of the field trials will be available by the end of the year. But especially the new eggplant cultivation technology in China will have a large positive financial impact on the smallholders and will lead to much lower pollution levels.
- Farmers who are now supplying the export company achieve higher income levels and because indigenous herbs are exported no pesticides are needed in production. So farmers are switching from vegetables with high pesticide consumption to indigenous herbs for which zero or only little amounts of pesticides are needed.

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

1) Future research on Rural Development and Sustainable Agriculture

- There is an enormous need for more applied research on vegetable cultivation. Especially improvements in agronomic practices can be achieved. Hardly any clear GAPs are available for farmers. The VEGSYS project developed a strong team which can develop GAPs. So far this has been done for four different vegetables, while in one village (of 400 farms) about 30 to 40 different vegetables are cultivated.
- Currently vegetable production is rotated during the year with rice production, which has a very bad impact on soil structure and costs farmers a lot of extra labour. Furthermore, farm income could be tripled if vegetables could be produced year round. The possibilities for such a radical farming system change should be studied and experimented in detail.
- Quantification at both micro and macro level of the impacts of new emerging supply chains (supermarkets) on rural development, poverty reduction and participation of the poor.

2) The role of research in generating policy-relevant information in support of LNV and other policy institutions

The project team generated policy briefs which contain recommendations on how to stimulate a transition towards more sustainable horticulture and poverty reduction.

3) Partnerships and development efforts in the South

- The VEGSYS project had a clear development impact in stimulating rural development by linking the farmers to high end consumer markets. This was done through partnerships with the private sector.
- The permanent presence of the project coordinator in Vietnam stimulated the development of networks with other research projects, institutes, donors and private sector.

4) Interactions between research and decision makers, both in The Netherlands and the South

- Within China and Vietnam a lot of interaction with district and provincial level policymakers was achieved. But this resulted in no clear outputs. Only in Vietnam the intense relations with provincial level policymakers facilitated all arrangements to get permits for the Dutch company to build a post harvest centre in the project village. In China the provincial level policymakers were very interested in the financial results of the farm monitoring, but it is not clear what they did with this information.
- An interesting link was developed with a national level governmental organization (ICAMA) who is responsible in China for the licensing of pesticides for

the Chinese market. They are very interested in using the tools which were developed and tested by Alterra in the VEGSYS, MAPET and MAMAS projects.
- Interaction with Dutch policymakers were limited to the Dutch Embassy in Hanoi and the agricultural councillors in Bangkok (responsible for Vietnam) and Beijing.

5) Which insights were gained by employing a multi-disciplinary methodology that would have been missed by disciplinary research?

- The insights which were gained during the Rapid Diagnostic Appraisal were based on the work of multi-disciplinary teams.
- During the VEGSYS project proposal design a mistake was made by not putting enough attention on agronomy. Thanks to the involvement of PPO, the crucial knowledge of vegetable agronomy became available and was of very big importance for the design of improved production technologies.
- The marketing research linked the farmers to markets where consumers are willing to pay for safe vegetables, which is an important incentive for the farmers to use the improved production technologies.

G) Unfinished business and future challenges

1) Which important things remain to be done that could not be achieved by the project?

- All original project objectives have been achieved but so much more needs to be done to improve vegetable production and marketing.
- It would be very useful to evaluate one year after the project ended if the developed technologies are being used by the farmers.
- Development of clear guidelines for which crops, pest/disease combinations what pesticides (which can be bought on the local market) are the least harmful to use and the specific GAP for that pesticide, crop-pest/disease combination.
- Developing a science-based system for pesticide admission in China and Vietnam.

2) Which important challenges in the area of RDSA in the tropics are there in the near future (say 5 to 10 years)?

- For both the research sites in China and Vietnam the challenge will be how all these smallholders can continue to grow out of poverty. Their small landholdings (0.27 ha per farm), makes it difficult to increase income. The coming 5 years there are still enough improvements which can be made, especially developing a sustainable system of year round vegetable production. But for the longer term it will be important to see how the government can create an enabling environment for good farmers (innovative, entrepreneurs). How can they grow? How can they obtain more land and capital? Land consolidation policies will be very crucial.

- How agro-chemical use by farmers can be influenced by a combination of policies, regulations, and market incentives.

3) What type of research could contribute to addressing these challenges?

- Applied research which can improve productivity of smallholders, especially developing sustainable year round vegetable cultivation systems.
- Policy research to find out how land consolidation should be organized, how land laws can be adjusted and how the growing group of farmers without land can be employed by successful growing farms.
- Impact assessment if government regulations and market incentives with regards to agrochemicals are influencing farmers towards the right direction.

H) For completed projects

1) What has happened since your DLO-IC project was completed?

   Not relevant.

2) Are there follow-up proposals developed and to whom are they submitted?

- Already in the second year of the project a new proposal was successfully submitted to the EU ProEcoAsia programme (see www.mapet.nl).
- A new project proposal on safe use of pesticides was developed and funded: start in 2006.
- A new proposal on linking small farmers to export markets was developed and submitted to a programme of ADB/DFID.

I) Additional information/remarks etc.

I would *strongly* suggest selecting several projects for an independent external evaluation and impact assessment. In my view this should have been a standard procedure for such a large programme as the LNV IC-404 programme.

VINVAL*

Impact of changing land cover on the production and ecological functions of vegetation in inland valleys in West Africa

A) Project setting

1) What was the background and motivation of the project?

