ADOPTION OF TECHNOLOGIES FOR SUSTAINABLE FARMING SYSTEMS

WAGENINGEN WORKSHOP PROCEEDINGS

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SÉMINAIRE DE WAGENINGEN

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FOREWORD

The workshop on *Adoption of Technologies for Sustainable Farming Systems*, hosted by The Netherland's Ministry of Agriculture, Nature Management and Fisheries, was held in Wageningen on 4-7 July 2000. The workshop drew together participants from agriculture and environment ministries and research institutes from OECD Member countries, the Commission of European Communities, FAO and the International Federation of Agricultural Producers. It formed an integral part of the OECD programme of work on agriculture and the environment under the auspices of the Joint Working Party on Agriculture and Environment. In addition to outlining directions for possible future work in this domain, the workshop offered an opportunity to share knowledge and experiences and, more specifically, to:

- share country experiences and approaches in developing and encouraging the adoption of appropriate technologies for particular farming systems; in light of these experiences examine the efficacy of different policy approaches and instruments;
- improve understanding of the sustainability of farming systems and technology, particularly in the context of future demand for food and other agricultural products;
- show key trends in farming practices and structures, consumer tastes and agro-food industries and the effects they will have on sustainable farming;
- look at the roles for governments and markets in stimulating adoption of appropriate technologies that can improve sustainability at the farm level; and
- identify policy approaches for stimulating the adoption of technologies that can improve sustainability at the farm level.

The workshop allowed for a great degree of interaction among the participants, especially in the smaller group sessions which addressed technologies and institutional arrangements, and their influence on the adoption of technologies at the farm level. Case studies prepared by countries formed the basis for discussion in these sessions. The last day of the workshop was devoted to a panel discussion covering all the different themes and was followed by a stocktaking of the lessons learned and discussion on the workshop conclusions.

A one-day study visit to experimental farms and various research stations provided the participants an opportunity to learn more about different technologies used in horticulture, pig husbandry and intensive and sustainable dairy farming. The tour included visits to areas where farmers are responsible for preserving agricultural landscape as well as to a nature preservation area which included agricultural land.

The OECD expresses its appreciation to the Dutch authorities for the active role they played in preparing, arranging and hosting the workshop, as well as to the other financial contributors: Canada, France, Hungary, Japan, Spain, Switzerland and the United States.

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CONCLUSIONS OF THE WORKSHOP

Technological change has been the major driving force for increasing agricultural productivity and promoting agriculture development in all OECD countries. In the past, the choice of technologies and their adoption was to increase production, productivity and farm incomes. Over many decades, policies for agriculture, trade, research and development, education, training and advice have been strong influences on the choice of technology, the level of agricultural production and farm practices.

Agriculture is becoming more integrated in the ago-food chain and the global market, while environmental, food safety and quality, and animal welfare regulations are also increasingly impacting on the sector. It is faced with new challenges to meet growing demands for food, to be internationally competitive and to produce agricultural products of high quality. At the same time, it must meet sustainability goals in the context of on-going agricultural policy reform, further trade liberalisation and the implementation of multilateral environmental agreements as agreed to by OECD Ministers.

Today, farmers, advisors and policy makers are faced with complex choices. They are faced with a wide range of technologies that are either available or under development; they must deal with the uncertainties of both the effects these new technologies will have throughout the agri-food chain and the impact that a whole range of policies will have on the sustainability of farming systems. In addition, there is increasing pressure on agricultural research and advisory budgets that must be accommodated.

The focus of the workshop was the adoption of technologies that have the potential to contribute to sustainable farming systems. *Technology adoption*, however, is a broad concept. It is affected by the development, dissemination and application at the farm level of existing and new biological, chemical and mechanical techniques, all of which are encompassed in farm capital and other inputs; it is also affected by education, training, advice and information which form the basis of farmers' knowledge. It also includes technologies and practices in the whole agri-food sector that have an impact at the farm level. Finally, it should be borne in mind that most of these new technologies originate outside the farm sector.

The concept of a *sustainable farming system* refers to the capacity of agriculture over time to contribute to overall welfare by providing sufficient food and other goods and services in ways that are economically efficient and profitable, socially responsible, while also improving environmental quality. It is a concept that can have different implications in terms of appropriate technologies whether it is viewed at the farm level, at the agri-food sector level, or in the context of the overall domestic or global economy.

One of the key policy conclusions of the workshop was that *technologies for sustainable agriculture cover the whole spectrum of farming systems*. All farming systems, from intensive conventional farming to organic farming, have the potential to be locally sustainable. Whether they are in practice depends on farmers adopting the appropriate technology and management practices in the specific ago-ecological environment within the right policy framework. There is

no unique system that can be identified as sustainable, and no single path to sustainability. There can be a co-existence of more-intensive farming system with more-extensive systems that overall provide environmental benefits, while meeting demands for food. However, it is important to recognise that most sustainable farming systems — even extensive systems — require a high level of farmer skills and management to operate.

Analytical aspects

Drawing on discussions, case studies and thematic analyses from across OECD countries, the main analytical conclusions from the workshop can be summarised as follows:

The adoption of technologies for sustainable farming systems is a challenging and dynamic issue for farmers, extension services, agri-business and policy-makers. The agricultural sector needs to employ a wide range of evolving technologies and farm practices across many different farming systems and structures to meet a variety of changing and heterogeneous demands from consumers and the public for food, fibre and other goods and services provided by agriculture, often with uncertain outcomes in terms of their effects on sustainability.

Demand is driving the adoption of technologies. Farmers have always looked to new technologies as a way to reduce costs. In addition, higher incomes, greater knowledge and improved channels of communication are leading consumers to demand low-cost food of higher quality increasingly produced through organic methods in many countries, with more variety, consistency and year-round availability. At the same time, consumers are increasingly demanding that their food be produced using techniques that conserve natural resources, limit environmental pressures and pay greater attention to rural viability and animal welfare. The process of trade liberalisation is widening the sources of supply and the degree of competition. The changing demands are reflected in policies and are powerfully transmitted to farmers by the media, pressure groups, food retailers and processors.

The ways in which technologies are developed and adopted differ across OECD countries. The different priorities and concerns related to achieving sustainable agriculture have resulted in a range of approaches and levels at which they are implemented. Some countries rely heavily on market signals and voluntary co-operative industry-led approaches to guide the development, dissemination and adoption of technologies. Others place a greater emphasis on government intervention. Such government involvement ranges from a facilitating to a mandatory role, and includes direct funding for research, payments for dissemination and adoption, legal restrictions, information and advice. Moreover, the overall context of agricultural policies and the level of support is a key factor in determining which technologies are adopted at the farm level and in which locations at the farm level.

Research efforts, farmer education and training, advice and information are shifting towards balancing economic efficiency with environmental and social sustainability. Historically, the focus of research and advice was to increase production, productivity and profits, whereas now the emphasis is on achieving those aims in a sustainable way, which often implies changing farm practices and using different technologies. As has often been the case, agriculture is drawing on and adapting technologies developed in or for other sectors of the economy. Although research is increasingly "problem based"

rather than seen as exogenous, it is not always clear which technologies are profitable for farming to develop and which farm practices will contribute to sustainable farming systems in the long-term. In the past, research was often directed at solving technical problems; now it is also aimed at defining research priorities and best technology to address current and future demands by society. Those priorities include biological pest control, biotechnology, information technology, bioremediation, precision farming, integrated and organic farming systems. Other issues, however, related to the educational and training system, institutions and the relative role of public and private research efforts are also important. Moreover, some sustainability issues are not necessarily best addressed through technological options, but simply by changing the level and type of agricultural production and its location.

Technologies are increasingly being developed in a global market, applied at the farm level but impacting on sustainability beyond the farm. Both conventional and newer technologies, in particular related to biotechnology, information and precision farming techniques, are global businesses. The dissemination of those technologies is often within the national market, but their application is local. However, the effects on sustainability of farm level adoption extend beyond the farm. With more vertical integration, either through formal ownership structures or contractual relations along the whole food chain, decisions on the adoption of technologies at the farm level often cannot be separated from decisions taken elsewhere in the food chain.

Adopting technologies for sustainable farming systems is multi-disciplinary. Taking into account the wider range of objectives related to moving towards a more sustainable agriculture, compared to those targeting farm production, more disciplines are having to work together.

Adopting technologies for sustainable farming systems involves uncertainty and trade-offs. Technologies that can contribute to an economically efficient farm sector and the financial viability for farmers, while improving environmental performance and which are socially acceptable, will provide "triple dividends" to sustainability. Given the scarcity of resources, however, there are invariably trade-offs in achieving these sustainability goals. Moreover, the aims are "moving targets" which must address new issues and changing priorities. Technological developments are rapidly evolving and information on the costs and benefits of adopting technologies in agriculture is often imperfect. Thus, the choices on technology adoption are made in a climate of uncertainty with a large element of "trial and error" in its application, and the speed and extent of adoption varies considerably among farmers. This can have important implications as to the structure of farms and the number of farmers that are able to survive financially in the future.

Several factors are facilitating the adoption of technologies for sustainable farming systems. Research and development efforts, the trend towards better education and training of farmers, the shift in the focus of advice, quicker and cheaper means of disseminating and sharing information, availability of financial resources, pressures from consumers, non-government organisations, the media and the public in general are contributing towards facilitating the adoption of sustainable farm technologies. Many policies, including those relating to agriculture, environment, and research and development, are providing a combination of incentives and disincentives to technology adoption. Environmental policies themselves increasingly constrain farmers' actions, as do zoning regulations, animal welfare standards and public health policies. However, the

combination of the many different economic, structural, behavioural and policy factors in a wide range of different situations means that there is no simple or unique explanation as to what leads farmers to adopt particular technologies.

Other factors are constraining the adoption of technologies. Often policies are giving conflicting signals which hinder the uptake of technology. Some agricultural policies are encouraging the expansion of agriculture on environmentally fragile land, over-exploiting natural resources and not requiring farmers to take account of environmental spill-overs into other sectors. Many support policies get capitalised into the value of land, encouraging a greater intensity of production and influencing the kind of technologies adopted. Some agricultural policies impose environmental constraints on farmers as a condition for receiving support, but at levels higher than otherwise to compensate for environmental damage caused by other agricultural policies. In some countries, the environmental benefits provided by farmers are remunerated, in others they are not. Inadequate levels of education, access to advice and pressures on financial resources for some farmers slow the adoption of some technologies, especially those that require a larger scale of operations and where the initial investment costs required are high.

Farmers need to face the right signals for the adoption of appropriate technologies. Farmers will invest in and implement sustainable technologies and farm practices if they expect the investment will be profitable, if they have the right education, information and motivation, and if government policies set clear goals. Agricultural policies can alter, however, the prices facing farmers for their inputs and outputs, which in turn will influence their decisions on investment and can lead to unsustainable farming practices. Where the environmental benefits from employing sustainable technologies are not expected to accrue to farmers, but to people outside agriculture, and where there are no markets for the benefits, levels of adoption could be sub-optimal from a societal perspective. Equally, where the costs of environmental effects of current farming activities are paid by other sectors, farmers will have no incentive to adopt environmentally sustainable technologies.

Assessing technologies for farming systems from a sustainability perspective is in its infancy. Until recently, the impacts of farm technologies were assessed according to relatively few, generally clear and measurable criteria: production, productivity, farm incomes, employment and trade. Assessing sustainability is more complex when environmental, social and ethical considerations must be taken into account. It is often not clear what the relationships are between the various elements of sustainability, what should and can be measured, and how the results are to be interpreted so that farmers, policy-makers and other stakeholders can identify with reasonable confidence which sustainable technologies work, which channels can best facilitate their dissemination and adoption in different conditions, and at what cost and benefit.

Policy aspects

The workshop identified a number of areas that could be considered by policy makers.

The overall policy framework needs to be consistent and coherent, in particular in the context of agricultural policy reform, trade liberalisation and multilateral environmental agreements. This requires a more integrated approach in terms of setting objectives for sustainable agriculture, defining research and development priorities, and targeting and

implementing policy measures at the appropriate level. For example, where the sustainability issue is local, objectives might best be addressed through local solutions. However, in practice it is a considerable challenge to achieve policy coherence across a range of government, ministries and other institutions.

Technologies can help reconcile the necessity for sustainable and profitable food production. The challenge is to identify what technologies work best in specific circumstances, and define and provide the right incentive framework, so as to facilitate the achievement of sustainability goals in ways that enhance global welfare, in accordance with policy principles agreed by OECD Ministers. Reconciling food production and environmental goals can sometimes be achieved through the adoption of appropriate technologies. Sometimes those goals can be reconciled simply by changing the level, type and location of agricultural production. Reconciling those goals, however, also means that the rights and responsibilities of farmers regarding the adoption of technologies and practices need to be clearly defined and applied (taking into account the current distribution of property rights), and thus the situations under which they are entitled to remuneration (provider gets) or obliged to pay (polluter pays).The attribution of property rights has important implications for the distribution of income, wealth and equity.

There is a need for greater follow-up in tracking the adoption of technologies for sustainable farming systems and in the accountability of research efforts and policies for technology dissemination and adoption. Rigorous *ex-post* assessments of results could help ensure that corrections are made before too much is invested in the wrong technology. This is important as technologies affecting agriculture arise from a wide range of sources; ranking technologies and identifying possible future trends can help the policy making process in moving towards sustainable agriculture.

The adoption of technologies for sustainable farming systems will be facilitated by a wider participatory approach involving a range of stakeholders. These stakeholders should include farmers, the agri-food industry, consumer groups and non-government organisations with an interest in sustainable farming. Sustainable technologies are implemented at the farm level, thus a key requirement is to engage farmers in the dialogue on technology adoption. Ideally, there should be a greater sense of "ownership" throughout the agri-food chain in the choice of technology. Upstream and downstream sectors influence the adoption of technologies by farmers, but they can also learn from farmers so that technologies implemented in the ago-food chain take into account the effects on the farming sector.

Public funding for research on technologies in agriculture is declining in many OECD countries. Public funds are limited and thus need to concentrate more on addressing public good rather than "near market" issues. The methodological, analytical and information needs on devising and adopting appropriate technologies are also resource-intensive. Some countries are concerned about the capacity of extension service to cope with the wealth of detailed and complex information available to farmers, highlighting the need for transparency in research and information. From the perspective of policy development, the informational and policy capacity requirements are new, large in dimension and will represent an intellectual challenge for the coming decades. This is also likely to require substantial resources.

Governments and the OECD can help to identify and analyse which technologies work in which circumstances and the most cost-effective ways to disseminate and adopt technologies. They can also provide information on what is helping and what is hindering the adoption of technologies able to achieve sustainability goals by contributing to the development of criteria to assess technology adoption, analysing the appropriate ways to measure and assess progress, and outlining alternative policy and market options.

OPENING ADDRESS

Ewoud Pierhagen[1]

I am very pleased to open this workshop on behalf of the Minister of Agriculture. He is very glad that the Netherlands is able to host this workshop as the issues to be discussed have a direct bearing on agriculture in this country.

The future of Dutch agriculture is presently under discussion, although these discussions are not limited to the Netherlands and Europe alone. The role of agriculture must be rethought, keeping in mind that there is one certainty: there must be a move towards sustainability, and I believe that new technology may help us in this. Before pursuing this theme, I should like to welcome the participants to this workshop.

I should first like to welcome the OECD representatives, and Mr Viatte in particular, who have the final responsibility for this workshop. I should also like to extend my welcome to Mr Doornbos, who represents producers, Mr Shinohara, Director-General of the research institute for agricultural economics of the Japanese Ministry of Agriculture, Forestry and Fisheries, and, finally, all those who have contributed to making what will certainly be a successful workshop.

Wageningen was chosen as the venue for this workshop as Wageningen University is synonymous with Dutch agriculture. Dutch agriculture is in our view rather special. The Netherlands is densely populated and farmers work on a relatively small area. As a result, pressure on land and on the environment is high. Agricultural production is nevertheless important. The Netherlands is either the second or third agricultural exporter in the world (exchanging ranks with France) depending on the year in question. The U.S. is by far the biggest exporter of agricultural products.

How is it possible to have such an important agricultural production on a limited area? This is due to the fact that our agriculture is relatively intensive. To be more precise, intensive production dominates agriculture production in this country. To illustrate this, 40% of our agricultural production consists of horticultural products and 20% of intensive animal husbandry. Arable crops represent only 10% of agricultural production in the Netherlands.

There are a number of reasons why agriculture has developed in this way. The first is due to generally favourable soil conditions, on the condition that excess water is gotten rid of and that there is proper drainage of the land. Secondly, our geographical position is favourable in the sense that we are close to many European countries with whom to trade. Thirdly, the Government's position has always been that agriculture should be market-oriented. As a result, Government policy over the past century has not been on protecting agriculture, but rather on making it more competitive largely by stimulating

1. Director of International Affairs for the Minister of Agriculture, Nature Management and Fisheries, The Netherlands.

agricultural research and education, as well as through advising farmers. Since the creation of the European market, our agriculture has only grown and intensified.

This development has also had negative consequences. We have become aware over the last decades that agriculture is causing important environmental problems, such as an excess of nitrates and phosphates which are threatening the quality of both our surface and groundwater. These are serious problems that we are working hard to solve. For example, our research efforts are focused primarily on how to combine an intensive agriculture with high environmental standards. In several cases, the results have been promising. It appears that technology can be of great help in combining intensive farming with high environmental standards.

This is important not only for our rather special situation, but also for the world in general because as agriculture inevitably becomes more intensive, more general environmental standards applied at an international level will have to be adhered to.

Where do we stand with agriculture when looked at on a world-wide scale? The world population will certainly increase from a present population of 6 billion people to 7,5 billion in 2020. In order to feed them, agricultural production will have to increase considerably. This production increase cannot take place anymore by just transforming unused land into cultivation. In fact, there is little unused land left and the land that is still available is mostly marginal and not really suited for a sustainable agriculture as it would be quickly degraded by erosion, etc.

This leads to the conclusion that the necessary increase in agricultural production will have to occur by increasing on existing agricultural land. In other words: by intensifying farm production. However, this must take be done in a sustainable way. As I have stated earlier, our national experience has shown that technological innovation can play an important role in combining the two.

The challenge to turn to sustainable farming does not apply to the richer countries only, but also for countries embarking on the process of industrialisation and economic growth, where the temptation to produce in a less sustainable manner is quite strong. Are the richer countries entitled to deny these countries to pursue that path? What can we do to prevent history from repeating itself? All questions are of great importance.

You have come together to discuss a much debated issue. I would therefore once more like to express my gratitude for being allowed to host this workshop which I hope will prove to be a fruitful one and that this will offer you all an opportunity to learn more about:

- the available technology;
- the relationship between sustainability and the function of agriculture; and
- on the task of governments in promoting sustainable agriculture.

