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