In Sub-Saharan Africa, the need for new agricultural land has been a strong argument for the extensive clearing of forests and savannah woodlands. This has resulted in widespread degradation of soils, water and vegetation. In order to preserve these natural resources for the future, there is a need to balance land use for both agricultural production and protection of the environment. The VINVAL project wanted to respond to this need by developing a map-based instrument for land use planning at the scale of small watersheds (<1000 ha), managed by village communities in Burkina Faso and Ghana. The instrument takes into account the balance between production and protection objectives, and assists in making informed decisions on land use activities of small holder farmers on both agricultural and natural land. Such decisions must be based on knowledge of the productive value of agricultural and natural land, and of the ecological functions of natural land. This knowledge was gathered in cooperation with farmers and local experts in the VINVAL project.

2) What was the institutional context (partners with which cooperated?)

The VINVAL consortium consisted of two strong national agricultural research institutes with divisions specialized in ecology and forestry: the Institut de l'Environnement et de Recherches Agricoles (INERA) in Burkina Faso and the Crops Research Institute (CRI) in Ghana. The other partners were European research institutes and universities, specialized in agricultural economics and development sociology (the Agricultural Economics Research Institute (LEI), the Netherlands) and in soil and water resource management for sustainable agriculture (Timesis, Italy; Center for Development Research, University of Bonn, Germany and Alterra, the Netherlands). The VINVAL project is executed under the umbrella of the Inland Valley Consortium (IVC), a large regional research and development consortium working on the sustainable use of inland valleys in West Africa. INERA, CRI and Alterra are founding members of IVC.

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* Questionnaire received 2006, revised May 2007; Project leaders S. Verzandvoort-Van Dijck (Alterra) and C.A. Van Diepen (Alterra)

B) Project objectives

1) What were the initial project objectives?

The overall objective of the project was to develop a tool for integrated land use planning at watershed scale that could contribute to improve sustainable agricultural production systems in inland valleys in West Africa. This tool takes into account the balance between production and protection objectives and should assist in making informed decisions on allocating land use activities of small holder farmers across the watershed on both agricultural and natural land.

Specific scientific and technological objectives were to:

- Quantify the production, regulation (water, sediment and nutrient flows) and biodiversity functions of natural and agricultural ecosystems at farm and watershed scale in three inland valleys in Ghana and Burkina Faso with distinct different land use intensities.
- Assess the economic importance of the tradeoffs and complementarities between natural and agricultural ecosystems and the different functions they provide.
- Develop a GIS-based tool for integrated, multi-functional watershed-level land use planning for use by extension services and planners.

2) Have there been any (major) changes to these objectives and for what reason?

Yes: (a) nutrient flows and groundwater fluctuations were not quantified and the results of the socio-economic survey were only partly processed into the tool due to delays in the release of funds, (b) the tool was tailored to the case study areas in Burkina Faso due to the delay in the supply of information, but not to the areas in Ghana.

C) Project activities

1) Which activities were employed to meet the objectives?

- Set up of project and collection of baseline information (WP1)
  Characterization of inland valleys, village-level interviews, aerial photographs and transect surveys, vegetation description, etc.
- Monitoring activities on various themes and at various scales (WP2-4)
  Biophysical monitoring of regulation functions at field and watershed level: rainfall, runoff and streamflow and components of the mass and energy balances: net radiation (radiometer), soil- (heatflux plates) and sensible heat (scintillometer) fluxes; latent heat flux or evapotranspiration was the closing term.
- Socio-economic monitoring at household level (WP4)
  Collection of socio-economic information at the household level, quantification of the production functions from both agricultural and natural lands, and

inventory of farmer's knowledge and farmer's views on land use processes. To monitor the agricultural and natural land production function, a sample of farmers was selected and visited twice a year (wet and dry season) for the agricultural production information and monthly for the natural production function. The agricultural production function was also measured through yield measurements.

- Development of land use planning tool and its application (WP5)
  Inputs and outputs of the agricultural production systems in the case study areas under given boundary conditions (current and future) were calculated using the technical coefficient generator Technogin (Ponsioen et al., 2004). Inputs and outputs were incorporated in a knowledge system (OSIRIS), where the information was combined with biophysical information and information on production systems on natural land. A user friendly interface was developed to allow easy inspection of results in the form of maps and graphs for different land use scenarios.

2) Can you identify disciplinary and multi-disciplinary activities?

- Disciplinary: inland valley characterization (soils, vegetation).
- Multi-disciplinary: integration of biophysical and socio-economic information in technical coefficient generator and knowledge system, analysis of land use constraints, land use options and stakeholder analysis in Village Planning Workshop.

D) General project outputs

1) What are the scientific contributions of the project (to RDSA methodology or more general scientific contributions)?

Biophysical and socio-economic characterization of inland valleys in study areas
New items are:

- Valuation of natural production systems.
- Highlighting of promising land use patterns and compositions (crops/natural vegetation) based on the application of the land use planning support tools (TCG and GIS-based), providing new perspectives on current land use systems.
- Realizing and testing natural resource and land use mapping exercise with local communities in research villages.
- Analysis of agricultural versus natural production systems.

2) What are policy-relevant findings of the project for Dutch and for Southern policymakers?

- The study area is an area with severe food shortages (especially Burkina Faso); agricultural and natural production systems in the first place serve food provision. However, for the agricultural production systems these are not the most profitable ones. Better benefits can be obtained with other crops and modified cropping systems. The access of farmers to land (tenure restrictions!), hired labour, fertilizers and cash is a vital prerequisite for a change. Future cropping strategies will be limited by access to land and labour.