The OECD has provided a varied programme which will enable you to learn more about the theories behind sustainability. I wish you a successful workshop.

ADOPTING TECHNOLOGIES FOR SUSTAINABLE FARMING SYSTEMS: AN OECD PERSPECTIVE

Gérard Viatte[1]

Solving environmental problems in agriculture requires developing and diffusing new technologies. The Netherlands has been in the forefront of developing and applying new technologies to its farming systems, which makes this a highly appropriate location for this workshop. I also have a strong personal interest in the topic as I have been involved in the discussions on how to organise agricultural research efforts in The Netherlands in order to contribute to a viable productive service.

The policy framework

Agriculture has changed dramatically over the past fifty years. It has succeeded in reducing food costs (although in many countries those costs are kept artificially high through support policies), feeding an increasing population, releasing labour from the farm and providing an ever greater choice of food throughout the year to consumers. Technology has played a major part in these developments, and is also addressing today, in an integrated way, environmental and social concerns.

At the same time, agriculture must be seen in the context of other developments in the world economy. Globalisation, agricultural policy reform and trade liberalisation all affect agriculture. Greater public awareness and emphasis on sustainable development also influence the way we view agriculture.

Interactions between agriculture and the environment are now major elements shaping agro-food policies in all the OECD countries. Agriculture is increasingly influenced by developments upstream and downstream. To ensure that agriculture produces sufficient food while respecting the environment, farmers need the right incentives, knowledge, and technology. It also means that coherent policies need to be in place — agricultural, environmental, trade and R&D policies in particular. It is vital to base policy decisions on robust, well-established scientific criteria so that the decisions are justified and can be explained to all stakeholders.

The interactions between agriculture and the environment will also be an aspect of the forthcoming discussions on international trade in agriculture. International trade can no longer be discussed in isolation; other objectives and concerns have to be taken into account, without calling into question the commitment of both the WTO and the OECD to a freer, more open system of agricultural trade. The challenge is to find win-win solutions.

When we speak of adopting technologies for sustainable farming systems we are taking about those technologies that are established and available, but not adopted by all farmers, and those

1. Director for Food, Agriculture and Fisheries at the OECD.

that are new or under development. Let me say a few words about the latter, and the challenge of the impact of these new technologies on the environment.

Many countries agree that new biotechnologies need to be assessed within a framework of sustainable agriculture, encompassing both economic and resource sustainability. There has been considerable discussion about the actual and future benefits of biotechnology and genetically modified (GM) crops. There is anecdotal evidence and scientific studies both supporting and questioning the benefits in terms of yields, costs and environmental impacts. Producer groups generally report favourable results but it is early days and experience is not widespread. Local climatic conditions may make a difference. Organic farmers, who represent a small but rapidly growing segment of agriculture, express concerns about potential damage from GM crops to neighbouring farms and raise questions about measures of protection and liability. Farmer groups feel they should be protected by legislation against liability for any damage contamination by GM products. But the fact that the growing of GMO crops has spread so quickly in some countries shows that — often contrary to popular belief — farmers can adopt new technologies very rapidly! The OECD has and will continue to look at the environmental impacts of GM technology.

We now recognise the enormous potential of new information technologies, especially the Internet, in providing access to direct, timely and world-wide information. Farmers and policy-makers are exploring the scope of Internet communication as a means of adjusting to scarce public funding for dissemination of information or development work. However, this development goes hand in hand with the necessity to ensure that information can be converted to accessible knowledge of relevance to end users. One can point to plenty of examples of researchers using the Internet to communicate with different client groups. The possibilities, for example, of e-commerce in the agricultural sector — which is often characterised by problems of farms being physically distant from markets — to get information, to sell their products and to advertise their other non-food outputs (such as farm tourism) are enormous.

Why is the adoption of technologies important?

Until recently, the choice of technologies available to farmers was largely determined by the need to increase production, profits and productivity. The main constraints were the availability of capital, knowledge of how to use the technology and market risks — risks that in many countries policies were shielded by government policies. In the past, “good policy practices” was therefore rather straightforward, relating primarily to increasing output and the aim of agricultural policies was to increase productivity in agriculture. Agricultural research and extension services could concentrate, for example, on improving the productivity of small farms.

Now agriculture has to fulfil diverse objectives: it needs to be internationally competitive, produce agricultural products of high quality while meeting sustainability goals. In order to remain competitive, agricultural producers need rapid access to emerging technologies. Farmers are faced with many more constraints — and also more opportunities. In addition to being profitable, they need to meet environmental standards and regulations, as well as deal with direct and indirect consumer and lobby group pressures. They may also be flooded with information from various government and industry sources, that make choosing appropriate technologies more difficult. Farmers also need to change their production and management practices in response to agricultural policies that include environmental conditions and I am confident that farmers have the capacity to do so.

Uncertainty may increase even more in the future. There may also be uncertainty related to the future policy environment, especially with respect to support, trade and pressures from the agro-

food sector. Adopting technologies by farmers is an investment. It takes time, however, for the rewards to flow and farmers may be reluctant to invest in an uncertain climate with more constraints, where some of the benefits are for society. Should it be the farmer or society that pays?

Technological change has been the basis for increasing agricultural productivity and promoting agricultural development. Research affects the productivity of farming systems by generating new technologies which, if appropriate to farmers' circumstances, will be rapidly adopted. Historically, researchers and extension workers have been primarily responsible for identifying and injecting economic and environmental factors into the process of developing and introducing an agricultural innovation. This is typically characterised as a top-down process, whereby researchers develop the innovation, extension workers promote its use, and farmers either adopt or reject the innovation based on the features important to them.

Why is the adoption of technologies an OECD issue?

The aim of the OECD is to provide sound analysis to improve policy practices in Member countries and to influence debate on policy issues with an international dimension. The OECD countries in aggregate account for around 40% of world production of agricultural commodities, and about three-quarters of its trade. Production technologies and farming systems within the OECD countries range from conventional to organic, intensive to extensive and from small-scale to large-scale enterprises across a spectrum of agro-ecological and climatic conditions. Despite these differences there are potential benefits from sharing experiences.

OECD Ministers in May 1999 noted that: "The pursuit of sustainable development, including global challenges such as climate change, the sustainable management of natural resources, and the conservation of biodiversity, is a key objective for OECD countries. Achieving this objective requires the integration of economic, environmental and social considerations into policy-making, in particular by the internalisation of costs, and the development and diffusion of environmentally sound technologies world-wide." The sustainability of natural resources and of agriculture will be given special attention in a major OECD report on Sustainable Development in 2001. The OECD also analysed biotechnology and food safety and provided an input to a recent G8 Summit.

The work in the Joint Working Party on Agriculture and the Environment feeds into the

more sophisticated medicines to some extent took pressure off of natural resistance. However, as consumers in OECD countries started demanding products that use fewer or none of these agents, a renewed stress on developing natural resistance can be expected.

Technologies that more precisely target pests and diseases. The need for medicines and pest control agents in agriculture is not likely to disappear any time soon, however. Technological advances in the science of pest control are expected to continue to produce chemical control agents that over time are at least as effective in controlling pests as the ones they replace, but which are also less toxic, less persistent and less mobile through the soil. The greater application of monitoring and knowledge-based systems, aided by reductions in the costs of electronic sensors and computers, should also enable farmers to be more economical in their use of pest control agents, especially insecticides: applying them only when and where necessary, rather than according to predetermined dosages and schedules.

Technologies that administer nutrients more efficiently. Farmers have traditionally relied on two main practices to supply nutrients to root zones: manuring and burning. Inorganic fertilisers allowed the separation of crop production from animal husbandry, restored fertility to depleted soils, and contributed to the development of livestock production based on grain and other feed ingredients. Research into the specific needs of particular crop-soil combinations and livestock have led over the years to more scientifically formulated fertilisers and feeds. Wider application of technologies that administer fertilisers only at the times and in the amounts needed can be expected to increase crop yields further while reducing leaching and runoff of nutrients.

Technologies that administer water more efficiently. Many of the technologies still used for irrigating crops are as old as civilisation itself. The problem — today just as in ancient Mesopotamia — is that conveying water through open channels and furrows is wasteful: much of the water evaporates before it reaches the root zone. In OECD countries, much of the water used in agriculture is carried to fields by pipes; but technical efficiency could still be improved through greater application of technologies that, like precision fertilisation, combine more accurate measurement of actual crop needs with means to deliver the water more accurately and in more precise dosages.

Technologies that reduce wastage following harvesting. The demand for primary agricultural commodities is a derived demand, which is determined in part by wastage between producer and final consumer. Technologies used in OECD countries to harvest, transport, store, process and distribute farm commodities are already highly efficient, and result in much lower levels of wastage than in countries where the requisite capital and infrastructure is in much shorter supply. Virtually every part of most crops and animals are recovered for some commercial use — if only for feed, fertiliser or energy. Some further reduction in post-harvest losses is achievable, but the most wastage (in proportion to the quantity purchased) takes place at the point of final consumption.

Technologies that disseminate knowledge. Historically farmers relied on their own experience and that of their neighbours with regard to adopting “good farming practices”. Advice and information from publicly funded agencies and agri-food industries is increasingly focused on environmental effects. The Internet provides further developments in the dissemination of information on sustainable technologies.

Policy impacts

The type and uptake of environmentally sustainable technologies is influenced by a range of policies, providing incentives or disincentives:

- environmental policies (constraining what farms can do);
- agricultural policies (encouraging expansion of output or requiring environmental conditions in return for support);
- Trade policies (which influence the location and type of production, and appropriate technology);
- structural policy (which affects the scale of farm, the type of technology applied and the specialisation); and
- technology and R &D policy (which encourages research and dissemination of technologies in light of current priorities).

Much of the recent debate has been on the kind of incentives and disincentives that policies should give. For example, if it is not profitable for a farmer to adopt environmentally sustainable technology, should the government encourage farmers with financial incentives? This question can also been explored in the context where environmentally sustainable management practices contribute to positive externalities in agriculture (*e.g.* enhance biodiversity). These issues give rise to a whole new paradigm — including debates on the joint links between agricultural production and environmental outcomes and public good aspects of agriculture — in that technologies have to serve both for increasing the efficiency of production and the environmental performance.

The issues are less controversial when there is a mutual benefit to adopting a new technology — that is to say, when it is financially profitable to adopt it, and its adoption also improves the environmental performance of the farm.

Factors affecting the adoption of technologies

Diffusion is the process by which a new idea, practice or technology spreads in a given population. The characteristics of technologies, such as relative advantage, complexity, divisibility, observability and compatibility affect their diffusion.

Farmers will be encouraged to adopt appropriate technologies for sustainable farming systems if the dissemination of information is efficient. There is a paradox here one must bear in mind, however. On the one hand, experience in other sectors undergoing the transition to less polluting or more resource-conserving practices shows that it is inefficient for governments to be too prescriptive. Those environmental policies that set performance standards, as opposed to forcing the use of particular technologies, tend to encourage innovation of a sort that lowers the cost of achieving a given result. Yet when a really important, useful technology comes along there may be an interest in encouraging its quick adoption. At that point, it is too late to start educating the educators, the extension agents and others responsible for explaining to farmers the merits of the technology.

It is thus important to facilitate the dissemination of improved farming system technology to farm households through farmer-participatory methods and to strengthen existing resource-planning capability and improve the research and extension capability.

Assimilation and adoption of new and available technology at the farm level is a function of science, economics and human behaviour. One or more of the physical sciences or biology serves as the foundation for technology development, and economics usually serves as a strong motivator for adoption. The psycho-social and human behavioural aspects of technology adoption are less tangible, but clearly influence the potential adoption of any technology to change.

Technology and change will most likely be assimilated and implemented when: the benefits of implementation will be quickly realised (within one to two years), the tools for implementation are readily available and accessible in the local marketplace, the risk of the implementation are small and the change or new technology can be comfortably integrated into other basic on-going aspects of daily life.

Several "barriers" have hindered the assimilation of new agricultural technology through extension:

- A perceived fundamental inability to demonstrate a linkage between profitable technology adoption and sustainable production at the farm level.
- The limited movement away from a discipline-based or uni-dimensional approach to a broader systems may have reduced the ability to evaluate the economic and environmental components of technology uptake.
- The instruction and demonstration of new technology within the controlled setting of a university research farm may not encourage farmers to adopt the technology for their own farms, which have distinct and different resources.
- The failure to recognise and address the psychological component of technology adoption as part of the educational process, because generating knowledge is not always synonymous with diffusing and adopting knowledge.

The adoption process involves an interrelated series of personal, cultural, social and institutional factors, including the five stages of: awareness, further information and knowledge, evaluation, trial, and adoption. Characteristics of a technology, such as simplicity, visibility of results, usefulness towards meeting an existing need and low capital investment promote its eventual adoption and should be considered when transferring any technology.

Profitability is a major concern to farmers. But given the vast array of available technologies, the uncertainty of their effects and the policy and market context, it is difficult to decide where and in what to invest. The opportunity to witness an investment in profitable technology by a fellow producer with similar facilities and resources often helps in decision making and can guide the changes ultimately adopted.

Surveys show that in most OECD countries farmers are becoming better-educated and are continuing their education and training throughout their careers. This is good news, since better-educated and informed farmers have always been at the forefront of technology adopters. Traditionally, publicly funded extension services have played a leading role in dispensing information and advice. However, in many countries extension services have been privatised since the mid-1980s. Privatisation has brought about a number of changes. The influence of farmers' representatives on the extension service is increasing. In the Netherlands, for example, provincial offices for agricultural affairs have been created, which effectively separates Extension advice on farm management from the provision of information on government policy by provincial offices.

Issues for the workshop

Before outlining what I see as the key questions that should be addressed by this workshop, it is useful to remind ourselves of the objectives of this workshop. This workshop forms part of the OECD Programme of Work on agriculture and the environment under the auspices of the Joint Working Party on Agriculture and Environment (JWP). The main objectives of the workshop are to share knowledge and experiences, and provide input to the JWP on the directions of its work on sustainable agriculture, which will specifically:

- share country experiences and approaches in developing and encouraging the adoption of appropriate technologies for particular farming systems; in light of these experiences examine the efficacy of different policy approaches and instruments;

- improve understanding of the sustainability of farming systems and technology, particularly in the context of future demand for food and other agricultural products;

- show key trends in farming practices and structures, consumer tastes and agro-food industries and the effects they will have on sustainable farming;

- look at the roles for governments and markets in stimulating adoption of appropriate technologies that can improve sustainability at the farm level; and

- identify policy approaches for stimulating the adoption of technologies that can improve sustainability at the farm level.

These objectives give rise to many questions related to the adoption of technologies for sustainable farming systems. Our primary focus in the OECD is on the linkage between the adoption of technologies and policies. In particular, which policies affect adoption, how policies affect adoption and how policy reform and trade liberalisation influence the adoption of technologies. We are particularly interested in looking at the relative role of policies and private, market approaches. And it is important to view the role of policies and markets in the adoption of sustainable agricultural technologies within the whole agri-food sector as what happens upstream and downstream can play a big part in influencing the adoption of appropriate technologies at the farm level. There are some of the big "contextual" questions that relate to the costs and benefits (economic, environmental, social) of technology adoption.

I would like to suggest a number of issues for the workshop to address:

- Are there common factors that have helped or hindered the adoption of sustainable technologies across OECD countries? Are there clearly defined relationships between the farming structures and systems and sustainable technologies?
- Are there economies to be exploited in sharing or concentrating on "centres of excellence" in research and co-operation in sharing knowledge? Is the institutional framework adequate to facilitate adoption on sustainable technologies in an integrated world?
- Is there a conflict between adopting technologies for increasing output and productivity to meet rising food demands and technologies which will ensure sustainability and also meet other demands?
- Does the issue of adopting sustainable technologies suggest that we need new indicators to track and evaluate progress? What would these indicators be?

- Is there scope for more international co-operation and co-ordination — even pooling of resources — in the area of R&D related to technologies and techniques that can improve the sustainability of farming systems?
- Can we clarify and rank sustainable technologies in terms of cost-benefit criteria (taking account of economic, environmental and social aspects) to identify those which provide the highest pay off in the shortest time?
- Are there lessons for non-OECD countries? What can the OECD countries learn from the non-OECD countries?

When we look at the role of policies (and which ones) we are necessarily asking questions about market failures and public goods and what we want to achieve. In brief, we are in this context asking whether there are market failures that impede the adoption of technologies for sustainable farming systems, or public goods that such technologies would provide to society. This leads to the fundamental issue of how governments, farmers and other stakeholders should put in place mechanisms to help the process of adoption. I hope this workshop can help provide some of the answers.

ADOPTING TECHNOLOGIES FOR SUSTAINABLE FARMING SYSTEMS: THE FARMER'S PERSPECTIVE

Gerard Doornbos[1]

Technological change is possibly the single most important factor driving globalisation and the development of world agriculture. The following observations can be made:

- the gap between rich and poor countries is often a technology gap;
- the changing relations between farmers and society are often a result of changes in technology used by farmers; and
- new technology is increasingly at the forefront of international trade conflicts.

I would therefore like to commend the OECD and the Government of the Netherlands for taking this initiative to examine the question of how to adopt new technologies with a view to developing the sustainability of farming systems. When farmers make decisions on adopting new technologies, they must take into consideration two important factors, which are the challenge of globalisation and the challenge of sustainability.

Farmers face a highly competitive global market place. They operate within a food chain dominated by a few large multinational companies and they work within a complex system of government regulations. They are also faced with falling government support for the farm economy. In order to survive, farm production must be cost/price driven. New technology is therefore needed in order to increase productivity. Farmers must keep up with improvements in technology in order to stay in business.

The 'challenge of sustainability', however, is not only an economic question. Although farmers must maintain a positive balance with their environment in order to ensure the production on which their immediate livelihood depends, and the long-term survival of farming as an economic activity, the concept of sustainability in a policy context is much broader than this, and differs from country to country. In developing countries, the priority is to adopt technology that helps to achieve food security and economic development. In the OECD area, sustainability is viewed more in terms of food safety and quality, the management of natural resources and maintaining rural communities. There are therefore several dimensions to the sustainability of farming systems.

Agriculture has the potential to make a unique and central contribution to a more sustainable society. Not only can it assure the continued development of an environmentally-sound supply of food to meet the needs of the rapidly expanding world population, it can also provide for the conservation of the rural environment with its wildlife habitat, genetic biodiversity, landscapes and cultural traditions. The ability of farmers to deliver this contribution is affected by market forces and by government policies.

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1. President of the International Federation of Agricultural Producers.