- The areas have inherent natural constraints to the development of natural and agricultural production systems: variable rainfall causing drought stress for crops and infertile soils. Soils are depleted under current major cropping systems. Together with demand for land due to immigration, these constraints lead to extensification of agriculture (larger field sizes) and provide the reason for continued land clearing. Intensification takes place in the form of shortening fallow periods (from 20 to 2-3 years in Ghana!), which in turn leads to soil nutrient depletion and loss of ecological functions of soils and land cover.
- The study has proven that farmers use, manage and commercialize natural production systems intensively. This need not always lead to the degradation of the natural resource base, as vegetation species valuable to food provision and income are protected by farmers. However, there is no safeguard of ecological functions of natural areas. The study has given insights in the ecological functions of current natural and agricultural land, and on the impacts of land use strategies on these functions.
- State laws and policies heavily impact on the access of people to yet uncultivated (natural) land resources; recognition of farmers' claims on uncultivated land may improve NRM, because people owning land are prepared to invest in it.
- Land use strategies differ between ethnic groups in the areas and within individual households. Through community mapping and planning exercises, the study has provided tools to solve conflict and strengthen synergy options of land use visions from different groups, and to end up with shared visions.
- A natural state of inland valleys is not per se beneficial for the population! Sites with low intensity land use and rich in non-timber forest products, lack extension, technical knowledge and transport facilities. Moreover water shortage problems are also experienced and not to a lesser extent in low intensity valleys.

3) What are the outputs in terms of capacity-building and partnerships?

- Besides providing instruments to support local land use planning processes, the VINVAL project trained researchers in managing the technical side of the instruments, and local field staff in participatory planning approaches, thus, strengthening the capacity for land use planning at the local level.
- Local and regional authorities of Gourma province and Kompienga region were invited to a feedback and discussion forum at the closure of the project in Burkina Faso.
- The project has also resulted in a PhD degree for a student from the study region.

E) Tangible outputs, dissemination and impact

Can you describe for the (max. 10) key outputs of your project:

1) Type of output

- Solid knowledge base on inland valleys in Ghana and Burkina Faso, including information on land use systems (biophysical, socio-economic), vegetation, use preferences of local stakeholders, impact of changing land cover on biophysical characteristics (water, soil quality);
- Participatory land use planning tool;
- Training material for extension officers;
- Scientific papers and working documents.

2) Dissemination of output/results (examples of dissemination: papers + articles; policy briefs; policy workshops; scientific conferences and workshops; website)

   Results have been published:

- On website, including all research papers;
- Numerous scientific publications, mainly by F. Bagayoko, PhD student involved in project;
- Training workshops;
- Regional policy workshop in Burkina Faso.

3) Have your results been used, and if yes by whom, where and how?

The approach of the participatory land use planning has been developed in Ghana and Burkina. The idea was to use this approach also in other member countries of IVC. Funding insecurity has been a major constraint in applying the tool at a regional scale.

4) What has been the benefit or impact (indicate evidence of impact, e.g., page hit count)?

No data on hit count of VINVAL website (http://www.alterra-research.nl/pls/portal30/docs/FOLDER/VINVAL/p_main.htm). But project is mentioned on 146 other websites (data 16 May 2007).

New perspectives on current agricultural production systems through application of a participatory approach, technical coefficient generator and GIS-based land use planning tool.

Analysis of agricultural versus natural production systems:

- Constraints and opportunities of both types, trade-offs and complementarities;
- Base material for developing land use scenarios;
- Village Planning Workshops;
- Training material for extension officers and researchers;
- Papers, policy workshops.

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

1) Future research on Rural Development and Sustainable Agriculture

Use a wider scale than the village or the watershed. Market influences, livestock, fauna and social networks reach far beyond the limits of a village or a watershed.

2) The role of research in generating policy-relevant information in support of LNV and other policy institutions

The role of research is important in highlighting links between biophysical and socio-economic situations which provide the basis for policy-relevant information, but research is slow and hampered by practical problems in large projects in African countries (communication, funds transfer). The bulk of interesting results cumulates at the end of projects, when time is short for integration and exploitation by coordinating parties.

3) Partnerships and development efforts in the South

Research should link up with the interests and problems of local stakeholders. Their perspective can improve scientific tools and integrating them into the research process leads to better understanding and insights. Working with researchers and research institutes in the South is key to make the link with local stakeholders. However, the capacity of national research institutes, especially in poor countries, is often limited. Research must deal with constraints such as poor infrastructure (transport, computers, etc.), which can only be partly solved by the project itself.

4) Interactions between research and decision makers, both in The Netherlands and the South

Involving decision makers in the South greatly improves the effectiveness of research, but is not always easy. Decision makers are usually involved in many issues and research may not always be their first priority.

5) Which insights were gained by employing a multi-disciplinary methodology that would have been missed by disciplinary research?

There is an intricate link between agricultural and natural production systems, though they are very differently valued by user groups even within the same village community. Besides technical and biophysical aspects, socio-economic aspects greatly influence the management of agricultural and natural production systems by small holder farmers in the studied region. This would not have come out of mono-disciplinary research into, e.g., the biophysical fluxes, the floristic composition or the socio-economic setting only of the inland valleys studied.

G) Unfinished business and future challenges

1) Which important things remain to be done that could not be achieved by the project?

Collection of accurate data (biophysical as well as socio-economical) and fine tuning of prices and other local inputs to the technical coefficient generator. This must be done by researchers from the target countries. Refinement of scientific definitions and mapping of production and ecological functions.

2) Which important challenges in the area of RDSA in the tropics are there in the near future (say 5 to 10 years)?

Incorporate social networks in analysis of land use systems. Map natural resource management by farmers (diffuse boundaries, overlapping activities).

3) What type of research could contribute to addressing these challenges?

Integrated research from sociologists, economists, soil-vegetation-hydrology scientists and GIS-experts.

H) For completed projects

1) What has happened since your DLO-IC project was completed?

Limited availability of funding hampered the regional use of the tool developed in other IVC countries. VINVAL partners are looking for funding opportunities for strengthening the tool and calibrate the tool in other IVC countries.

One MSc student from Wageningen University did her thesis research on stakeholder perspectives on the use on natural vegetation for different purposes in Benin and Togo. These activities were coordinated through the Regional Coordinating Unit of IVC.

2) Are there follow-up proposals developed and to whom are they submitted?

No.

RMO-BEIJING *

Resource Management Options in the Greater Beijing Area

A) Project setting

1) What was the background and motivation of the project?

During the 1990s, China's urban population has grown by about 10 million per year, to a total which is estimated at 430 million. It has been estimated by some urban planners that by 2015, 40% of the population will be living in urban areas, bringing the total to about 670 million. This urbanization process and rising incomes are important driving forces behind changes that occur in the agricultural sector, and the impact of this sector on the environment. For example, people living in urban areas, eat on average twice as many eggs and 50% more meat than people in rural areas. The associated increase in animal production causes pollution of the environment. Also, the increasing production of horticultural crops around urban areas that generally require large fertilizer and biocide applications, has shown negative effects on the environment.

For the Beijing Municipality the quantity of available water resources and the quality of the available water have already become matters of major concern. Rapid urbanization and the strong intensification of the agricultural sector have led to serious water scarcity and, at many places, to poor quality of the water resources. Finding sustainable solutions requires, among others, integrated planning, which takes into account the multiple objectives of future land use and the resource constraints.

To analyse these problems and to explore future options for improved resource management, the project *Resource Management Options in the Greater Beijing Area* (=RMO-Beijing-project) was launched in September 2002. The aim of this project is to raise awareness among city planners, policymakers and stakeholders (e.g., farmers) in peri-urban Beijing about the impact of different agricultural production systems and technologies on environmental quality, and in particular water quality, in Beijing Municipality and to identify sustainable options for solving such problems. This is to be achieved by quantifying the impacts of agricultural activities on the degree of pollution and environmental (mainly water) quality, with special attention for the most intensive forms of agriculture such as vegetable and livestock production.

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* Questionnaire received 2006, revised May 2007; Project leaders R. Roetter (Alterra) and C.A. Van Diepen (Alterra)

2) What was the institutional context (partners with which cooperated?)

The Sino-Dutch project consortium was composed of the research institutes BAAS, CAU and IGSNRR in Beijing, China, and Alterra, ID, LEI and PRI of Wageningen UR, The Netherlands.

BAAS	Beijing Academy of Agricultural and forestry Sciences, Institute of Integrated Development of Agriculture, Beijing
CAU	China Agricultural University, College of Rural Development/Center for Integrated Agricultural Development, Beijing
IGSNRR	Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing
Alterra	Alterra Green World Research Institute, Wageningen
ID	Institute for Animal Science and Health, Lelystad
LEI	Agricultural Economic Research Institute, the Hague
PRI	Plant Research International, Wageningen

B) Project objectives

1) What were the initial project objectives?

The main objectives of the RMO-Beijing-project were:

- To create a knowledge base on agriculture-environment interactions for the main agricultural production systems and on main impacts of agricultural intensification;
- To develop tools for analysing alternative land use scenarios;
- To evaluate present land use processes and possible future land use changes with respect to their impact on the water system (quality and quantity);
- To apply these tools to identify the major constraints to achieve sustainable agricultural production systems and to protect environmental quality;
- To explore the agricultural and environmental consequences of changed (e.g., more sustainable) agricultural production systems and land use, and the policy options in close cooperation with the local stakeholders.

2) Have there been any (major) changes to these objectives and for what reason?

Objectives have not been changed. However, project has been stopped during phase 2 because of lacking (external) funds.

C) Project activities

1) Which activities were employed to meet the objectives?

In the first phase of the RMO-Beijing project, information has been collected on the agricultural production systems and land use and on the water use and water resources (both quality and quantity) in the Beijing Municipality. This gave information on the agriculture – environment interactions and on the main impacts of agricultural intensification. This showed for Beijing Municipality that

- Current water consumption is much higher than water supply and consequently groundwater levels have strongly dropped;
- Arable land areas decreased rapidly due to conversion to urban areas;
- Grain cropping areas decreased rapidly and were converted to vegetable crop areas;
- Fertilizer use per hectare increased strongly;
- Total water use for irrigation decreased strongly;
- Livestock numbers increased rapidly, in particular cattle, sheep and poultry;
- Quality of surface waters has deteriorated; and
- Groundwater has severely been polluted.

In the second phase of the project, the first steps of a case study have been executed on pressing issues in Beijing Municipality. These issues are in particular the intensification of agricultural production (i.e., vegetable cropping with high fertilizer use and increasing livestock intensity and production) and its impact on water quality and the competitive demands (i.e., from agriculture and urban areas) on the limited water resources. First, land use and agriculture in Shunyi district (outer suburb of Beijing Municipality) were studied in a Rapid Diagnostic Appraisal (RDA). Officials of government institutions in Shunyi were interviewed and during three days a team of nine Chinese and Dutch researchers visited three townships in Shunyi district and interviewed local leaders and farmers on farm structures, farming systems, water-related issues and future developments. In addition, documentation and statistics about land use development and agriculture in Shunyi have been collected, The resulting RDA-report gives a general description of land and water use developments in Shunyi and the major characteristics of the visited farms and agriculture in general. Second, a farm management survey was implemented using the NUTMON methodology. This survey included 25 farms of eleven different types in the Shunyi district. Analysis of the survey data focused on farm typology, land use, livestock, agricultural nutrient flows and management.