Impressive gains have been made in farm productivity, particularly through the adoption of improvements in plant and animal genetics. Only 50 years ago, wheat yields in Europe averaged about 2 tonnes per hectare whereas today the average is 7 tonnes per hectare, and it is not uncommon for some farmers to produce 10 tonnes of wheat per hectare.

Typically, market-driven technological progress has led to the intensification of farming systems, the use of more industrial inputs and the adoption of management methods that stress low costs and high yields. However, this pursuit of productivity and efficiency has, in many cases, put pressure on the natural resource base. It has also led to significant consumer concern about the safety and quality of food produced in modern, intensive agricultural systems, which in turn has led to the disappearance of many small farms. Thus, on the ecological and social sides, the technologies adopted after the war — which allowed Europe to emerge from food shortages — have become increasingly unsustainable in relation to changing objectives that society places on agriculture. Today, the adoption of new technology in agriculture is looked upon much more critically than it is in most other sectors. In many OECD countries, farmers are faced with consumers who are sceptical about the sustainability of modern farming systems. Many consumers, in fact, would prefer to go back to using more traditional farming methods**.**

Farmers are sensitive to these concerns and most are actively involved in various strategies to achieve greater agricultural sustainability. Such strategies include better targeting the use of farm inputs and increasing the use of conservation farming methods. Where this has occurred, the following can be observed:

- the use of pesticides has been reduced dramatically, by over 50% in some OECD countries;
- the use of integrated crop protection methods has increased;
- nutrient balance is being optimised, *e.g.* through nutrient bookkeeping. Huge investments have been made for manure storage and management in intensive livestock operations;
- filter strips have become commonplace around water courses, where farmers use no chemicals;
- water is used more efficiently in irrigation systems and waste water is being recycled;
- crop land is increasingly being farmed under ‘no-till’ or ‘direct seeding’ systems;
- greenhouse horticulture is moving towards a completely closed systems; and
- precision farming techniques are being used more widely.

Farmers' organisations are also playing a role in facilitating transfers of technology and know-how through exchange of information and ideas among farmers and farmers' organisations. For example, such organisations have developed codes of good environmental farming practices, and have set up quality assurance schemes. In addition, they have taken the lead in voluntary, community-based initiatives (*e.g.* setting up water user groups or land care programmes).

It is clear, however, that despite these actions market forces alone will not be able to deliver the multiple functions expected by society from sustainable farming systems. There is usually little market incentive to develop technologies promoting the social and environmental aspects of sustainable farming systems. Governments in OECD countries are therefore increasingly looking at technological innovation as a public policy issue.

Public policy must approach agriculture in an integrated manner, in terms of the whole complex, diversified system of production, nature management and livelihoods in rural communities. It must strengthen this system by building on the knowledge of farmers and by helping farming systems to become more sustainable. Any public policy discussion in this area raises many issues. These include:

- directing investments in research in the right direction;
- better explaining technological developments to consumers, farmers and to society in general;
- finding the appropriate balance between voluntary initiatives and the complex array of legislation on what farmers can and cannot do on their land;
- bringing consistency and coherence to international regulations governing such items as intellectual property rights, health and safety standards, use of the precautionary principle, multilateral environment agreements and international trade rules;
- strengthening competition policy; and
- supporting the right of farmers to save their own seed for replanting on their farms.

In terms of developing appropriate technologies for sustainable farming systems, IFAP views with serious concern the reductions that have occurred in government funding for agricultural research. The best research today is increasingly concentrated in the hands of a few large multinational corporations where it is protected by patents. The issue of who owns and controls research greatly determines who benefits from it. More funds need to be invested in the public sector so that high-quality scientists will work on agricultural research that is available to all. A target should be established to increase public funding of agricultural research so that it at least matches that of the private sector. Increasing public interest in food and environmental issues should help to achieve this goal.

OECD should encourage the establishment of research partnerships to help farmers preserve their land and water resources, and to meet other environmental, as well as social, objectives. Helping farmers in this area is not commercially attractive to private companies, but it should be a role of the public sector. Policy research is also important to guide and support technological change. It should cover such questions as intellectual property rights, biosafety and food safety.

The need to better explain technological developments to consumers, farmers and others in society is also critically important. It is a paradox that more people are better fed today than at any time in history, that life expectancy is rising ever year and yet that public opinion is often negative. The current debate on the introduction of new technologies is too often driven by emotional considerations, thereby hurting farmers in the marketplace and causing conflict in international trade. Education is therefore an important factor for facilitating the smooth introduction of new technologies.

Objective criteria are essential for the analysis and management of risks of new technology for public health, the environment and the social sustainability of the rural economy. We look to scientists for an opinion, but they are mainly absent from the public debate. In future, they should be more involved in the public education process concerning technological innovations.

Education is also critical in order for farmers to make progress in a ‘knowledge economy’. Farmers must be aware of the technological and policy changes on the horizon. Thus developments in research need to be accompanied by training for farmers on new developments and how they should adapt. Consideration should be given to establishing regional centres where information on best

practices or success stories can be accessed by farmer organisations and others. Wageningen Agricultural University could be one such centre.

As a farm leader, I am very concerned that student numbers at agricultural universities in OECD countries are falling rapidly. The critical mass of knowledge in agriculture in the OECD region seems to be falling with the drop in the number of farmers. However, it is not the number of farmers that should determine the need for research and technological innovation. Rather, this should be determined by the increasingly complex and multi-functional demands that consumers make on agriculture and the fact that farmers will have to double food production over the next 50 years to meet the needs of a rapidly growing world population. Therefore, more resources and not less need to be channelled to agricultural universities if we are to generate the knowledge base for technological innovations that will support truly sustainable farming systems.

In conclusion, in a world of rapid and deep change, all of us must look at what we need to do to be "sustainable". Farmers need to look at how "sustainable" they are in terms of their own farming operations; governments need to look at the "sustainability" of their own policies, programs and structures. Governments cannot say, for example, that they want to preserve small-scale agriculture, hedges for wildlife, an attractive landscape, etc., without providing both the policy framework and the necessary funds to support it. Liberalised market forces will give exactly the opposite result.

In the final analysis, agriculture will only be sustainable if it is capable of renewing itself by attracting younger farmers to take up a career in farming. This means not only adopting appropriate technologies for sustainable agricultural systems, but also appropriate incentives and an appropriate policy framework to sustain an economically-viable agriculture and a vibrant rural economy.

ADOPTING TECHNOLOGIES FOR SUSTAINABLE FARMING SYSTEM: THE PUBLIC INTEREST PERSPECTIVE

Takashi Shinohara[1]

Introduction

This workshop is timely in the present circumstances and I am sure that the outcome will improve our understanding of sustainable agriculture. I would like to befin by presenting some general ideas on the topic.

As we move into the 21st century, I believe we will need to change our way of life quite drastically as a result of our limited resources and, more significantly, because of the degradation of the environment and the state of the earth. I am very impressed with the workshop papers as they cover a broad range of issues and contain important ideas. For example, the Austrian paper on organic agriculture includes a presentation of the paradigms of traditional, modern and new agriculture that can be applied more widely (Figure 1). The key terms to describe modern agriculture can be summarised as follows: mechanisation, labour saving, yield (productivity) enhancing, intensification, specialisation, concentration and economies of scale. This has resulted in more production with less effort in a shorter period of time.

Although these are presented as the general characteristics of modern agriculture, Japanese agriculture has not succeeded in meeting them. The same terminology can be used to describe other sectors of the economy, such as manufacturing, which in Japan has enjoyed high economic growth in the past. Despite the high productivity and specialisation, however, the Japanese economy is currently facing the biggest recession since World War II.

Industrial waste problem

I fear that the strong economic growth in Japan in the past will cause serious environmental problems in the future. Japan is one of the biggest exporting countries in terms of monetary value, but it is also the biggest importer in terms of volume or weight of materials. We import 800 million tons of petroleum, iron ore, timber, seed grain, etc., whereas our exports are less than 100 million tons. In effect, this amounts to 700 million tons of industrial "waste" in Japan. In the United States, exports and imports each amount to 300 million tons; their main partner is Canada. Therefore, owing to lower quantities and shorter distances, the impact of transport on the environment caused by the trade flows to and from the United States is smaller than the impact of trade flows to and from Japan. Waste is scattered across Japan in the form of residues, manure, dioxin, etc. The Japanese public has finally realised that environmental concerns are more important issue than economics or money. Despite the

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current recession and much to my surprise, many people in Japan are more concerned about protecting the environment than the economic recovery.

Table 1. Paradigms of Agriculture

	Traditional Agriculture *prior to 1950*	**Modern Agriculture** *1950 - 1985*	**New Agriculture** *as of 1985*
Technology	Relatively constant technology	Mechanisation Agrochemical Better seeds and breeds	Information technology Biotechnology Integrated technologies
Organisation	Relatively stable	Labour saving Yield enhancing Intensification Specialisation Concentration	Quality orientation Protecting the environment Direct marketing Ethical marketing New products
Social impact	Static rural society	Dynamic structural change	Continuing structural change Rural development Direct payments Pluriactivity
Driving forces	Driven by tradition	Driven by economies of scale (produce more, faster, easier)	Driven by markets Consumer preferences and information
Innovators	Individuals "Local geniuses" Outsiders	Technical experts Sector specific innovation	Social experts Strategic innovation
Technology forecast		Visions of technical experts What is the technical solution to a technical problem?	Social experts looking for mega-trends Technology assessment What is a good technology that meets with consumer and social preferences?

Manure Disposal Problem

Waste problems are not unique to manufacturing, they also feature prominently in agriculture. Farming methods must be changed in order to make agriculture more sustainable. The developments in the Japanese livestock sector are similar to developments in prosperous manufacturing industry: huge amounts of feed grain are imported from the U.S. and processed by Japanese farmers into beef, pork, eggs and milk. The Japanese livestock industry does not export the produce, while in the Netherlands, for example, this is a successful processing and exporting industry.

Sixteen to twenty million tons of feed grain result in a lot of livestock manure, which remains in Japan. If we apply the recycling principle of materials in society, all this manure should be returned to the U.S. and spread on the agricultural land where the feed grains were originally grown. If this is not done, the nitrogen levels in Japan will continue to increase and those in the U.S. will

decline. Although I am not familiar with the current soil nutrient levels in the U.S., I know that in some parts of Japan the soil and groundwater suffer from nutrient contamination.

The concept of food miles

Japan is one of the most polluted countries of the world, so naturally Japanese people are very concerned about food safety. Other primary concerns include environmental degradation and the state of the earth. I believe these concerns are common among the OECD Member countries. Economic theory tells us that if the Engels[2] co-efficient is below 20, consumers become more concerned about food safety or quality than the price of food.

Consumers want to have sufficient information on the products available on the market, including information on the impact of agricultural production methods on the environment. However, unlike for manufacturing products, information on these methods is often limited. Consequently, it is difficult for consumers to know who is the producer and when, how and where the agricultural products were produced. With the expansion of the food market through globalisation, such information has become even more difficult to obtain. Therefore, consumers need labels for example on the production methods and ingredients used (*e.g.* organic and GMO products). However, it is not always clear how much information is available and how accurate that information is.

Against these developments, Japanese consumer groups (mainly composed of housewives) have begun to advocate the idea of food miles, calculating the distance between the place of production and final consumption. For example, tuna caught in the Antarctic travels 6 000 km, beef imported from Australia is shipped 5 000 km and bread made of flour and imported from the United States travels 4 000 km. Thus, the total transport distance for the ingredients of one meal can exceed 20 000 km. A high value of food miles should thus be regarded as a warning signal. The consumer groups advocating for low food miles use a slogan derived from Buddhism: the body cannot be separated from the soil and therefore we should eat food that is produced in nearby areas. This slogan also prevails in Korea. In order to keep food miles low, consumers should avoid buying those agricultural products that are not in season, such as strawberries in December, because of the long transport distances involved.

Consumer preferences

Many consumers are no longer willing to buy agricultural products produced in a farming system that has adverse effects for human health and the environment. According to a recent survey in Japan, many people expect rural areas to be “areas which are symbiotic with the rich natural environment” or “areas where farming practices are mostly in harmony with the environment.” Consumer preferences are partly reflected through the purchase of agricultural products produced in an environmentally friendly manner.

The demand for relatively high priced organic products reflects consumer interests. International and national standards for organic products have been established and a certification system for organic food is now used in many countries. It is difficult to identify the factors why consumers choose organic foods: Is it for food safety, for on-farm and off-farm environmental conservation or both? If it is both, what is the proper balance between the two elements?

2. According to Engel's law, the proportion of a consumer’s budget devoted to food declines as income increases.

It is necessary to maximise the positive effect of this movement using consumer signals effectively. To improve reliability of certification on specialised products, including organic food, it is important to develop a reliable certification system. For example, to avoid “fake” products, technical guidance for both inspectors and farmers is important. Ten years ago, about 45% of agricultural products traded on Tsukiji, the biggest wholesale market in Japan, were labelled organic or organic-related food, prompting the Ministry of Agriculture, Forestry and Fisheries to produce guidelines and then to enact a law.

Public perspective

In so far as farming is concerned, the following three factors are important in promoting the adoption of technologies for sustainable farming systems:

- research and development;
- extension service; and
- dissemination of information.

Research and development

Interactions between agriculture and the environment are complex, site-specific and non-linear. The impact of agriculture on the environment and the effects of the environment on agriculture vary widely reflecting, for example, differences in climate, topography and farming history, and, as Mr Doornbos stated, differences between developed and developing countries.

In addition to producing agricultural products, agriculture can contribute to preserving land and other environmental resources, maintaining landscape values and supporting local communities through activities that are in harmony with the natural environment. The diverse functions referred to as the "multifunctionality" of agriculture relates to the non-commodity outputs of agriculture that are produced alongside the commodity outputs. Most of these non-commodity outputs are economic externalities and their values are generally not fully reflected in market prices. Multifunctionality in agriculture was one of the hot topics discussed at the ministerial conference of the WTO held in Seattle.

Agricultural activities can be harmful to the environment and unsustainable farm management practices can damage the environment both on and off the farm, through, for example, soil erosion, soil compaction and nutrient leaching. Unless farmers are held fully accountable for the environmental damage caused by their activities and bear the cost of carrying out pollution prevention measures, agricultural products are likely to be supplied to the market at a price that does not reflect the true costs. It is thus necessary to introduce regulatory measures to prevent harmful farm management practices and to offer technical support to encourage farmers to adopt alternative farm management practices. These measures will help to prevent a vicious circle of environmental degradation.

In the case of pesticide use, small amounts of pesticides may cause serious environmental damage in some climatic conditions or if applied inappropriately, whereas much larger doses may have very little impact when applied in an appropriate way. In this context, the market alone can not send sufficient signals for farmers to switch to more economically and environmentally sustainable farming practices.

Technological development is also important to correct market failures. The development of technology for assessing the impact of agriculture on the environment can stimulate farmers' adoption of appropriate farm management practices. For this purpose, it is useful to distinguish general mechanisms in certain processes, such as groundwater pollution due to excessive fertiliser use, and the site-specific effects of this process. Both experimental and empirical approaches are necessary to tackle these problems.

Extension service

A good extension service is essential. Even if farmers are aware of the damage that their management practices cause to the environment, it is difficult to change those practices without proper information and guidance. For example, reductions in the quantity of fertilisers may significantly lower productivity and cause financial difficulties or even bankruptcies. On the other hand, advances in the fertiliser industry have brought better fertilisers to the market and prompted changes in farm management practices. Once farmers are aware of the advantages of the new products and practices, they implement the changes.

Moreover, it is important that the information on new technologies available describes if and how these are applicable to local conditions. Local research stations and demonstration farms thus have an essential role in providing this information. In Japan, the local governments of 47 prefectures have their own research stations that employ about 10 000 extension workers. In line with the on-going administrative reform, all the state-run research institutes or experiment stations, with the exception of the National Research Institute of Agricultural Economics, are scheduled to become semi-governmental organisations in the next fiscal year. Mr Doornbos was particularly concerned about this problem. Farmers can use these results to obtain correct information to adopt suitable practices.

Dissemination of information

Dissemination of information related to technology is important. In general, farmers have conservative attitudes and need more time and information to be persuaded to adopt new technologies. It is therefore important that the public sector provides reliable and site-specific data. Issues related to information and technology are areas the OECD might look in more depth in the future.

Smooth dissemination of new technology requires reliable data and technical guidance adapted to local conditions. Demonstration plots in typical local conditions are useful because farmers like to get first hand information when deciding whether to adopt a new technology. Demonstration plots can provide this practical information to guide farmers in a smooth adoption of new technology.

Farmers also need to have access to abundant and neutral information covering both technical and broader issues. With such detailed information and technical guidance, farmers can minimise the risk of implementing new technologies. In addition, there will likely be great consumer trust knowing that farmers have received adequate technical guidance.

Changing farming technology towards sustainable farming may sometimes result in a reduction of the quantity produced. It may thus be necessary to compensate farmers for loss in income during the transition period.

Conclusions

A distinguished Japanese professor of history of science has said that the 19th century was the century of chemistry and the 20th century that of physics. In agriculture, chemistry produced chemical fertilisers and pesticides, whereas physics helped to create the machinery for agriculture — tractors, combines, etc. The extensive use of these inventions has also caused various environmental problems, as mentioned earlier. The professor regards the 21st century as a century of biology and, more specifically, of bio-industry. Consequently, I believe that sustainable agriculture is an important factor that will shape the 21st century. If we can achieve sustainability in agriculture in this century, it will be a century of sustainable primary industry. On the other hand, environment, population, food and energy are common issues throughout the world because the survival of human beings and the earth is a major concern.

These three critical issues are closely related to farming. The manufacturing industry is harmful for the environment, so it cannot therefore be a solution. Consequently, I believe that sustainable agriculture will be key to the 21st century.

Fortunately even under the WTO agricultural agreement, expenses for research and development, extension and dissemination, etc., are regarded as green box measures. Therefore, I hope that all Member countries will increase these expenses without being criticised for their actions by the OECD in the annual monitoring and evaluation of agricultural policies!

ASSESSING SUSTAINABLE TECHNOLOGIES IN DEVELOPING COUNTRIES: MEASURING ENVIRONMENTAL, ECONOMIC AND SOCIAL IMPACTS

Arie Kuyvenhoven and Ruerd Ruben
and
Johannes Roseboom[1]

Abstract

The development, spread and adoption of sustainable farming technologies in the Third World can be evaluated from a public and private perspective. In this section, attention will be focussed on different criteria (profitability, input efficiency, factor substitution, risk and sustainability) to assess the impact of sustainable land use technologies on factor productivity and the environment; distributional implications and external effects will also be taken into account. Appropriate markets and institutional arrangements are required to ensure adequate returns to new technologies for sustainable agricultural intensification. We conclude that a combination of selective reliance on external inputs, well-targeted public investment, further market development and better integrated farming practices, provides a feasible framework to warrant equitable and sustainable growth.