In the planned third phase of the case study, consequences of present and alternative future land use scenarios for agricultural production systems, water resources, water quality, etc. would need to be analysed. Results of such an analysis may indicate the need for changes in land use, water-saving, improved production technologies and more environment-friendly agricultural production systems. For this case study, a most interesting district of Beijing Municipality, Shunyi, was selected. This district strongly shows at present the effects of intensification of agricultural production systems (i.e., high livestock density, high level of fertilizer use) on environmental quality.

In the final phase of the case study, most promising options for future development as based on the case study analyses for Shunyi, and supportive policies will be developed in close interaction with stakeholders. These analyses should indicate the range of possible policies, the future options for urban, industrial and agricultural development, possible conflicting effects of the policies, and the resulting land use, soil and water pollution, water quality, water supply and demand in the case study area for the different policies.

2) Can you identify disciplinary and multi-disciplinary activities?

Main activities are multi-disciplinary. For example, land use change, agricultural intensification, farm management changes and changing socio-economic conditions strongly interact in the peri-urban areas of Beijing Municipality and cause rapid changes in agricultural production systems, employment and environmental pollution and cause increasing shortage of scarce resources such as water, land and clean air.

D) General project outputs

1) What are the scientific contributions of the project?

Wolf, J., Van Wijk, M.S., Xu Cheng, Roetter, R.P., Jongbloed, A.W., Yanxia Hu, Changhe Lu, Van Keulen, H. and Wolf, J., 2003. Urban and peri-urban agricultural production in Beijing municipality and its impact on water quality. Environment & Urbanization 15, 141-156.

Van Diepen, C.A., Van Wijk, M.S., Xu Cheng, Hu, Y., Van Diepen, C.A., Jongbloed, A.W., Van Keulen, H., Changhe Lu and Roetter, R.P., 2003. Urban and peri-urban agricultural production in Beijing municipality and its impact on water quality. Alterra Report 757, ISSN 1566-7197, Wageningen, The Netherlands.

Kamphuis et al., 2004. Agriculture and water in Shunyi district, Beijing. Results of a Rapid Diagnostic Appraisal. Alterra report 950, Alterra, Wageningen, 102 pp.

Vlaming et al., 2004. Agriculture and water in Shunyi district. Results of NUTMON farm management survey. RMO-Beijing Project report no. 1, Alterra, Wageningen, 41 pp.

For more details, see RMO Beijing (LNV-DLO-IC) documentation website: www.rmo-beijing.alterra.nl or via www.splu.nl

2) What are policy-relevant findings of the project for Dutch and for Southern policymakers?

(a) From study on Agricultural Production and Water Quality in Beijing municipality (see above, Van Diepen et al. 2003):

The review of water use and water resources for Beijing Municipality indicates that current water consumption is much higher than water supply and that consequently groundwater levels have strongly dropped. This indicates the need for changes such as water saving especially in agriculture, more wastewater treatment and use of regenerative water, and more run-off interception for use. In the long term, the water supply may be increased by water diversion from the Yangtze river.

The main changes in the agricultural production systems in Beijing Municipality during the last decade are: (1) loss of arable land areas due to conversion to urban areas; (2) rapid reduction in arable land areas and rapid increase in orchards; (3) rapid reduction in grain crop area and rapid increase in vegetable crop area; (4) strong increase in fertilizer use per hectare; (5) strong reduction in total water use for irrigation; (6) shift in livestock from the near-suburbs to the outer suburbs and counties; (7) rapid increase in livestock numbers, in particular cattle, sheep and poultry.

The quality of surface water has deteriorated since the 1970s when the diffuse pollution (from agricultural land areas) increased, as well as total water use by industry and urban life. However, the treated fraction of sewage waste was low and hence, rivers and lakes became severely polluted. The quality of groundwater has deteriorated since the 1980s. The frequency that environmental standards for groundwater were exceeded, was high, in particular for nitrate. Water pollution from agricultural activities is mainly caused by both run-off and leaching of pesticides, organic and chemical fertilizers from in particular the intensive (i.e., characterized by high input levels of fertilizers and biocides) arable and vegetable cropping areas. In addition, the intensive livestock sector and the associated large manure production are major causes for water pollution.

Case studies are to be carried out on pressing issues in Beijing Municipality and other mega-cities. These issues are in particular the intensification of agricultural production (i.e., vegetable cropping with high fertilizer use and increasing livestock density and production) and its impact on water quality and the competitive demands (i.e., from agriculture and urban areas) on the limited water and land resources. Such studies may indicate the need for changes in land use, water-saving, improved production technologies and more environment-friendly agricultural production systems.

Case study analyses should indicate the range of possible policies, the future options for urban, industrial and agricultural development, possible conflicting effects of the policies, and the resulting land use, soil and water pollution, water quality, water supply and demand in case study areas of Beijing Municipality and other mega-cities.

(b) From RDA for Shunyi district in Beijing municipality (small part of discussions):

Officers from Science &Technology Committee of Shunyi

- The key issue for agriculture is how to increase income for farmers;
- Efficiency of the available resources need to be increased;
- Restructuring of agriculture is required;
- Development of secondary and tertiary industries is necessary to increase employment opportunities, particularly for (surplus) rural labour;
- Land is limited in Shunyi, so, agriculture in Shunyi should focus on high value commodities, such as developing breeding animals (pigs and sheep) and seed/ seedling production (vegetables, melon and flowers);

- Rural tourism should be stimulated; leisure, sightseeing, fruit picking by consumers;
- More funds should be made available to create an information platform.

Officers from Water Resources Bureau

- Only 50% of the water demand in Shunyi district can be covered by surface water, because of the high demand of Beijing;
- Reducing runoff loss. Several 100's of million Yuan have been invested in Chaobei He for building dams, to reduce runoff and thus to increase recharge of the groundwater;
- Introduction of new irrigation systems (e.g., drip irrigation) is recommended;
- All enterprises are encouraged to collect rainfall (in summer) and to re-use industrial water;
- About 1.2 billion m^3 (on an annual basis) will be diverted (from south China) to Beijing (mainly for industries), probably before 2008.

Public Health Bureau

- The RMO-Beijing project team should pay more attention to the quality of the resident's drinking water, and if possible add some indexes of drinking water to the research.

3) What are the outputs in terms of capacity-building and partnerships?

The end of the RMO-Beijing project in 2004 temporarily stopped the scientific partnerships and prevented the main part of the case study work for Shunyi district (see above, point C1).

E) Tangible outputs, dissemination and impact

Can you describe for the (max. 10) key outputs of your project:

1) Type of output

For the scientific output, see point D1;

2) Dissemination of output/results (examples of dissemination: papers + articles; policy briefs; policy workshops; scientific conferences and workshops; website)

Other output and project activities than those described in C1, were stakeholder meetings as described by Kamphuis et al. (2004).

3) Have your results been used, and if yes by whom, where and how?

Outputs have been use by Chinese scientists for giving advice to the planners and other government authorities of Shunyi municipality.

4) What has been the benefit or impact (indicate evidence of impact, e.g., page hit count)?

Mainly fellow scientists benefited from the information collected.

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

1) Future research on Rural Development and Sustainable Agriculture

The required firm and continued financial basis for this type of integrated studies (due to the many partners from different research fields involved) appears to be a weak point to overcome.

2) The role of research in generating policy-relevant information in support of LNV and other policy institutions

Integrated studies are effective in producing policy-relevant information. Such studies are able to show the integrated results from different policies, the interaction between different factors (e.g., changes in land use, agricultural intensification, environmental protection, changing consumption patterns, etc.), and the trade-offs between factors (e.g., intensification versus pollution, land use change versus income and pollution, etc.).

3) Partnerships and development efforts in the South

Partnerships should continue over sufficient time to have a tangible effect. This, of course, requires financial continuity.

4) Interactions between research and decision makers, both in The Netherlands and the South

Idem point F3 above.

5) Which insights were gained by employing a multi-disciplinary methodology that would have been missed by disciplinary research?

See point F2 above.

G) Unfinished business and future challenges

1) Which important things remain to be done that could not be achieved by the project?

See point C1.

2) Which important challenges in the area of RDSA in the tropics are there in the near future (say 5 to 10 years)?

Peri-urban areas: agricultural intensification, land use change, water shortage, land shortage, sufficient food production, environmental protection, sufficient employment, increase in income, urbanization, increasing efficiency in water use, increasing efficiency in land use, increasing efficiency in nutrient use.

Rural areas: sufficient food production, interesting cash crops, increase in income, options for agricultural development, availability of inputs (e.g., fertilizers, good seed) and money (credit system), infrastructure and markets (e.g., good roads and transport options) to allow efficient product transfer to market and product specialization, sustainability in agricultural systems (both economic and bio-physical), protection of agricultural land areas and soils (against erosion, soil degradation, nutrient depletion, etc.), distribution of knowledge on efficient and sustainable agricultural production systems.

3) What type of research could contribute to addressing these challenges?

(a) Integrated agricultural systems analyses; and
(b) Integrated studies in representative case study areas.

H) For completed projects

1) What has happened since your DLO-IC project was completed?

Project has been terminated, as explained in point C1. Thereafter, a lot of interest has been indicated in follow-ups, e.g., by the Dutch Embassy in Peking, and by Chinese researchers; however, former project personnel with relevant expertise was not available for such follow-ups.

2) Are there follow-up proposals developed and to whom are they submitted?

Follow-up proposal has been submitted in 2004 to the ASIA PRO ECO programme of the EU, but was not accepted due to non adhering to required formalities (retreat of a local government project partner).

SEARUSYN*

Seeking synergy between urban growth, horticulture and the environment in Asian metropolises

A) Project setting

1) What was the background and motivation of the project?

The project was built upon a mission to Vietnam that examined the situation in the rural area around Hanoi. One of the conclusions was that urban growth rates in East and South-east Asia are often faster than what governments and city planners can manage. Consequently, the developments in the urban fringe are hard to control. Quality of spatial planning and agro-ecological aspects hardly play a role in the decision-making process. Fertile agricultural land, often used for valuable horticultural production (market gardening), is allocated to urban functions. Not only land, but also the local expertise on agricultural production and marketing gets lost, a waste of human capital in particular in a knowledge intensive sector such as vegetable production.

Such a process is, to a certain extent, inevitable but it is expected that the allocation of land to various functions could be improved by means of an integrated approach that brings together researchers, policymakers and other stakeholders in city planning, waste management, food production food safety and marketing. For that purpose, the SEARUSYN project has been initiated in order to explore the possibilities for an economically and environmentally sustainable horticulture in the urban fringes of Hanoi and Nanjing in consultation with researchers and stakeholders in these areas.

2) What was the institutional context (partners with which cooperated)?

The project is funded by the INCO programme of the Directorate-General Research of the Commission of the European Union and the International Co-operation Research Programme of the Ministry of Agriculture, Nature and Food Quality of The Netherlands. The project partners are:

Wageningen University and Research Centre, The Netherlands

- LEI (Agricultural Economics Research Institute)
- ALTERRA (Green World Research Institute)
- PRI (Plant Research International)

* Questionnaire received 2006, revised May 2007; Project leader B. Kamphuis (LEI)

New University of Lisbon, Portugal:
- Center of Studies for Geography and Regional Planning

Nanjing Agricultural University, China:
- College of Land Management (CLM)

Hanoi Agricultural University, Vietnam:
- Centre for Agricultural Research and Ecological Studies (CARES)

Institute of Sociology, Vietnam
- Part of the Vietnam Academy of Social Sciences

B) Project objectives

1) What were the initial project objectives?