Introduction

Large parts of the developing world have witnessed unprecedented growth in food production in recent decades. Thanks to the development of Green Revolution technologies and the massive adoption of high-yielding varieties in staple foods by, for example, Asian farmers, famines in that region have been averted, hunger and malnutrition are declining, and many countries are basically self-sufficient. Environmental benefits are important too: sustained increases in yields have prevented over-exploitation of marginal land and slowed down the pace of deforestation.

Several concerns remain, however. The new agricultural technologies are hardly successful in Sub-Saharan Africa, where hunger is on the increase. Important pockets of poverty remain in areas characterised by rain fed agriculture or fragile soils and which affects close to one billion people. Yield growth in high-external input systems is slowing, serious environmental problems have emerged, and both land and water constraints limit further expansion of irrigated agriculture. As a result, several high potential areas show decreasing marginal returns of further intensification that, in many cases, compares unfavourably with the potential returns of developing more fragile land (Hazell and Fan, 2000).

A major challenge for the next decades is the development of technologies and practices that enable continued agricultural growth to match the growing demand for food and feed. To reduce rural poverty and hunger, the agricultural growth process needs to be equitable and to be designed in such a

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way that the natural resource base is maintained and pollution is controlled. Hazell and Lutz (1998) show that this type of agricultural development is broad-based, market-oriented, participatory and decentralised, and driven by new approaches to agricultural innovation that enhance factor productivity and conserve the resource base. To reduce excessive dependence on external inputs, there is an increasing interest in agroecological approaches which focus on favourable growing conditions for plants and animals as part of a larger ecosystem (Altieri, 1995). Major aspects of the latter system include diversification of activities, interaction between cropping, livestock and forestry activities, biological control of pests and diseases, and control of soil erosion and nutrient depletion.

Benefits of alternative systems are mostly measured in biophysical terms (soil organic matter, physical yields). Far less attention is given to the welfare implications in terms of farm household income, consumption and labour use. We propose the concept of Sustainable Agricultural Intensification (SAI) to capture protection of the natural resource base to safeguard soil nutrient balances and land productivity, and efficient combinations of production factors that improve farm household income including returns to labour. As trade-offs between agroecological and welfare criteria are likely to arise, we focus our attention on "win-win" technologies which enable a simultaneous improvement on both scores. Such improvements are, however, not likely to be equally shared by all farm households. Households have different access to resources, markets, knowledge and information, and differential technology adoption can be a source of economic and social concern.

This section deals with the assessment of environmental, economic and social impacts of more sustainable technologies in the context of developing economies. As empirical evidence on sustainable farming systems is still limited and often incomplete, we confine ourselves to the *ex ante* assessment and possible policy implications of new SAI approaches. After some general observations on productivity growth in agriculture and sustainable land use, five criteria to assess SAI systems and their possible adoption are proposed. How the impact of such new systems can be measured is briefly examined. We then turn to the policy question of how to create an enabling environment to accelerate the adoption of promising sustainable farming approaches. These and other findings are brought together in the concluding section.

Productivity and sustainability

Productivity growth

Agriculture plays an interesting and apparently paradoxical role in the development process. At low levels of per capita income, a rapid increase in productivity is required in order to improve rural incomes and maintain the food supply for the urban population, the raw materials supply for ago-industrial development, and crash crop production for export earnings and taxes. These contributions of agriculture to economic development require a specifically defined policy framework that offers appropriate incentives to farmers to improve productivity in a sustainable manner, while reducing past demand on public expenditures.

With higher levels of income, reflecting improved factor productivity, consumption expenditures shift increasingly towards non-food items. While productivity increases in farming remain substantial, the rate of expansion of agricultural output is usually lower than for most other economic activities. As a result, the importance of agriculture in the macro-economy declines statistically, and this process is accelerated by the rapid adoption of more productive technologies. The very fact that productivity growth in agriculture and its relative decline in size occur simultaneously has often proved a source of confusion for policy-makers.

The analytics of the agriculture sector's response to policy measures (particularly relative prices for agricultural inputs and outputs, trade and exchange rate policy, availability of public goods and services, and access to markets and information) is largely based on supply response analysis. Supply response can take the form of area extension, technology change, or substitution in crop choice, each with rather different consequences for resource allocation and for the environment. Responses will vary among different types of rural households (*i.e.* dependent on their resources and risk attitudes) and can be lagged as a result of differences in expectations and adjustment costs. Household variability, in particular with regard to access to markets, knowledge and information, is therefore an important source of differential technology adoption and diverging income-earning opportunities.

Sustainable land use

Empirical studies on the impact of agricultural policies and structural adjustment on the sustainability of land use are not conclusive. Some authors argue that price reforms will encourage soil depletion, while others claim a positive effect on farmers' investment in soil conservation activities (Barrett, 1991, provides a summary of the arguments). These different opinions on the relationship between prices and soil degradation originate from differences with respect to the specification of discount rates and relative risk aversion. Moreover, market imperfections may hinder the transmission of higher output prices towards the farm household level.

For a comprehensive analysis of the impact of changes in relative prices on agricultural resource allocation, four different potential response reactions can be distinguished: *(i)* area expansion (extensification); *(ii)* increased input use (intensification); *(iii)* technological change (input substitution); and *(iv)* crop choice adjustment (output substitution). A distinction should be made between adjustment of recurrent costs (productivity enhancing investment) and investment in fixed assets to prevent further soil deterioration (*i.e.* terraces, windshields, etc.).

Supply response reactions to changing relative prices are usually analysed from the perspective of substituting fertilisers for reduced availability of nutrients from natural sources due to soil loss. Alternative approaches treat natural soil fertility as a function of capital and/or labour investment in conservation measures. Both factors tend to be scarce, especially in African agriculture. Soil mining practices appear to be a recurrent phenomenon and promotion of sustainable land use requires complementary strategies for selective intensification and productivity-enhancing soil conservation measures.

The relationship between agricultural policies, farmers' supply response and the implications for sustainable land use is not yet fully understood. When increased agricultural supply originates from area expansion, environmental effects in terms of deforestation, overgrazing, erosion and sedimentation are to be expected. Binswanger *et al.* (1987) find that an increase in output prices leads to a corresponding increase in area and only a small increase in yields. Area expansion could be consistent with improved land use if, simultaneously, shifts in cropping activities occur, the final effect being dependent on the negative effects of cropping activities on resource (*i.e.* soil) quality. Complementary effects between input use and chemical or physical soil properties are mostly not considered. Therefore, changes in input efficiency (of fertilisers and labour) related to soil organic matter contents or soil conservation investments are not adequately captured. Further analysis of these issues requires a more detailed framework based on linkages between welfare and sustainability effects.

Criteria for assessment: a micro perspective[2]

SAI implies that farmers attempt to increase returns to scarce factors of production in such a way that the stock and quality of their natural resource base is maintained. While most agroecological approaches tend to focus on land productivity as a major indicator, far less attention is usually given to returns to labour (Low, 1993). Farmers tend to consider yield increasing technologies and practices based on agroecological principles from five different perspectives: *(i)* profitability, *e.g.* the possible contributions to household income and consumption, *(ii)* implications for input efficiency, *(iii)* consequences for input substitution and labour use, *(iv)* dynamic risk management and *(v)* sustainability. We will discuss farm household behaviour that guides decision-making procedures regarding sustainable technologies, and derive a number of key principles that enhances their socio-economic attractiveness.

Profitability

Sustainable agricultural technologies and practices can only be expected to be adopted when farmers attain higher and more stable income and consumption opportunities. Profitability entails both the existence of effective market outlets and favourable output/input price ratios. Market distortions or inefficient exchange networks reduce incentives for investments in soil conservation activities. Agricultural intensification may become unsustainable when farmers stick to subsistence cropping and rely almost exclusively on locally available resources Low, 1993; Lockeretz, 1989).

Contrary to what is often expected, farmers are likely to apply yield-increasing and sustainability-enhancing inputs for commercially-oriented production activities (Reardon *et al*., 1999; Putterman, 1995). In the cotton belts of southern Mali and Burkina Faso, chemical fertilisers, crop residues and animal manure tend to be used for cash crops that guarantee sufficient monetary returns to warrant these costs (Sissoko, 1998; Savadogo *et al*., 1998). Similarly, animal traction and improved tillage yield higher returns when applied on more fertile fields where commercial crops are grown. In the Central Chiapas region of Mexico, crop residue mulching only appears to be profitable when combined with animal traction on fields devoted to intensive market-oriented cropping activities (Erenstein, 1999).

Farmers' engagement in market exchange can thus be considered a necessary condition for profitable and sustainable agriculture. Engaging in trade provides financial resources for the purchase of complementary inputs and consumption goods. Those households that maintain a net demand position on the food market will benefit from low commodity prices. Where access to formal credit services is limited, investments can be financed from income derived from off-farm employment (Ruben and van den Berg, 1999). Market development could enhance the willingness to invest, while involvement in market exchange generally improves farmers' responsiveness to price incentives. Hence, when market failures prevail, policy reforms remain a first best solution. In their absence, increasing reliance on low external input technologies tends to be the pervasive outcome.

Input efficiency

Prospects for sustainable agricultural intensification depend on the possibilities to improve input efficiency, *e.g.* the marginal returns derived from an additional unit of (organic or inorganic) inputs. Production ecology approaches point attention to the fact that nutrient efficiency (*i.e.* fertiliser

2. The following three sections draw heavily on a paper by Kuyvenhoven and Ruben (2000).

uptake) is determined by the availability of complementary micro- and macronutrients, notably soil organic matter and phosphorus (Van Keulen, 1982). Substitutes for chemical fertilisers are generally characterised by a fairly low recovery fraction due to immobilisation of nutrients and slow decomposition of organic matter.

Nutrient recovery and the efficiency of uptake can be enhanced through (i) soil and water conservation measures that reduce the soil nutrient retention capacity, and (ii) frequent nutrient applications based on timing of operations according to the crop growth process *(e.g.* shortly after sowing and with sufficient rainfall). Both activities are highly labour-demanding, but can hardly be mechanised. Moreover, mechanical or animal tillage only speed up nutrient release from the soil.

Agricultural yields depend on the most limiting factor and can only be increased when input combinations are made available that ensure adequate synergy effects based on strict *complementarities* between different growth-enhancing inputs (*i.e.* nutrient and water, phosphorus-nitrogen, and carbon-nitrogen ratios). Studies regarding input efficiency refer to the functional relations between soil carbon content and (in)organic nitrogen supply to prevent the immobilisation of nutrients, and the proportional relationship between nitrogen and phosphorus to guarantee an adequate rhythm of organic matter decomposition (Penning de Vries and van Laar, 1982). This implies that input efficiency tends to be low when complementary inputs are not available at the right time or in sufficient amounts.

Farmers have commonly learned how to combine different productive activities to generate positive synergy effects. Organic and chemical inputs are not full substitutes, and combinations of locally available resources with selectively applied external inputs often yield the best results. In practice, farmers hesitate to refrain completely from the use of purchased inputs because it permits better timing of activities, reduces the demand for labour in critical periods and contributes to a better appearance of the produce in the marketplace. Given the low nutrient content and the delayed nutrient availability from organically produced fertilisers (green manure, mulch, dung, compost), use of chemical fertilisers cannot completely be abandoned. Since organic matter decomposition is time-consuming, optimal results are reached when applications of chemical fertilisers are gradually reduced towards a minimum level.

Nitrogen derived from cover crops through biological fixation can be made more effective if sufficient phosphate is available. Since soils in tropical areas typically face phosphorus shortage, applying phosphate fertiliser or rock phosphate will be helpful in increasing overall input efficiency (Kuyvenhoven *et al*., 1998*a*). Similarly, nitrogen requires a minimum amount of water and organic matter to become effective. Where exclusive reliance on internal inputs threatens nutrient efficiency, selective application of complementary external inputs should be encouraged (Triomphe, 1996; Buckles *et al*., 1997). Similar complementarities are found in integrated pest management programs (IPM) where improved nutrient application is considered a major device for controlling pests and diseases. Farmers that use small amounts of chemical fertilisers suffer far less crop loss from competition or infestation. When no fertilisers are applied, diseases easily penetrate into the fields, whereas with high doses of fertilisers the incidence of weeds begins to threaten yields.

Factor substitution

Most analyses of natural resource management practices devote major attention to short- or long-run yield effects, but generally do not give any indication of labour requirements and returns to labour. Implicitly, family labour is thus considered an ‘abundant’ resource. While technical efficiency is usually evaluated against the background of the most limiting factor for yield increase (*i.e.* water,

nutrient, energy, pests and diseases), economic efficiency should be based on an analysis of critical factors that determine farm household income (land, labour, capital, knowledge). Moreover, certain limitations regarding the possibilities of substituting external inputs by labour should be recognised.

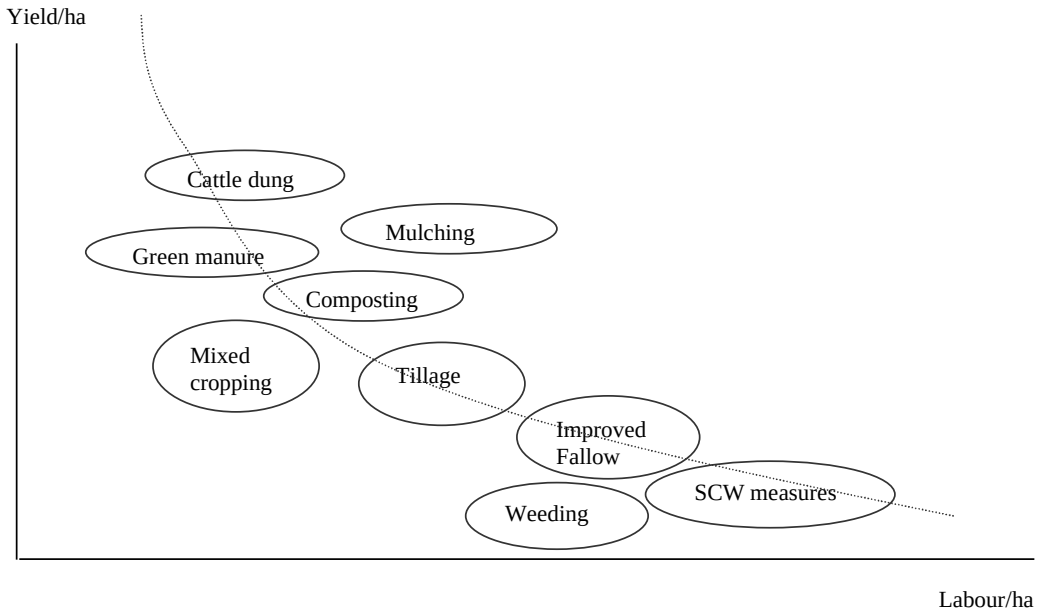
Sustainable agroecological practices tend to be relatively intensive in the use of labour. Physical soil conservation measures promoted in the Central American hillsides and West African lowlands have resulted in small yield increases, but require large amounts of labour for construction and maintenance and involve substantial costs for the purchase and transport of materials (Stocking and Abel, 1989). Given their high labour intensity and long gestation period, returns to labour of such measures are mostly critical (Lutz *et al*., 1994; de Graaff, 1996). Similarly, green manure practices and crop residue mulching require additional labour for harvesting, transport and under-ploughing (Ruben *et al*., 1997; Erenstein, 1999). Most mixed cropping and agroforestry systems demonstrate low returns to labour due to high establishment, maintenance and harvesting costs (Current *et al*., 1995). Production of fodder crops for livestock feeding improves the availability of manure for arable cropping and enables farmers to recycle their crop residues, but both activities entail considerable additional labour demand (Breman and Sissoko, 1998). Labour requirements for integrated pests and disease management are equally high due to the substitution of manual for chemical operations. For most of these natural resource management practices, mechanisation is not a feasible option due to strong terrain slopes and the small scale of operations.

For a systematic evaluation of the attractiveness of natural resource management practices from the farm household perspective, returns to land and labour need to be compared simultaneously (Reardon, 1995). Attention must be given to marginal returns compared to other activities (*i.e.* off-farm employment; hiring-out of land). Even when sustainable agroecological practices can improve nutrient stocks and soil organic matter content, the improvement in yield is usually small compared to the additional input requirements. This can be explained by the fact that labour is required to guarantee timely availability of nutrients to the cropping system. Consequently, returns to labour tend to be outweighed by conventional technologies that are largely based on input complementarities.

Figure 1 provides an overview of major natural resource management practices, taking into account expected yield effects and labour requirements. The final selection of natural resource management practices made by the farmer is likely to depend on the labour/output price relationship. Soil fertility-enhancing measures give best results on both scores, followed by mixed cropping and minimum tillage. Soil and water conservation measures and intensive weeding are attractive for cropping activities with a high value added and in situations where labour costs are relatively low.

The high labour intensity of most farm management practices can be considered as major limiting factor for adoption. Labour tends to be scarce in semi-arid areas during the periods of soil preparation, weeding and harvesting, and competition for labour occurs when mulching, manuring or crop residue recycling are introduced. Otherwise, resource-poor farmers are likely to derive part of their income from off-farm activities that have to be reduced when labour-led intensification of their farming system takes place (Reardon *et al.*, 1988). Farmers are likely to adjust their production system only when the additional income derived from those activities favourably compares to labour's opportunity cost. Other farm management practices, notably physical soil conservation measures, can be executed in off-season periods, but take up leisure time that may be reserved for social or communal purposes.

Figure 1. Factor intensity and yield effects of major farm management practices



Risk management

Resource-poor farmers are inclined to rely on fairly diversified patterns of activities to ensure appropriate levels of risk management. Diversification of cropping and livestock production and their integration with (ago)forestry, aquaculture and improved fallow practices could reinforce the resilience of farming systems through processes of nutrient recycling, biodiversity management and integrated pests and disease control (Muller-Samann and Kotschi, 1994). Consequently, yield levels tend to be more stable and dependency on purchased inputs can be reduced.

It is increasingly recognised, however, that risk management can also take place through farmers' engagement in off-farm and non-farm activities (Reardon *et al*., 1994). The revenue streams derived from these activities are far less dependent on variable weather conditions and thus provide an adequate insurance against co-variate shocks (Udry, 1990). In addition to cropping systems diversification, diversification into non-agricultural activities can be considered a suitable risk management device. Reliance on this strategy becomes feasible when labour demand for agricultural activities can be reduced, and household members possess sufficient skills and knowledge for entering into wage labour or self-employment (Reardon, 1997).