The *overall objective* of this project is:

To contribute to the synergy between urban growth and agricultural development in the urban fringe of Hanoi and Nanjing, in order to improve the welfare of both rural and urban communities.

The *specific project objectives* are:

- To create an institutional basis for constructive policy dialogue and planning between key stakeholders in the peri-urban fringes of Hanoi and Nanjing.
- To identify and analyse the dynamics and tradeoffs with respect to peri-urban land allocation between urban and agricultural uses.
- To assess the changing livelihood strategies of peri-urban farmers and the associated changes in the local economy.
- To determine the key technical and economic constraints and opportunities for environmentally sustainable agriculture in the peri-urban fringe.
- To design and propose options for peri-urban land allocation that integrate urban growth and sustainable agriculture.

2) Have there been any (major) changes to these objectives and for what reason?

The project objectives did not change during the project.

C) Project activities

1) Which activities were employed to meet the objectives?

The project consisted of several activities that were executed by the different partners. The project activities are divided in *three phases* of ca one year each.

2003/04: City level analyses:

Platform building and pilot area selection: identification of major stakeholders, selection of pilot study areas and determining key project goals; analysis of available data/documents.

2004/05: Local level analyses:

Collecting and analysing relevant aspects of spatial, socio-economic and environmental developments in the pilot study areas.

2005/06: Integration:

Formulating scenarios and developing a plan of action.
The project was concluded by the end of 2006.

During *the first project phase*, in 2003 and 2004, the activities were focussed on getting acquainted with the urban fringe problems of the two cities. Comprehensive analyses of the developments in the peri-urban areas in Hanoi and Nanjing have been carried out in order to identify the key problems that should be addressed in the project and to select suitable pilot areas in consultation with the stakeholders. In both cities available documents, statistics, survey data and policy reports, were collected, translated and synthesized in three separate reports about land use, agriculture and environment respectively. For that purpose the researchers in both countries visited several research and governmental institutions as well and (together with their European counterparts) investigated projects of integrating urban development with horticultural modernization in The Netherlands.

In *the second phase*, in 2004 and 2005, the focus of the project shifted towards the local level, in particular to the selected pilot areas, three villages in Nanjing and two in Hanoi. In these villages a Rapid Diagnostic Appraisal (RDA) was carried out in order to get up-to-date information on the current situation and the development in the recent past with respect to land use and socio-economic developments. For that purpose various local stakeholders, farmers, traders and representatives of governmental bodies were interviewed. After that, various research activities have been carried out, mainly focused on two case study areas, Dong Du village in Hanoi and Suoshi village in Nanjing:

- Urbanization impact survey, to study the influence of urbanization on horticultural development in the peri-urban area of Hanoi and Nanjing in general and on migrant farmers in Nanjing in particular.
- Agro-technical survey, to investigate the use of water, fertilizers and pesticides by farmers in the case study areas.
- Soil and water analyses, to investigate the quality of soil and water for sustainable horticulture.
- Integrated Pest Management (IPM) policies survey, to study the institutional, political and price factors influencing pesticide use in Hanoi and Nanjing.
- Organic farming survey, to explore the possibilities for introducing/strengthening organic horticulture in Hanoi and Nanjing.
- Market survey, to explore the market potential for high value vegetable production in the peri-urban areas of Nanjing and Hanoi.

In *the third phase*, 2005-2006, the results of the various research activities and consultations have been used for designing different scenarios for the future development of rural and urban land use in the case study areas. These scenarios ranged from maximum conservation of the most productive agricultural land amidst urban expansions to maximum urban uses with some bits of open space remaining to be farmed in an appropriate way, mainly as an ‘amenity’ for the new urban residents. The scenarios have been presented and discussed during policy seminars (in both cities) in November 2005 and during follow-up meetings in March/April 2006. Officials from local, district and metropolitan level (‘Province’ in Vietnam and ‘Municipality’ in China) involved in rural and urban planning attended these seminars and discussed the possibilities for productive green zones in new urban areas in both cities.

2) Can you identify disciplinary and multi-disciplinary activities?

The project had a multi-disciplinary approach in which researchers with different backgrounds (economics, sociology, production ecology, soil sciences, physical planning, land management, landscape architecture and process management) worked together in order to find options for integration of horticulture with new urban functions in (peri-) urban areas. Parts of the study were quite technical and involved dissemination of, and debate over new research techniques within these disciplines. The ‘participatory planning’ approach was new to most members of the international research team and was an important tool for bringing the specialized, technical topics together.”

D) General project outputs

1) What are the scientific contributions of the project (to RDSA methodology or more general scientific contributions)?

During the project, several project reports were written on various topics and made available on the project website, www.searusyn.org. The project results have been integrated in an Alterra report and a final consolidated project report.

During the entire project a participatory approach was followed, in order to find solutions that are understandable and acceptable for all stakeholders in the developments in the urban fringe of both cities. However, the project’s experience is that ‘multi-stakeholder platforms’ – as a form for participatory research and planning – appeared not to be suitable for the required interaction. Therefore, a more diversified process of communication and involvement of the various stakeholders in the project activities was followed, with separate consultations with stakeholder groups or individual stakeholders bringing them gradually together in joint consultations.

2) What are policy-relevant findings of the project for Dutch and for Southern policymakers?