Another issue related to short-term risk management refers to the farmers' capacity to adjust input use under changing weather or environmental conditions. Adaptive behaviour strongly depends on the learning capacity that enables prompt reactions to unexpected events (Fujisaka, 1994). Although most agroecological practices have been developed through participatory and horizontal extension methods (*e.g.* farmer to farmer approach; farmer field schools), there is a rather weak understanding of the dynamics of production systems. An example is the disadoption of maize-cover crop systems in Honduras, which can be explained from inadequate response to weed invasion and the subsequent abandonment of 'companion technologies' such as live barriers, contours, crop residue recycling and reseeding (Neil and Lee, 2000).

Sustainability

SAI implies that the production capacity of the resource base can be maintained in the long run. This does not necessarily mean that at each moment in time agroecological balances should be strictly maintained. In principle, farmers might allow resource depletion in the short run while investing in its recovery in subsequent periods. This interpretation of "weak' sustainability" (Pearce and Turner, 1990) is usually applied in the economic analyses of land use systems.

Typical examples of 'optimal depletion' can be found in traditional fallow systems that are allowed to recover after some period of permanent exploitation. Similar natural regeneration can occur for wildlife species, fisheries and forestry systems (Bulte, 1997). For given prices and discount rates, an optimum composition of the stock of renewable resources can be determined that satisfies intertemporal welfare criteria. Consequently, it can be economically rational to reduce stocks in the short run and to earmark investment funds for their recovery in subsequent periods.

Farmers' preference for weak sustainability can be explained from a trade-off perspective. For the comparison of current and future costs and benefits, discounting procedures are used that reflect farmers' relative time preference. People facing more risk tend to maintain a high discount rate, reflecting their preferences for immediate revenues. Investment activities with long gestation lags are especially sensitive to high discount rates as Current *et al.* (1995) demonstrate for the case of agroforestry projects.

A second type of trade-off occurs when farmers assess the welfare and sustainability implications of alternative technologies (Kruseman *et al*., 1996). Farmers' adoption of sustainable practices can only be expected when positive welfare effects are present. In practice, however, agroecological sustainability frequently implies a sacrifice in terms of income or consumption objectives. Moreover, production systems may become sustainable at lower system levels (field, farm), but can still exhibit externalities at higher system levels (village, region). In such cases, (agrarian) policy instruments can be helpful to overcome trade-offs and suitable incentives should be identified that permit a simultaneous improvement of welfare and sustainability ("win-win" scenarios; Kuyvenhoven *et al.*, 1998*b*).

Measuring impact

Empirical studies on the efficiency of sustainable practices and technologies tend to focus on yields and resource balances. Positive returns to land are usually considered as an indication of financial feasibility. However, an economic evaluation of their attractiveness from a farm household perspective requires that additional criteria be taken into account. Based on the five criteria that play a role in the socio-economic appraisal of agricultural technologies and production systems, different (combinations of) analytical methods can be used (Ruben *et al*., 2000).

The profitability aspects of agricultural intensification can be measured in a rather straight-forward manner, making use of conventional cost-benefit analysis (CBA). However, it should be recognised that attaining profitability is only a necessary condition for adoption, as it does not take into account non-income farm household objectives. CBA provides an appraisal of average costs and revenues at prevailing prices, usually in a partial equilibrium framework. It is mostly applied for the appraisal of specific natural resource management practices, like soil and water conservation, crop residue mulching or agroforestry systems. Other than income, objectives can be taken into account by extending CBA into multi-criteria analysis (MCA). Its partial character, however, is normally retained.

For a thorough appraisal of input efficiency, information regarding marginal returns to factors of production is required. Therefore, production function analysis (PFA) provides a useful analytical framework. PFA can be used to estimate marginal returns to land and labour for agroecological and conventional production technologies, and enables to identify the range of input-output price ratios where conversion is likely to take place. Moreover, typical farm household characteristics related to the adoption of sustainable technologies can be revealed.

A full analysis of the economic attractiveness of sustainable technologies considering prospects for factor substitution requires reliance on farm household modelling (FHM). Farm household models explicitly consider complementarities between inputs and provide an analytical framework for simultaneous evaluation of production and substitution effects. Further extensions towards village-wide models also include market linkages and general equilibrium effects. FHM offers useful procedures for policy simulation, assessing farmers' supply response to different types of economic incentives.

Aspects of risk management can be included in programming models and econometric procedures. However, explicit appraisal of farmers' risk behaviour and coping strategies requires a separate treatment. Therefore, portfolio analysis can be used to assess the variability amongst different household income categories (farm, off-farm, non-farm) and to identify major strategies for consumption smoothing. Consequently, due attention is given to linkages with non-agricultural sectors, and differences in supply response between food deficit and food surplus households can be accounted for.

Finally, for a comprehensive analysis of the sustainability implications of production technologies, bio-economic modelling is recommended. Bio-economic models enable an appraisal of both current and alternative (more sustainable) technologies and their contribution to farmers' welfare and agroecological sustainability. Trade-offs between both objectives can be established and policy instruments to enhance the adoption of sustainable practices can be identified.

Policy implications

Sustainable production technologies and practices are widely promoted by farmer groups and non-governmental organisations (NGOs). Local projects provide substantial support in developing alternative nutrient sources and covering the sunk costs of soil conservation measures. In the long run, however, genuine sustainability requires that these practices become economically feasible and independent of external support. Hence, economic policies and effective institutions should be in place to facilitate sustained adoption.

It is well-known that a number of individual factors influence adoption behaviour. New agricultural technologies tend to be adopted earlier and more frequently by farm households that possess better access to land and capital resources and that are more involved in market exchange (Feder *et al*. 1985). Moreover, factors like age, education and gender also influence farmers' willingness to invest. Agroecological practices are likely to be adopted by subsistence-oriented, medium-size farms in remote regions where opportunity costs are usually low. Adoption of labour-intensive technologies by small and marginal farm households is faced, however, with major constraints due to their high engagement in off-farm employment. Sustainable agricultural intensification can only contribute to poverty alleviation when returns to land and labour simultaneously increase. Therefore, agrarian policies should provide incentives that guarantee both farmers' welfare and sustainability of the resource base.

Agrarian policies for promoting SAI and poverty alleviation in marginal areas ask for specific incentive regimes. Training, education and extension are considered important to enhance access to knowledge and information regarding appropriate technologies and feasible marketing strategies. While participatory technology development (PTD) has become increasingly popular as a procedure for interactive design and local adaptation of sustainable agricultural practices, experimental research is still required to identify critical limiting factors.

Farmers involvement in market exchange and institutional networks is equally important to enhance access to inputs and information. Input price subsidies frequently induced perverse and skewed effects, leading to excessive use of purchased inputs on marginal fields. Stable and remunerative market prices for agricultural products are more effective as incentives to mobilise resources into sustainable production systems. Public investment in rural infrastructure can be helpful to reduce transaction costs and enhance market development in remote regions. Fan and Hazell (1999) show that marginal effects of investments in fragile areas are still high; since current production levels are low, important yield increases can be reached at relatively low costs.

Agricultural intensification also implies that land, labour and capital resources can be effectively mobilised. Concerted action in these areas is imperative to ensure that small farmers can benefit from new and improved technologies. Secure and recognised land rights are an important condition to enhance farmers' willingness to invest. Well-defined land ownership, use and transfer rights permit farmers to invest in land improvements and input purchase, and provide a suitable collateral for lending (Besley, 1995; Ruben *et al*., 2000). Although private ownership guarantees most direct incentives, secure land rights can also be found under common property regimes.

Rural financial systems are required to facilitate farmers' borrowing for investment, input purchase and insurance purposes. While formal banks are usually less inclined to lend to smallholders, local credit and savings schemes could contribute substantially to reduce transaction costs and risks for rural investment. When access to rural financial institutions is constrained, farmers are likely to increase their engagement in off-farm employment as a means to secure investment funds. Given the profitability of sustainable agricultural technologies and practices, mobilisation of investment funds seems to be fully warranted.

Technology development in agriculture is strongly influenced by the dynamics in rural labour markets. Agricultural intensification is likely to take place when labour is scarce and its opportunity are high. Labour supply to land conservation practices can only be increased for intensive commercial cropping activities in response to new market opportunities (Tiffen *et al*., 1994). Diversification of labour in non-farm activities is a common procedure for portfolio and risk management, enabling farmers to finance their input purchase. In the latter cases, land use technologies are required that economise on wage labour and raise the marginal productivity of family labour.

Further promotion of SAI requires institutional support by different types of agents (Picciotto, 1997). Non-governmental organisations play a decisive role in the development of communication networks for sharing access to knowledge and information regarding sustainable land use practices. Informal co-operative arrangements and other types of social capital could provide local frameworks for risk-sharing that favour private investment. The role of the state primarily focuses on the enforcement of legal property rights. Moreover, public investment in physical infrastructure is required to enable the development of local factor and commodity markets. Private agents and financial institutions are likely to follow once sufficient market surpluses become available.

Conclusions

In low external-input agriculture, as practised in particular in the poorer parts of the developing world, sustainability concerns focus mainly on the depletion of the natural resource base due to increased pressure on land. In this paper we have dealt with sustainability in this particular way, emphasising a combination of selective external-input use and better farming practices. This requires that farmers become more integrated in the market economy and sell some of their output to earn cash to buy inputs. The development of well-functioning markets and a transport infrastructure are crucial elements in this strategy. The identification and selection of sustainable and profitable farm practices requires in-depth understanding of production processes and choices made at the household level. The crux of the problem is to translate this detailed understanding into a set of general best-farming practices and to transfer this knowledge to large numbers of farmers. Access to such knowledge can be enhanced through training, education and extension. Farmer organisations, co-operatives, fairs, and markets also play an important role in the exchange of knowledge and information in rural societies.

In high external-input agriculture, as practised in most developed countries, sustainability concerns are quite different and focus mainly on negative externalities of agricultural production (*e.g.* pollution), loss of genetic diversity and nature, and standards related to food safety and animal welfare. Not only the problems at stake are different, but also the institutional setting within which these problems can be solved. Markets, support services, knowledge and information exchange mechanisms, and legal systems are all relatively well developed.

In this setting, it is often through negotiation and legislation that governments try to reduce negative externalities of agricultural production. Targets (sometimes voluntary, but more often enforced by law) are set to phase out undesirable production practices, such as the use of certain pesticides or livestock raising methods. Setting such targets usually involves considerable political hassling, including hefty debates about the scientific proof brought forward by governments to introduce tighter restrictions. Once approved by parliament, enforcing such legislation can at times be difficult given the still large numbers of farmers. Not only governments can restrict agricultural production practices, but increasingly consumers as well. Their tolerance level is at times considerably lower than that of the government and they can express their concerns most effectively through consumer organisations and market channels.

The phasing out of undesirable production practices hinges to a large extent on the availability of technological alternatives. Usually, governments in developing countries cannot offer generous financial incentives, and a major constraint for the adoption of more sustainable practices remains their economic feasibility. Returns must be sufficiently attractive compared to income derived from off-farm employment, and sustainably-produced products must eventually be competitive in the market. Even when cost-benefit appraisals yield positive results, farmers carefully consider other factors and risks. Given the high labour requirements of most agroecological practices and the existing limitations to factor substitution, returns to land and labour have to increase simultaneously. Thus, additional reliance on purchased inputs may be a preferred mechanism to maintain farmers' incomes and improve food security prospects. In addition, at least three conditions should be satisfied to make sure that both farm productivity and household incomes can be improved through SAI.

First, the economic viability of more sustainable practices can be strongly enhanced when public investment and services are made available to farmers in remote regions. Without such efforts, low-input technologies tend to be restricted to medium-size farmers that are only marginally engaged in market exchange. Market development and reduction of transport costs are most important requirement for agricultural intensification, since exchange relations favour access to complementary

inputs and provide incentives for investment. Therefore, improving poor farmers' access to physical infrastructure represents a major condition for equitable and sustainable rural development.

Second, sustainable intensification requires improved access to (information on) factor and commodity markets to reduce uncertainties and enable flexible responses to changing production and exchange conditions. Substantial increase in agricultural productivity can only be reached when internal farm household resources are combined with selectively applied external inputs. Considering the requirements of input efficiency and factor substitution, agricultural yields strongly depend on the possibilities to overcome critical input constraints. Therefore, availability of complementary inputs and supply of labour to guarantee their timely application are required.

Third, the adoption and maintenance of sustainable production systems critically depends on policy measures that enable farmers to invest their resources in better integrated farming systems. Even when land and water conservation practices, improved tillage systems and better nutrient management offer wide prospects for enhancing productivity, from the viewpoint of poverty alleviation the availability of financial services, marketing outlets and off-farm employment opportunities are equally important. While structural adjustment policies generally improved market prices, input costs remain high and delivery systems inefficient (Kuyvenhoven *et al*., 1999; Reardon *et al.*, 1999). Access to inputs proves to be strongly dependent on individual characteristics (mainly education) and community networks. Therefore, investments in both human and social capital can be particularly helpful to enhance the adoption of sustainable practices and technologies.

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HOW DEVELOPMENTS IN THE AGRO-FOOD CHAIN ARE AFFECTING TECHNOLOGIES AND FARMING SYSTEMS

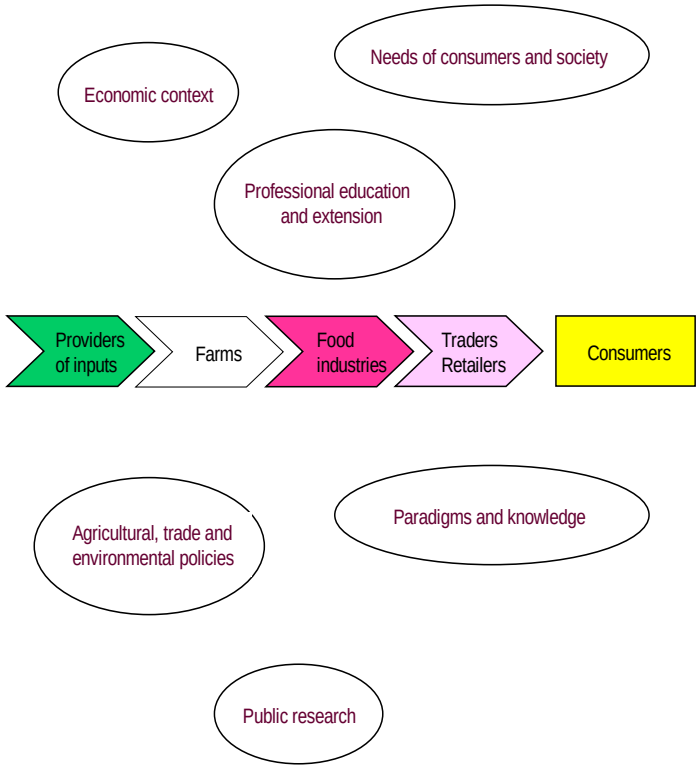
Bernard Lehmann[1]

The agro-food chain

There are five basic components to the overall framework of the agro-food chain, and it is the complex inter-relationship of these components which influences many of the changes to this chain. The agro-food chain is composed of the providers of inputs (upstream industry), followed by the farmers, the food industry, retailers and traders (the latter two components are referred to as the downstream industry) and, finally, the consumer.

The external driving forces that define the agro-food chain can be summarised as: needs of the consumers and society; paradigms and knowledge; economic context; public research; agricultural, trade and environmental policies; and, education and extension services.

Figure 1 Context of the agro-food chain



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External factors defining the agro-food chain

Agricultural production has an effect on the environment and produces not just food, but also shapes the landscape and habitats. It is thus helpful for the analysis to split the demand for agricultural products into demand for "food" and demand for "landscape and habitats", both of which are characterised by different preferences. Food must offer "value for the money". By value, one is referring, for example, to nutritional and health values, convenience, low negative impact on the environment, functional aspects and variety. Landscape and habitats are no longer regarded today as residual values of other activities. Their use requires (democratic) regulation because they are regarded as increasing public utility (value).

The development of the agro-food chain is influenced by the existing paradigms and the level of knowledge. These include:

- attitudes concerning the effectiveness and efficiency in private and public economy;
- attitudes concerning welfare distribution;
- perception of the role of agriculture; and
- knowledge and attitudes concerning environmental and animal welfare issues.

The following factors must be considered in the economic context:

- the price level of factors of production (labour, capital goods, other inputs) necessitates substitution in the agro-food chain;
- the price level of products and services supplied by the farmers. These provide a further potential for product differentiation; and
- the level of different types of direct payments linked to agri-environmental issues.

The public research topics can be grouped under three headings:

- *Food processing* has to create utility for consumers by increasing the importance of processing and by decomposing and recomposing food.
- *Agronomy and related basic sciences* should put emphasis on improving efficiency, productivity and sustainability (quality and environmental impacts).
- *Agricultural economics s*hould focus efforts on increasing the competitiveness in agriculture and on extending environmental and resource economics to better support sustainable development.

The current policies in place are based on three strategies:

- *Price support* — narrowing of the domestic and world price gap means a greater exposure to market conditions.
- *Direct payments* — payments are increasingly linked to environmental issues, these payments compensate farmers for their supply of environmental goods.
- *Policies for structural adjustment* — the policies are intended to achieve structural development that is both competitive and socially acceptable (social welfare for farm-families).

The education system should equip farmers with appropriate professional skills, so that farmers can be successful and competitive, face decreasing producer prices and use natural resources sustainably. Education and extension should deliver farmers the necessary know-how as well as the adequate know-why.

The developments upstream the farmgate

Private research and development should put the emphasis on:

- business to business-marketing,
- competitiveness and environment, and
- need for a short "pay back" time.

In practice, the emphasis is too often placed on finding solutions to partial problems. Research efforts lack consideration of the long-term aspects of the "system" and do not represent "sustainable development of the agro-food chain in its environmental context". It is therefore important to emphasise that research efforts should be more stakeholder orientated and take into account direct use, option and existence values.

A technology assessment research project on GMO-use dealt with the implications of adopting GMO-crops by Swiss farmers. It showed that the consequences of technology adoption should not be evaluated with a narrow set of criteria. The project looked at the following genetically modified agricultural plant characteristics: rape, wheat, maize, sugar beet and potatoes; and, diverse resistance (based on actual "pipeline content").

On the input side, the modified farming practices would reduce the use of fungicides and insecticides, but generally increase the use of herbicides. The consequences on the output side would be a more stable crop yield with less yield risk. In the short run, this would result in a higher profit per hectare (10–15% increase in gross margin). However, the relative attractiveness of the crops would be modified with the price changes; acceptance of these changes by consumers (price effect) is not at all clear. It is equally difficult to assess what would be the possible impacts on biodiversity and GMO-free agriculture.