The major conclusions from the project are the following:

- The project results confirmed that the interests of the rural population and the agricultural sector play only a marginal role in the urban planning process of Hanoi and Nanjing. There is, however, a growing resistance of the rural population to be moved without having their interests being taken into account properly.
- There is, also, in both cities a tendency towards the creation of more green spaces in and between the new urban areas.
- This development provides opportunities for integrating rural and urban functions.
- The project made urban planners aware of these possibilities of having agricultural producers taking care of green space and they indicated that they will further explore these opportunities at pilot level.
- For that purpose, the project started a dialogue between urban planners and the local population, but the introduction of participatory approaches in the planning procedures does not comply with the governance structure in both countries, yet.

In summary, the project showed that it is possible to create productive green zones in new urban areas, but that it requires intensive consultations among the involved stakeholders, from farmers up to urban planners, to achieve a situation that meets the interests of both the inhabitants of the new residential areas and those farmers who are keen to continue farming in these green zones.

3) What are the outputs in terms of capacity-building and partnerships?

Most of the research activities were carried out by the researchers in Hanoi and Nanjing, but in all cases, the Dutch researchers had the lead in the research approach and design. Vietnamese and Chinese researchers have been trained in several aspects, such as participatory action research, institutional and stakeholders' analysis, policy process analyses, rapid diagnostic appraisal, marketing research, interview techniques and scenario development. About 50 researchers and students were involved in various trainings.

The working relations between the project partners have been strengthened and it is the intention to continue co-operation in new projects. In 2004, Wageningen UR stationed a representative at CARES-Hanoi University to intensify the contacts in Vietnam and other South-east Asian countries.

E) Tangible outputs, dissemination and impact

Can you describe the (max. 10) key outputs of your project:

1) Type of output

- Various project reports, papers, articles and website.
- Apart from the written output, an important output is the increased capacity at the partner institutions in participatory research activities.

2) Dissemination of output/results (examples of dissemination: papers + articles; policy briefs; policy workshops; scientific conferences and workshops; website)

- The project website www.searusyn.org provides all research findings and project reports.
- Meetings with various stakeholders have been held for triple purposes: dissemination of project findings, indirect communication between representatives of different policy fields and collecting additional information for research purposes.
- Policy workshops in both Hanoi and Nanjing (November 2005).
- Round table meetings on various aspects in Hanoi and Nanjing (March/April 2006).

3) Have your results been used, and if yes by whom, where and how?

Apart from the project partners and stakeholders, the results have not been used directly, but the planners and policymakers in both Hanoi and Nanjing considered to use the participatory project approach to explore integrated solutions trough scenarios in an interactive process in pilot projects, in China for instance in the frame of the 'New Socialist Rural Area Campaign', which started at the end of 2006.

F) Lessons learned

What lessons have you learned from science, policy-oriented and capacity building activities that could improve:

1) Future research on Rural Development and Sustainable Agriculture

An integrated, multi-disciplined approach is crucial to analysing sustainable land use issues in peri-urban areas. The problems in these regions are multi-dimensional and technical solutions should always be combined with an analysis of the socio-economic and institutional settings and conditions. Active participation of the major stakeholders, including policymakers, in RDSA projects is recommended in order to gain the commitment required to turn research results into actions. Besides, involving stakeholders in a research project will also help to get a better, richer understanding of the present circumstances and developments in peri-urban areas. It enables researchers to include different viewpoints in their research results (from farmers to policymakers at different levels and private companies as well).

2) The role of research in generating policy-relevant information in support of LNV and other policy institutions

Research questions should closely be aligned to the priorities and interests of policy-makers. However, RDSA research has a long-term orientation, which does not always answer specific, short term policy questions but is valuable for long term policy development.

Through the project, both academic and policy making staff of various institutions in the two cities became more aware of the ways problems of the dynamic rural-urban interface are dealt with in The Netherlands, which makes them more interested in seeking further policy and research support from The Netherlands. Certain specialized forms of agricultural production proved to be sustainable in areas undergoing rapid urbanization. Urban planners are quite willing to provide space for such forms of production, while those in the Ministry of Agriculture seem to underestimate the capacity of these often very competitive producers.

3) Partnerships and development efforts in the South

Good partnerships with (research) institutions in the South, and in this case Asia, are crucial to the success of an international research project. Establishing and developing networks with partners in these regions are important to Wageningen UR, in order to strengthen its international scientific position and obtaining funds, others than those from LNV. In the same way, the research institutions in these regions benefit from the collaboration with Wageningen UR and other European institutes, for instance from training and capacity building activities in the joint research projects.

4) Interactions between research and decision makers, both in The Netherlands and the South

Active participation of decision makers, through steering committees, stakeholders' platforms, and seminars and workshops is crucial for building the stepping stones for turning research results into actions. In general, however, policymakers are not interested in research approaches and methods as such, but mainly in the results, while on the other hand, researchers are not always familiar with decision-making processes. So it may be difficult for them to decide when and how to involve decision makers in a research process. For that reason, the interactions between researchers and decision makers should be well targeted and professionally organized in order to prevent that the decision makers are loosing their interest in the project.

5) Which insights were gained by employing a multi-disciplinary methodology that would have been missed by disciplinary research?

Without the different disciplines involved in the project, it should not have been possible to explore different options for agriculture in the dynamic peri-urban areas. (See Lessons learned ad. 1).

G) Unfinished business and future challenges

1) Which important things remain to be done that could not be achieved by the project?

The project has raised awareness of the possibilities for integrating sustainable horticulture and new urban functions in the peri-urban areas. In follow-up projects, these options could be further explored with the involved stakeholders, from farmers to investors and decision makers at local and regional level.

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