The developments downstream the farmgate

Concentration process in the processing and retailing sector

At the downstream level, the farm-gate the future situation is characterised by greater international competition, agricultural support that is more focused on farm activities, the decreasing competitiveness of products sold in small quantitiens and transported over long distances (farm-industry), and requirements for (inter-) national quality standards.

As a consequence of the concentration process it will be necessary to create a new marketing strategy for farmers and food industry professionals in difficult situations. They can become more competitive by lowering costs (adjustments, possible trade-off with other functions of agriculture) and differentiation of the products (demand).

Research and development in the processing and retail sector

Research and development in the processing and retail sector is the answer of the food industry to address the "consumer and societal needs." Food processing occurs in three ways:

- *The classical way:* farm products are combined with processing.
- *The organic way:* significant market share in some cases.
- *The functional-convenience way:* the farmer acts as a supplier of ingredients - the food industry is the effective creator of the food.

The strategy recommendations for the processing types are:

- *The classical way:* classical vertical co-operation including communication.
- *The organic way:* generally entertains an intense co-operation (labelling conditions and communication).
- *The functional-convenience way:* the only strategy for farmers is production of commodities.

The social needs (agriculture and public goods)

In order to meet social needs, agriculture must deliver products that are competitive in quality, price and convenience. In addition to the private good "food", agriculture produces and greatly influences a variety of public goods. Agriculture, however, has a direct impact on the environment and the following factors should be considered:

- management of farm land: biodiversity (use, option and existence values); landscape design (idem); minimal impact on resources (water, air,...); option value or existence value of soil fertility;
- maintenance of abandoned farm land; and
- providing land for other uses (ecological areas, non-agricultural activities).

The influence of these external factors is increasing in importance. In economic terms, for example the classical portfolio approach, externalities have so far been neglected. To keep pace with the increasing importance of externalities, it would be reasonable to create an instrument that for evaluation purposes takes into account these externalities.

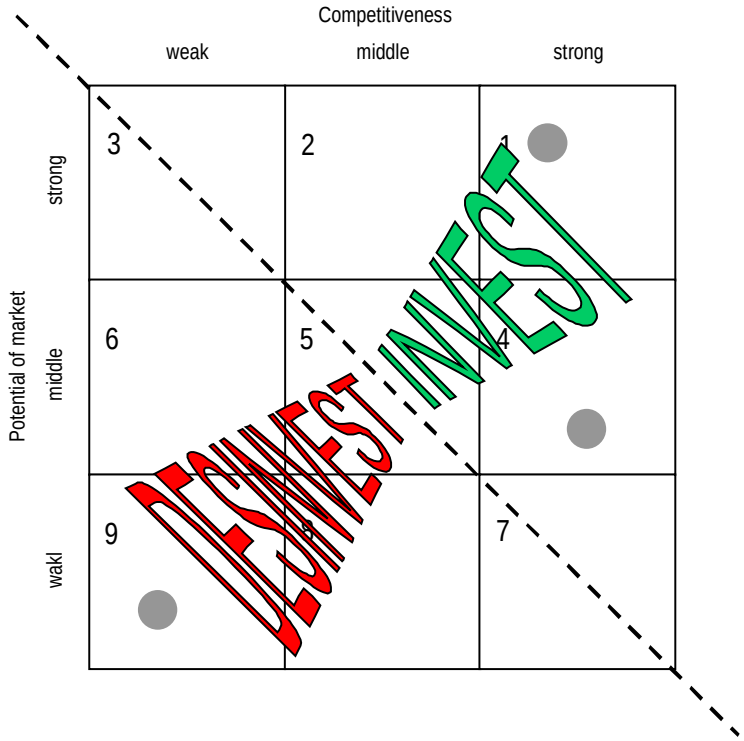
Portfolio analysis of agriculture (agro-food chain): the classical approach

The classical portfolio approach (Figure 2) allows to visualise complex interactions in a simple and clear way. The analysis results in success-relevant factors. These factors consider performances (output) which are measurable over the market. But all side effects (externalities) caused by the production and the consumption of agricultural products, are not taken into account. The ways in which the side effects can affect the environment are shown in Figure 3.

Figure 3 shows the (side) effects of a production practice has on public goods. In the theoretical example, any crop can be used to illustrate the externalities. The amount as well as their characteristics are responsible for the allocation of public goods. The five measured indicators (I – V) represent a selected choice of relevant indicators. The selected indicators are a result of preceding

evaluations. With these indicators the amount of externalities (positive or negative) can be shown with the height of the pillars, divided in three levels for both kinds of externalities (positive externalities: +,++,+++; negative externalities: -,--,---).

Figure 2 Classical portfolio matrix

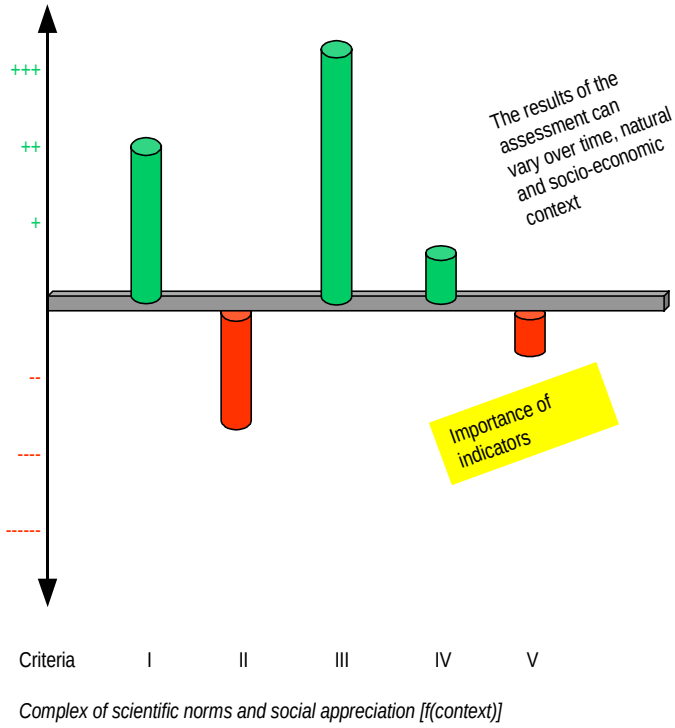


Source: General Electric

It should be emphasised that the selection of a criteria bunch is a very sensitive and difficult process. The later evaluated results are always a result of the quality of the selected criteria. It is further relevant to consider that the results can vary over the time, its natural and socio-economic context.

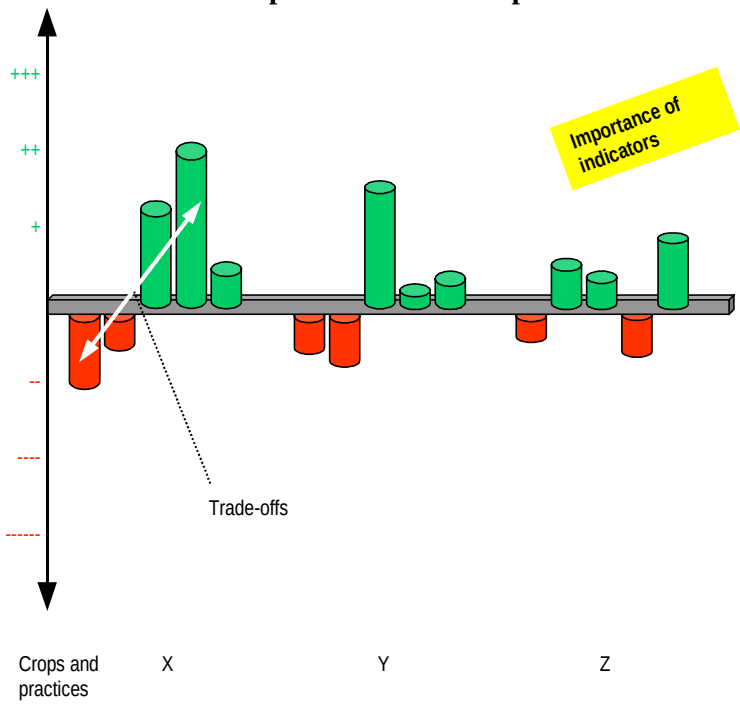
Figure 4. shows the assessment of the effects that different crops and production practices have on the allocation of public goods. For example, conventional, integrated and biological milk production management. In practice “x” a trade-off from the highest negative extension to the highest positive extension would be desired.

Figure 3. Assessment of the effects of production practices on public goods: one crop with one practice



Source: Own

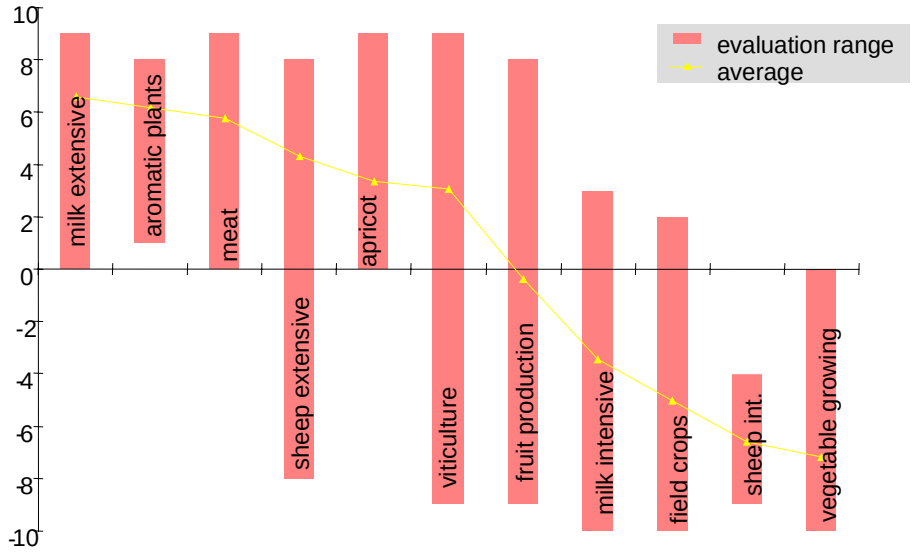
Figure 4. Assessment of the effect of production practices on public goods: different crops and/or different practices



Source: Own

Figure 5. shows the assessment of landscape quality of different productions by a group of stakeholders. These figures are a result of the not yet published project “Valais”. To remain with the above mentioned sample of milk production management the figure shows that the criterion “milk extensive” results with a high amount of positive externalities. It has therefore a high positive impact on public goods. Whereas the criterion “milk intensive” results with a high negative impact.

Figure 5. Assessment of landscape quality of different productions by a group of stakeholders

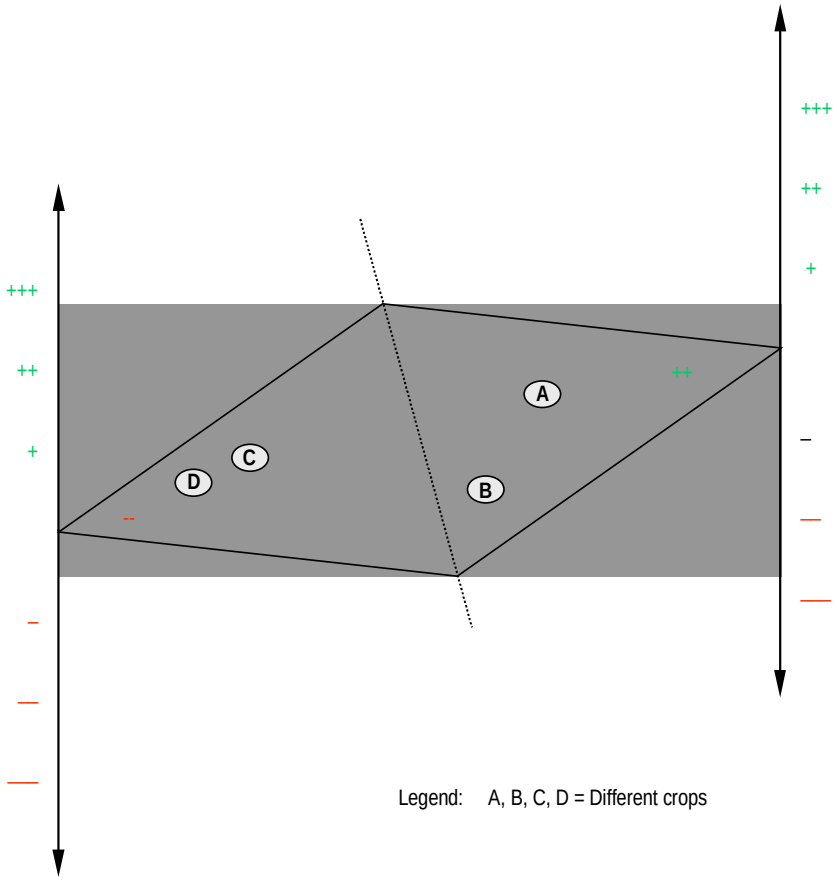


Source: Project “Valais”, 2000 *(not yet published)*.

The extended portfolio for agriculture

The extended portfolio approach for agriculture allows to take into consideration the effect of externalities on the allocation of public goods. The agricultural production is therefore viewed not only under the perspective of economically successful criteria like competitiveness and market potential.

Figure 6. The extended porftolio for agriculture



Notes:
Three levels of positive externalities: +,++,+++
Three levels of negative externalities: -, --, ---

Source: Own

The extended portfolio approach is based on the classical McKinsey multifactor concept. The illustration of externalities is made by introducing a third dimension, illustrated with a double-sided beam (Figure 6). At each case one beam indicates the extension of the positive respectively negative externalities. The classification of their amount is indicated with three different levels.

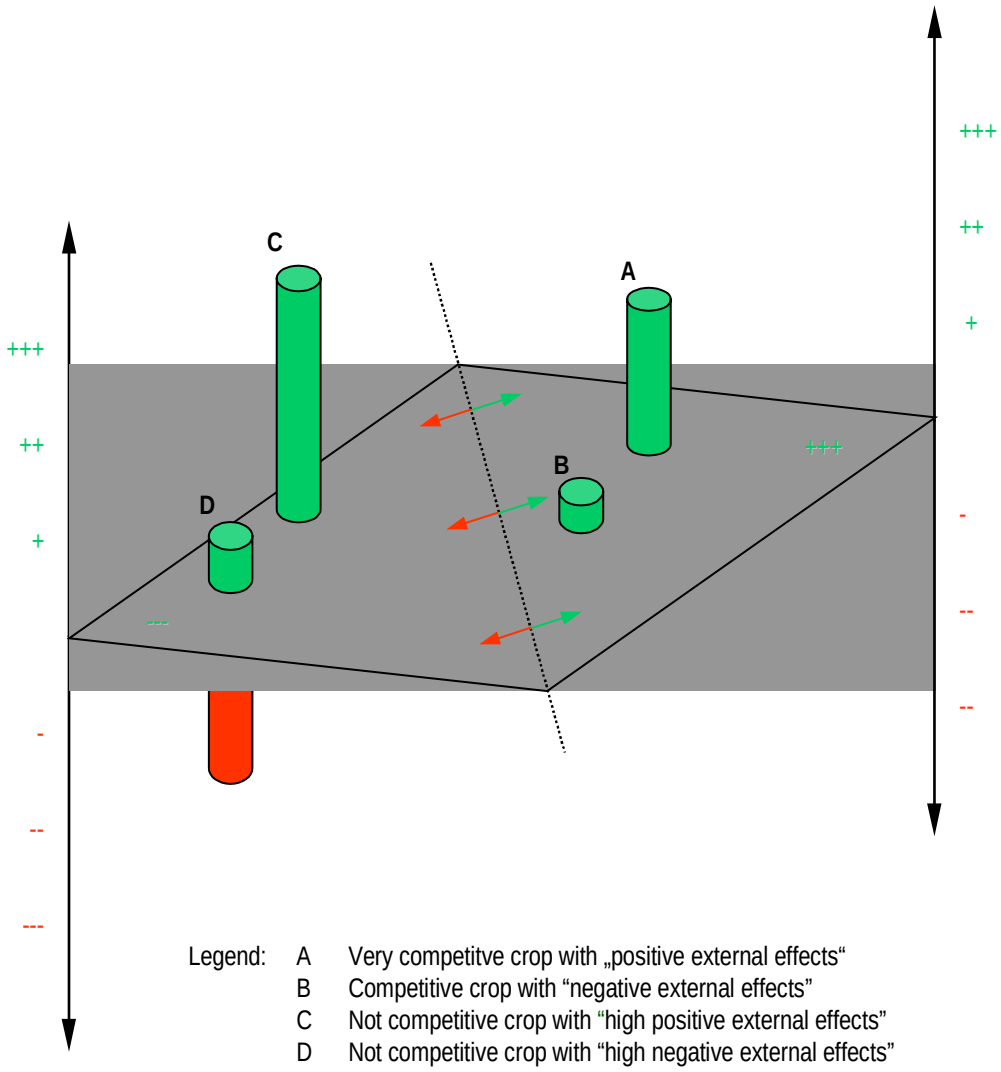
The extended portfolio for agriculture. The "Valais" case study.

The case study "Valais" tries to transform this extended portfolio approach to agriculture. The aim of the study is to see what production practices or crops would make a high contribution to positive externalities. In the increasing (global) market competition the amount of positive externalities will play a key role. As they are not portable and can therefore only "produced" buy the local agriculture in contrast to most of the "classical agricultural product".

Figure 7 shows with four different crops the varying possible extension characteristics of externalities. It has to be emphasised that the aggregation of externalities has to be developed first. The presumptive characteristics are for:

- *Crop A:* very competitive with a surplus of “positive external effects”.
- *Crop B:* competitive with “a surplus of negative external effects”.
- *Crop C:* not competitive with a surplus of “high positive external effects”.
- *Crop D:* not competitive with a surplus of “high negative external effects”.

Figure 7. The extended portfolio for agriculture



Source: Own

The role of strategic management for the farmers (long run stakeholder based decision taking)

According to the four different externality expressions (Figure 7), the following strategies can be derived:

1. *Crop A*: Very competitive with a surplus of "positive external effects" (PEE) => *synergy market - "PEE"*.
   Strategy: priority
2. *Crop B*: Competitive with a surplus of "negative externalities" (NEE) => *trade-off market - "NEE"*.
   Strategy: change technology or downsizing
3. *Crop C*: Not competitive with a surplus of "large positive externalities (high PEE)" => *trade-off market - "high PEE"*.
   Strategy: improve competitiveness without reduction of "high PEE" (technology?)
4. *Crop D*: Not competitive with a surplus of "large negative externalities" (high NEE) => synergy between market and "high NEE".
   Strategy: downsizing, suppression.

The key roles for policies

The key role of policies consists in leading reactive farmers and sustaining the efforts of pro-active farmers. The following four policies can be distinguished:

1. *Crop A:* Very competitive with a surplus of "positive external effects" (PEE). => synergy between market and "PEE".
   Policy: monitoring

2. *Crop B:* Competitive with "a surplus of negative external effects" (NEE) => trade-off between market and "NEE".
   Policy: polluter pays principle

3. *Crop C: Not competitive with a surplus of "high positive external effects" (high PEE) => trade-off between market and "high PEE"*.
   Policy: incentives

4. *Crop D*: Not competitive with a surplus of "high negative external effects" (high NEE) => synergy between market and "high NEE".
   Policy: exclusion of any support

Conclusions

- Farming must fulfil an increasing set of criteria that address both market and non-market concerns (public goods and externalities).
- The available technologies do not automatically respond to the requirements for market and non-market concerns. Technology implementation should be driven by stakeholder needs.

- (Public) research has a role of guidance to aid farmers to implement technology; stakeholder acceptance of research is important.

- Transfers of public funds should "only" be based on criteria linked to the external effects of agriculture (public appreciation included).

- Transfers of public funds and PPP-measures should be designed at the "adequate level of aggregation" (more than one level).

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HOW ARE GOVERNMENTS INFLUENCING INNOVATION AND UPTAKE OF TECHNOLOGIES FOR SUSTAINABLE FARMING SYSTEMS: PESTICIDES AND BIOTECHNOLOGY

Joyce Tait[1]

Abstract

This paper explores the validity and implications of the assumption that it is possible for conventional intensive farming systems to be as sustainable as any other type of farming system. Based on the results of an EC-funded project,[2] it describes the European policy environment within which industry is developing innovative technology for agriculture, specifically pesticides, GM crops and seeds. The relevant policies and regulations, at national and international levels, include those designed to promote technological innovation, to promote environmental protection and biodiversity, and to promote trade liberalisation, including reform of the Common Agricultural Policy. While some policy initiatives are encouraging industry to develop new technology, it is more usual to find that policies emerging from different areas of government counteract one another and lead to sub-optimal outcomes. There is a need for policymakers to be better informed outside their own specialist area and better integrated across functional areas.

Interpretations of sustainability in an agricultural context

Sustainable development is a social concept relevant to the management of a natural resource for a human purpose. It is therefore open to different interpretations depending on the interests and values which underlie that purpose. Farrell and Hart (1998) have described two competing views of sustainability.

- The *Critical Limits* view focuses on concerns about the earth's carrying capacity and resource limitations and the need to preserve natural assets to provide the services that the human population relies on for survival.

- The *Competing Objectives* view of sustainability focuses on balancing social, economic and ecological goals and aims to meet a broad range of human needs, including health, literacy and political freedom as well as a healthy natural environment and other purely material needs.

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2. This paper is based on a research project studying strategic decision making in agrochemical and related industries, 'Policy Influences on Technology for Agriculture' (PITA) EC Framework Programme 4, Targeted Socio-Economic Research Programme, project No PL97.

In many parts of the world, a number of different types of farming system currently co-exist, ranging from *organic* systems at one end of the spectrum to *conventional intensive* systems at the other end (Box 1). Organic and intensive systems have each been argued, with considerable passion, to be more sustainable than the other (Myers and Simon, 1994) but more usually the *critical limits* perspective is invoked to support the view that the only truly sustainable form of agriculture is organic and that society must accept the limits this would impose on the number of people in the world and the lifestyle they can enjoy. It gives primacy to the single objective of environmental sustainability which is assumed both to over-ride the interests of all other stakeholders and to favour a precautionary approach to environmental risks associated with farming systems (Tait and Morris, 2000). Thus, the argument goes, in order to feed the world population using organic farming systems, our lifestyles and consumption patterns will need to be adjusted dramatically.

The c*ompeting objectives* perspective on farming systems, on the other hand, would accept that, in order to satisfy a complex array of human needs [multifunctionality of agriculture (Legg, 2000)], compromises are required among a wide range of objectives. It seeks to balance long term agricultural use of land with economic viability, reduction of environmental harm, fulfilling public demands for food and providing the landscape benefits derived from agriculture. The relevant question then becomes: how far are we able to compromise between competing stakeholder interests in any particular farming system? This view allows the interests of all relevant stakeholders in any development or activity to be balanced in the overall policy equation, but it runs the risk of making trade-offs which allow ultimately unsustainable practices to continue unchecked.

The design and development of future farming systems, and much else besides, will depend on which view of sustainable development is adopted by planners, policy makers and their advisers. The choice, as in most areas of human endeavour, will depend on personalities, values and self-interest as well as on scientific evidence. Discussions about the relative merits of different farming systems are therefore inevitably emotionally charged, even although they may appear on the surface to be based on science and economics.

Considering the range of farming systems outlined in Box 1, intensive or conventional high yielding farming systems on fertile soils are usually resilient to perturbation and, with some notable exceptions, they have been apparently sustainable in purely agricultural terms for at least 50 years (Tait and Morris, 2000). In *competing objectives* terminology, these are the farming systems that must remain sustainable from agricultural and economic perspectives if we are to continue to be able to feed the world population, and some would also argue that they are needed if we are to retain some farmed land where we are able to give priority to biodiversity and landscape objectives (Avery, 1993). However, although intensive farming systems may appear sustainable from the narrow perspective of the farm itself, they may have impacts on the wider environment which are perceived as unsustainable or at least unacceptable.

In more fragile agricultural environments, on marginal land, steep slopes, poor soils or areas of low rainfall, extensive farming systems based largely on organic or related approaches may have existed, apparently sustainably, for centuries at low levels of productivity. They tend to become demonstrably unsustainable when practices are changed in an attempt to improve yields, for example through inappropriate cultivation or irrigation, use of chemical inputs or over-grazing. While the sustainability of such extensive farming systems is often vital to the subsistence farming communities that rely on them, they are unlikely to make a significant contribution to the world food supply and the role of technological innovation in sustainable improvement of yields in such areas is likely to be localised and context-specific.

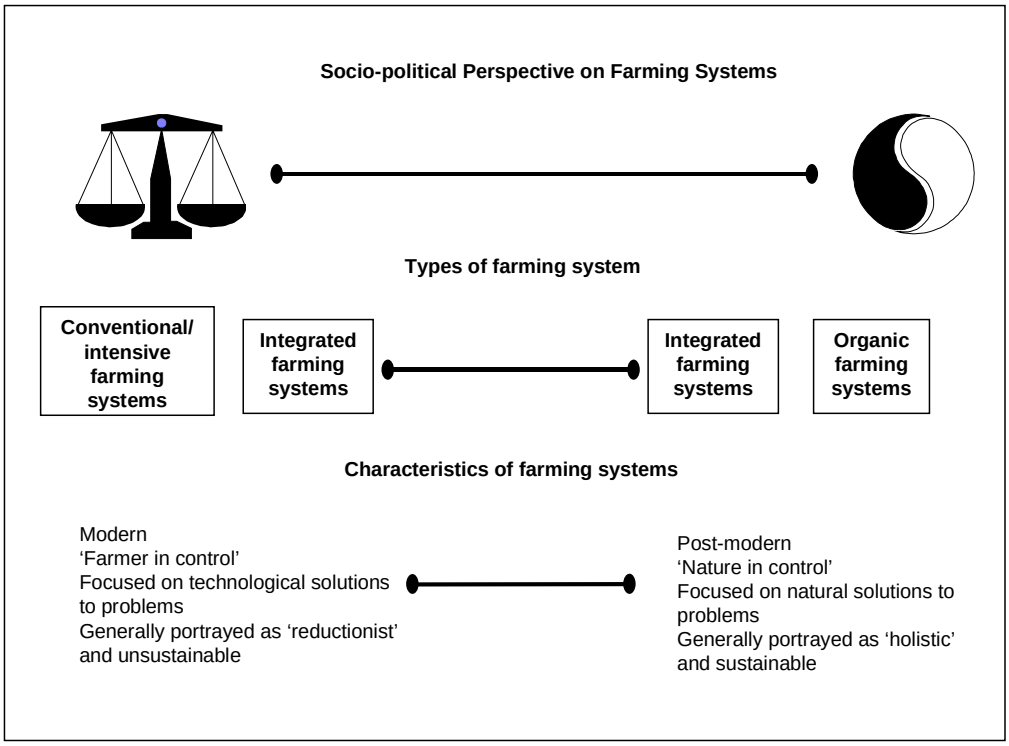
Much of the debate about sustainability of agricultural systems hinges on the extent to which they are able to support a high level of wildlife biodiversity on farms. Different types of farming system will inevitably have a range of different impacts on wildlife biodiversity but there is an important distinction between the presence of wildlife on the cropped area of the farm and alternatively in field margins and non-cropped areas (Soil Association, 2000). Claims for greater sustainability of organic farming systems are often based on the greater levels of biodiversity on the cropped areas, but it is rarely possible to encourage only the species that do not have an impact on crop production. For most commercially oriented farmers (organic or conventional) the presence of wildlife on the cropped area reduces productivity and is seen as undesirable (Carr and Tait, 1991). Where farmers wish to be competitive (and hence economically sustainable) it is more realistic for policy makers to accept that they are unlikely to have the encouragement of biodiversity as one of the primary objectives for the cropped areas of the farm. On field margins and other non-cropped areas it should be possible to minimise the impact of the farming system on wildlife biodiversity by making effective use of 'clean technology'. Thus, adopting a 'competing objectives' perspective, conventional farming systems need not have a negative environmental impact, except in the context of the biodiversity of the cropped area.

Maximum biodiversity at a regional level will most likely be achieved by a mosaic of crop production systems to satisfy competing production, environmental, biodiversity and aesthetic needs, involving a mix of integrated, organic and conventional cropping systems (Dawson, 2000). Important provisos here are the need to avoid inappropriate intensification of agricultural systems in more fragile areas or over-use of technological inputs such as pesticides or fertilisers in any area. The ideal proportions of different types of cropping system in a region will depend on the balance of agronomic, landscape and biodiversity-related needs and the varied potential of the land area to satisfy those needs. The WorldWide Fund for Nature, UK, for example, supports the Organic Food and Farming Targets Bill which sets a target of 30% of UK farmland to be organic or in conversion by 2010 (Soil Association, 2000) but, even if this target is achieved, organic farming systems are unlikely to be evenly distributed across the country's farmed land areas.

Technological options to improve the sustainability of farming systems

The focus of most agricultural policy makers on organic and related integrated farming systems as the route to sustainability generally ignores the needs of conventional farming systems on the most fertile agricultural land. Some years ago, Scottish Natural Heritage took up this challenge and set up a project (TIBRE) to investigate the range of technological options that could encourage such systems to become more environmentally sustainable without undermining their economic competitiveness (Annex 1 to this section). More recently, an EC-funded project (PITA) has been investigating the effects of national and international policy environments on the innovation strategies of companies (large and small) developing products in the areas of pesticides, biotechnology and seeds which could have the potential to reduce the environmental impact of all farming systems, including conventional/intensive (Annex 2 to this section).

Box 1. Socio-political perspective on farming systems



In most areas of the world there are two contrasting agricultural paradigms, epitomised by the symbols at the top of Box 1. The scales represent modern enlightenment philosophy, embracing scientific rationality and associated technological routes to the solution of problems. The yin/yang symbol represents post-modern philosophy, harking back to an earlier era which worked in harmony with nature, eschewing 'technological fixes' as a solution to farming problems. This socio-political perspective reflects the nature of the debates vying for influence on farming policies rather than any fundamental truths about their nature.

At the left hand side of this spectrum are conventional or intensive farming systems and at the right hand side are organic systems. In the middle ground, the term 'integrated farming systems' is claimed by both sides of the debate, on the one hand as espoused by the agrochemical industry to mean the use of technological options to reduce dependence on pesticides and fertilisers; and on the other hand to mean the use of natural controls, crop rotation and a range of agronomic practices to encourage pest predators, reduce incidence of diseases and reduce the need for chemical or biotechnological inputs.

Organic systems are generally portrayed as holistic and sustainable and conventional farming systems as the opposite. However, as argued in this paper, there is no reason why both cannot be equally sustainable; and both are certainly equally holistic in the sense that they behave as organised systems of inter-connected components and that the behaviour of the system will be changed, perhaps radically, if components are added or removed. This systemic nature in both cases is confirmed by the difficulties farmers experience in moving across the central divide between conventionally-based and organically-based systems and the relative ease with which they can move in either direction to or from that divide.

Building on this experience, in considering how governments influence innovation and uptake of technologies for sustainable farming systems, this paper adopts a competing objectives perspective on sustainability. This seems most likely to deliver the plural set of policies needed to cope with the complex and inter-connected nature of modern farming systems in the context of:

- globalisation and World Trade Organisation (WTO) negotiations,
- potential perturbations such as short term climate fluctuations or global climate change,
- competing uses for agricultural land (to produce fuel, fibre, commodity chemicals for industrial processes, high value-added pharmaceutical products and also wildlife and biodiversity benefits).

Technological innovation has a potentially important role to play in improving the sustainability of these farming systems through a range of innovations in engineering, information technology, pesticides and biotechnology, reducing the load of known toxins, substituting safer alternatives, protecting ground or surface waters, protecting natural habitats, reducing nutrient loads in soils, reducing gaseous nitrogen loss (Pitkin *et al.*, 1996; Scottish Natural Heritage, 1996; Tait and Pitkin, 1995) or reducing the amount of non-renewable energy used in the cropping cycle.

The paper focuses on European intensive/conventional farming systems on the most fertile soils as we will be reliant on these systems to feed an expanding world population in this turbulent physical and policy environment. It is conceivable that, as globalisation of food production systems and market liberalisation put farmers under increasing commercial pressure, they will respond by being more risk averse than before. Farmers who supply commodity markets will be under pressure to ensure that they have a good crop in terms of both quality and quantity in years when crop prices are high but they will have to make decisions about fertiliser use and pest control inputs before they have information on relevant market prices. They will thus be more likely than before to use inputs on an insurance basis but they will want to minimise the cost of this insurance, possibly leading to the use of older, off patent, and potentially more environmentally damaging technology. The adoption of new technology is likely to be more acceptable to these farmers and to have a larger and more rapid impact on the sustainability of European farming systems than any other currently available option.

The paper presents some of the results from the PITA project, covering innovations in pesticides, biotechnology and seeds (Annex 2 to this section), based on published and unpublished reports and interviews with Government officials and industry managers. A series of Policy Reports for the UK, Denmark, Netherlands, Spain and France, and the EU dated December 1998 give the full results of this phase of the project. These reports are available on the project web-site at http://www-tec.open.ac.uk/cts/pita/index.html and the titles are listed in Annex 3 to this section. The points selected here from each report are those most relevant to the present topic and the views expressed in the analysis are those of the author; they do not necessarily reflect the views of other project participants.

The following points are dealt with in this section:

- the policy environment within which companies developing new technology for agriculture have to operate;
- the impact of this policy environment on the strategic decisions of the companies involved; and
- the resulting challenges for policy makers wishing to encourage innovation and uptake of cleaner technology on farmed land.

Policy signals to farmers and to industry

As the title of this section implies, governments can influence both the development and the uptake of technologies for sustainable farming systems. Factors influencing the development of technology by companies will include:

- regulatory and approval systems for new products entering the market, *e.g.* for pesticides and GM crops; the clarity and certainty of these systems and the ease with which companies can meet them;
- restrictions on the use of some products regarded as damaging to the environment or to health;
- policies to stimulate technological innovation and hence international competitiveness.

Factors influencing the uptake of new technology by farmers will include:

- availability of subsidies and other production-related supports;
- availability of support for organic and related farming systems;
- the farmer's ability to make a profit at world market prices.

While there are opportunities to improve the sustainability of conventional farming systems through the adoption of new technology, our research has shown that the policy environment is sending confusing or contradictory signals to the companies developing the technology and the farmers who might use it. Under WTO rules, reforms to the CAP have shifted the justification for agricultural support away from the encouragement of food production and technological innovation towards rural development in disadvantaged areas and specific environmental objectives such as the preservation of species and habitats (CAP Review Group, 1995). The general policy trend is towards the right hand side of Box 1, shifting farmers away from technology-based, conventional farming systems towards organic and associated integrated systems.

Arguments about the need to maintain or increase food production currently do not carry much weight in policy circles and this makes it more difficult to focus on the encouragement of sustainability through the development and use of new technology. The assumption driving most agricultural policy initiatives seems to be that food surpluses will continue to be a problem rather than an asset for the foreseeable future (Anon, 1994; Jordan and Hutcheon, 1994). However, this perception could be changed by more extreme short term climate fluctuations or longer term climate change which affected food production in important growing areas, leading to shortfalls in some years and pressures to increase production. We could also see increased pressure on agricultural land for non-agricultural uses such as the production of fibre, commodity chemicals for feedstock for industry, high value-added chemicals and vaccines for the pharmaceutical industry, or renewable fuels to provide 'carbon credits' under the Kyoto Protocol, in addition to the need to produce food for a growing world population for the foreseeable future (Conway, 1998).

A more robust and precautionary policy approach would be one which allows for the option to increase food production without causing increased environmental harm in the event of any of these plausible scenarios. This then implies a need for a policy environment which encourages technological innovation and at the same time fosters international competitiveness of our more productive farming systems world-wide.

The first phase of the PITA project examined the policy environment relevant to the development of pesticides and GM crops in a range of European countries and also at the EU level. It

focused on policies with a range of potential direct and indirect impacts on innovation at the company level and the uptake of new technology at the farm level to improve the sustainability of farming systems:

- science, technology and innovation policies which could have a direct impact on research and development (R&D) and decision making in industry;
- policies promoting environmental protection and biodiversity, regulating the environmental impacts of farming systems, directly promoting sustainability and biodiversity, regulating pesticides and GM crops; and
- farm support policies and CAP reform.

Science, technology and innovation (STI) policies

In most European countries biotechnology is seen as an emerging technology area in need of state support to encourage the more rapid transfer of knowledge from the laboratory into the market place to ensure Europe's competitive position in the global economy (Tait and Williams, 1999). However, the much greater investment in pharmaceutical biotechnology reflects the greater profit potential of that market in comparison to the agricultural biotechnology market which is seen as publicly contentious and relatively depressed.

The agrochemical industry itself, although seen as extremely important for the overall competitiveness of European industry in world markets, is not seen as being in need of support to encourage innovation.

United Kingdom

Biotechnology is emphasised as an area with significant opportunities to develop a leading international profile for the UK, partly because of the strength of its pharmaceutical and agrochemical sectors and partly because of the strength of the biological sciences in UK universities and public sector research establishments (PSREs). Government initiatives support innovation in the agricultural biotechnology and seeds industries, mainly through Foresight and the LINK Programme.

Foresight brings together people from industry, public groups, academia and Government to identify trends and opportunities and to guide research supporting the future success of UK industry. Maintaining a strong publicly funded science base is presumed to ensure the continued attractiveness of the UK as a base for multinational companies and to foster indigenous small companies. The first round of Foresight suggested that EU agriculture should focus on high value products rather than bulk commodities to compete in global markets, and should develop of new methods to increase productivity in ways that are politically and socially acceptable. The current round incorporates cross-linking social themes such as sustainable development alongside the previous emphasis on competitiveness.

The Office of Science and Technology (OST, 1996) predicted that global political and technological changes will require the EU to produce for world markets and/or to substitute for current imports; trade liberalisation will further drive down EU food prices while biotechnology (among other technologies) will increase efficiency of grain production; and as Asian countries import grain to produce meat, the EU countries may find an export opportunity. A later report (OST, 1997) expressed doubts about the feasibility of EU countries engaging in such competition and technological futures

were seen as subordinated to EU policies which can gain public consent. The potential for global competition is seen to lie in high value products, not bulk commodities, with agricultural futures guided by socio-environmental goals. Agriculture will need to make the resources it buys more productive using methods which command political and social consent and technology is seen as essential both for the development of improved methods on the farm and for the exploitation of new markets.

France

STI in France is characterised by the importance of public sector research funded to preserve national competitiveness. This system leads to important scientific outputs but the development and marketing of innovations is weak. A series of biotechnology programmes has tried to establish a compromise between the preservation of scientific excellence and the promotion of links between public and private sectors

One programme on plant breeding and six others on biotechnology (mainly in the health sector) are ongoing or recently completed. Pharmaceutical research may have applications in ago-chemicals/seeds sectors and vice versa so the incentive and structuring effects of these programmes is wider than the funds specifically dedicated to plant biotechnology, the environment and the ago-food area.

At the beginning of the 1980's the French seed sector was seen as being in need of support and integration with biotechnology, focusing on new varieties with improved yield, optimal use of factors of production, resistance to pests and diseases, and improved quality.

The largest biology programme, BioAvenir, was initiated by Rhône-Poulenc in 1991, with the participation of French ministries and PSRE. The objective was to mobilise skills, strengthen collaborations and accelerate the transfer of knowledge between basic research and applied and industrial research. Controversy arose over the efficiency of such public policy instruments as the programme mainly followed Rhône-Poulenc's interests (Ducruet, 1998) and a 'national champion' does not spread new technologies over the whole sector.

In 1997, the two most important French seed companies, Limagrain and Coop de Pau, created a joint-venture (Biogemma) combining their potential on biotechnology R&D. They presented this initiative as the 'French reaction to the global stake of plant biotechnology'. Since then, the two companies have lobbied decision makers to develop a national programme on genomics modelled on the American 'Plant Genome Initiative'. They argue that the European seed industry is now jeopardised by the widening gap between American and European research in the field of biotechnology.

Netherlands

In the Netherlands, two separate ministries deal with fundamental and strategic research but the two goals are usually combined within research programmes. The agriculture ministry also has a role to play in STI policies which in the Netherlands are increasingly designed to stimulate stakeholders to innovate where they see advantages.

The 1980s was seen as a strategic growth area with three specific lines of action – public communication, formulation of clear approval policies and stimulation of technology. Barriers

experienced by industry included technological barriers, availability of alternative technologies, consumer acceptance, labelling issues, finance, patents, and the fact that biotechnology is not a priority technology in every part of the value chain (MEZ, 1997). Biotechnology is no longer targeted specifically but Government expenditure will not drop significantly as it has been integrated into long term science and technology funding and the industry collects a significant proportion of European research funding. The overall goals of STI policies are to bridge the gap between fundamental and applied research, to increase public involvement in the debate, and to improve international competitiveness.

The agrofood industry is the strongest economic cluster in the Netherlands (Veenendaal, 1995). It has its own Ministry and system of research, development and education. Recently, restructuring has led to more autonomy in agricultural research and to privatisation of extension, with the government focussing more on setting the context and providing for explicit public needs (agricultural education, an adequate research and development network, knowledge needs where market forces do not work properly (nature management), research for public goals) and supporting research only where there is a free-rider problem or for initiatives concerning restructuring and innovation (MLNV, 1995). Government funding of components that do not fit with these core tasks, will be progressively diminished.

Denmark

Danish public opinion is highly sceptical of GM crops but at the same time the Danish food sector needs to maintain and improve its international competitiveness. Government policies resolve this dilemma by supporting the development of biotechnology and at the same time developing the organic sector as a strategic growth area. Public concerns have not yet been reflected in political barriers to programmes to encourage the food sector to be more innovative, including a number of public/private sector projects on plant biotechnology launched in the mid 1980s which are regarded as successful.

The Ministry of Food, Agriculture and Fisheries strategic research plan for 2000 reflected the need to support the adjustment of agriculture to changing market conditions, the development of sustainable forms of production and the quality of food products. It recommends strengthening research in novel foods as part of a wider strategy to:

- focus on security, quality, health and nutritional value as means to retain the strong international position of Danish food production;
- intensify research in biologically and economically sustainable food production with increasing emphasis on ethics, the environment and working conditions;
- maintain and improve the level of knowledge concerning genetically-modified and functional foods, including safety assessments
- support research on new production technology, including biotechnology, within the food industry.

Public concerns are reflected in the strategy's emphasis on food quality, health, nutritional value, and methods of production.

Spain

The National Agricultural Research and Development Programme has its basis in the socio-economic importance of agriculture in Spain. There are three agriculture-related areas covered by the objectives:

- application of molecular biology to crop improvement (vegetables, industrial and ornamental crops; resistance to diseases and pests; improved stress tolerance, including low-input conditions).
- plant protection developments (risk assessment and prediction of pest, disease and weed incidence; cultural and biological methods for crop protection and optimising the use of phytosanitary products; and the development of integrated control programmes);
- soil management (sustainable production systems, nutrient dynamics, improved efficiency in fertiliser use, application of urban and ago-industrial waste).

There is little research on integrated pest control or agrochemical replacement. There are attempts to reduce inputs and discourage the use of broad spectrum pesticides but there are few approved projects.

The impact of public sector research on the agrochemical and biotechnological industry is small but growing. Knowledge transfer is sporadic and national companies prefer to co-operate with public research centres rather than multinational companies which generally carry out research in other countries. In contrast to most EU countries, Government is the main investor in innovation as Spanish companies must increase their research activity to increase their international competitiveness.

Biotechnology is seen as a strategic technology with a strong horizontal character and the National Biotechnology Programme will increase the funds allocated to establish R&D centres, purchase equipment and train staff. The sectors in which modern biotechnology is a key technology account for 15% of Spain's GDP (pharmaceutical, diagnosis, chemical, food, farming and environmental). Companies, mostly SMEs, with plant biotechnology activity account for 23% of the total and there is a strong presence of multinational company branches that supply the national seed market.

Policies promoting environmental protection and biodiversity

United Kingdom

In the policy debate on sustainable development there is an assumption that greater sustainability of farming systems will be achieved by reducing the level of inputs, and that there will be a corresponding reduction in productivity per hectare (HMSO, 1994). A consultation paper outlining a revised UK strategy for sustainable development (Department of the Environment, Trade and the Regions (DETR, 1998) made the point that economic growth should not come at the expense of the environment, wildlife and landscapes but also states that our prosperity and quality of life depend on competitive businesses producing high quality goods and services and suggests that we can use innovation to encourage reduced use of energy and materials, *e.g.* through information technology and biotechnology. The DTI also saw CAP reform and the end of production incentives reducing the incentive for farmers to 'milk the soil' but they questioned whether we should maintain, rather than reduce, the rewards for production and ensure that the sector remains competitive.

Statutory control of pesticide production and use is based on the UK Food and Environment Protection Act, 1985. This enabling legislation has been implemented through Control of Pesticides Regulations covering what pesticides to use; when to use them (*e.g.* harvest intervals to avoid the presence of residues in food, wind speed regulations, prohibition of use of some chemicals in cold weather); and how to use them (operator safety and training requirements, protective barriers along watercourses, disposal of toxic wastes, guidelines on machine application specifications).

The DETR is the lead agency regulating GM crops under the Environmental Protection Act (1990), which implements the EC Deliberate Release Directive 90/220. In the risk assessment, the effects of any transgenic crop are compared to the effects of the corresponding conventional crop under current agricultural practices. The Advisory Committee on Releases to the Environment (ACRE) advise whether GM organisms are at least as safe as the parents from which they are derived (substantially equivalent) (ACRE, 1998). By December 1998, ACRE had supported market-stage approval for several transgenic crops on grounds that they could cause no harm. However, emerging public opposition to GM crops since then has led to the imposition of a virtual moratorium on commercial growing of GM crops.

Partly in response to public pressures the UK Government has set up the Food Standards Agency to formulate policy and advise Government on all aspects of food safety and advise UK ministers on the Agriculture, Consumer Affairs and Internal Market Councils of the EU. Its guiding principles are protection of public health, unbiased safety and standards assessments based on scientific advice, balanced public information, decisions taken with due regard to both costs and benefits, avoidance of over-regulation, independence from sectoral interests and open transparent consultation.

On the issue of GM crop regulation, industry needs certainty about how long the process will take, but the UK Government position is that it is more important for the EC to resolve such issues on a long-term basis than to have short-term benefits for industry. Farmers, plant breeders and agrochemical suppliers have formed the Supply Chain Initiative on Modified Agricultural Crops (SCIMAC), which emphasises the importance of GM crops for international competitiveness of UK agriculture and devises voluntary plans for market-stage monitoring, especially of GM crops.

France

The main environmental and health issues are water contamination by pesticide and fertilisers, GM organisms and biodiversity. The Ministry of Agriculture (MoA) tries to establish a compromise between farmers' interests and environmental protection (*e.g.* agri-environmental measures) but the Ministry of Environment (MoE) favours more drastic measures (preservation of National Parks, ecological taxation). Until recently, the political weakness of the MoE compared to the MoA lowered the efficacy of environmental policies from both ministries.

Intensive agriculture leads to high residues of nitrate and pesticides in water bodies and also overuse for irrigation leads to a threat of drought. There is fragmentation of responsibility for water quality with reliance on voluntary agreements, local case by case intervention, linking agri-environmental schemes and pesticide reduction projects in vulnerable areas, and consensus between administrators, farmers' unions, industry representatives, public research, technical institutes, water agencies. Government actions on pesticide use are generally less effective because of unsolved questions about relevant products and threshold levels. France delayed implementing the European Drinking Water Directive for 15 years, retaining the WHO standard, and it is difficult to find a national overview of drinking water quality.

The MoE is considering implementing an ecological taxation system for pesticides based on the 'polluter pays' principle. The political context is now favourable to a more balanced influence on agricultural issues between the MoA and MoE.

An OECD report (1997) stated that French policies aimed at reducing the use of pesticides should be based on the precautionary principle, following the example of countries in Northern Europe which have carried out pesticide use reduction programmes and that substitutes for chemical pesticides should be adopted.

Public opinion on intensive farming systems and GM crops has become more radical in recent years in France and some GM crop trials and products have been destroyed. The Government was criticised for allowing Bt maize cultivation before there had been any public debate. However, the debate today is wider than GM crops, with discussion about agricultural practices and the different options for sustainable agriculture. Health issues are important in the context of consumer mistrust after the BSE crisis, particularly in the context of application of the Novel Food Regulation and the issue of labelling. Important questions include the rights of consumers to be informed and the detectability of GM organisms. The evaluation of environmental risks (*e.g.* problems of gene flow) and health effects (*e.g.* antibiotic resistance gene markers, problems with allergies) are all subjects of scientific controversy and the political debate turns around procedures for risk assessment and precautionary measures before marketing GM crop derived food.

A public debate on GM crops has been launched and the French government is developing a new policy based on:

- *case by case decisions* - a moratorium for the marketing of any species other than corn, in particular oil seed rape and sugar beet, until the conclusion of the public debate and until the research is completed;
- *biovigilance policy* – setting up of post marketing surveillance of GM crops;
- consideration of socio-economic impacts of GM crops.

Netherlands

The main issues on environment, public health and biodiversity are the use of chemical crop protection agents and the introduction of transgenic crops. There is a broad consensus on the necessity to reduce pesticide use, while the introduction of transgenic crops is controversial. The reduction of overall pesticide use has been significant, but the use of harmful herbicides and insecticides remains at a problematic level. The government will make an effort to promote the organisation of identifiable GMO-free production and distribution chains.

The Multi Year Crop Protection Plan (1991-2000), has significantly reduced pesticide use. In anticipation of the requirements of Directive 91/414/EEC manufacturers and distributors of pesticides agreed to apply for renewed approval of products resulting in the elimination of several environmentally harmful chemicals in 1996. A 40% reduction in pesticide use by 1995, compared to 1984-88 was close to the target level with further reductions to 50% planned for 2000.

The Rathenau Institute (1996) advocated a move to a more preventive approach to crop protection and sustainable production, from the current 'end of pipe approach', through intermediate preventive strategies within companies and ultimately to prevention on a higher system level, while recognising that chemical crop protection methods will remain indispensable. Most Dutch farmers are now seen as being in transition from the first to the second stage. The approach so far only refers to

reduction in the quantitative use of chemicals; there is still scope for improvement in the quality of the products used.

EC Directive 90/220 on deliberate release of GMOs was implemented as an extension of the Toxic Waste Act in 1992 with the objective of providing a precautionary regulation that facilitates identification of possible risks, delivered as part of a case-by-case procedure.

There is general agreement between consumer and environmental organisations, policy makers and industry about the main issues of concern regarding the introduction of transgenic crops, but there are differences of opinion on what precautionary measures are required. In 1995 there was agreement between consumer organisations and industry on the labelling of GMO-based products but because of concerns about public reaction actual labelling did not occur until January 1998 when Unilever became the first manufacturer to use the Dutch system of labelling on a European scale. Efforts are also being made to promote identifiably GMO-free production and distribution lines.

Denmark

The main environmental protection issues are the release of GMOs, water policy and pollution and agrochemical use. Related policy issues include the possibility of incorporating the EU environmental guarantee (Maastricht Treaty, Article 100A, 4) into Danish law and the use of green taxes versus statutory measures. This policy area is highly relevant to discussions on Denmark's relations with the EU, particularly the farming sector.

Water quality is an important national policy area as Denmark relies almost entirely on ground water for its drinking water supply. The whole country has been designated a Nitrate Vulnerable Zone. In 1987, two sequential Action Plans to reduce pesticide use to environmentally acceptable levels and to shift use away from the most environmentally damaging products were introduced, while recognising that agricultural production could not take place without pesticides. Levies have also been introduced on pesticides at varying levels. In 1997 a report was commissioned on the implications of abandoning altogether the use of pesticides in agriculture. As a result of these measures, frustration is beginning to build up in the farming community with tensions between farmers, policy makers, the press and the public.

There is general scepticism on genetic manipulation, with strong public support since the mid-1980s for environmental pressure groups calling for restrictions on GMOs. Denmark regulated gene technology several years ahead of the EC Directive 90/220, with a focus on environmental effects. Denmark has also been a strong advocate of including secondary effects of a GM crop as part of the 90/220 assessment, *e.g.* the impact of herbicide resistance on patterns of herbicide use and the environmental implications of these changes. There has been a long term commitment to labelling of GM products, even where there are no detectable differences from non-GM products, to allow consumer choice. The effect of such labelling has been to ensure that there are no products containing GM ingredients on the Danish market.

Spain

Nature conservation policies cover biodiversity (preservation and sustainable use, access to genetic resources and technology, the equitable distribution of benefits from resource use and preservation of existing phytogenetic resources) but these policies are not binding.

Spanish public opinion, environmental organisations and consumers are increasingly aware of environmental issues and have launched campaigns against pesticide use and GM crops and in favour of organic farming. Consumers are demanding more information on these issues and lower pesticides residues in fresh food although Eurobarometer surveys indicate that Spanish people are more supportive of GM crops than many other European countries.

Agricultural policy now emphasises the reduction of environmental impacts, the protection of biodiversity and the development and use of higher quality (in terms of agronomic characteristics) and more environmentally friendly inputs. On the other hand, policy also favours reorientation of agricultural production to more competitive products that could have a higher environmental impact.

The main concerns regarding plant protection products are soil pollution (caused mainly by the excessive use of fertilisers and pesticides) and water management (over-exploitation and pollution from excessive use of fertilisers and, to a lesser extent, pesticides). The water policy is essential to the sustainability of farming in Spain and it includes both a savings policy and a quality policy. Priority actions include the consolidation and improvement of existing irrigated lands to promote water saving and increase the competitiveness of irrigated crops. The Agriculture, Fisheries and Food Ministry plans to extend and modernise irrigation farming but it has not yet been possible to achieve consensus for its approval, the most controversial issues being water transfers between basins and the establishment of fees.

The National Agriculture Research and Development Plan promotes the use of natural pest control and the development of integrated control systems.

Biotechnology policy aims to prevent harm to the environmental and human health. Contained use, release and marketing of genetically modified organisms is regulated by the Law 15/94 and Executive Order 951/97 which transpose EC directives 90/219 and 90/220. Environmental organisations are putting pressure on the Spanish government to stop research on GMOs, to draft stricter regulations, to declare a moratorium on intentional release of GMOs in order to assess potential risks, to apply the precautionary principle in genetic research, to provide information on the research carried out, and to allocate more public resources to other types of bio-science research, avoiding the concentration on biotechnology.

Farm support policies

United Kingdom

The UK Government shares the key objectives of Agenda 2000 (the EC proposals for reform of the CAP) (CEC, 1998). It views competitiveness as a priority but at the same time it supports environmental objectives and switching support from production to rural development to help communities adapt and compete at home and in world markets The preferred policy would be to remove all payments that might be viewed by the WTO as coupled to production and to give EU member states discretion over how best to compensate farmers (*e.g.* with moves to less intensive farming methods and development of complementary economic activities. The Ministry of Agriculture Fisheries and Food (MAFF) envisage a dual approach with farmers either maximising production or, in marginal areas receiving payments to conserve or enhance countryside features.

France

Agriculture is considered as a strategic economic activity as France is the most productive and export-oriented country in Europe. In discussions on the *Loi d'Orientation Agricole* and the project to establish Farm Territorial Contracts, agricultural policy is evolving to strengthen the economic sustainability of agriculture through diversification or organic farming. Social importance, in terms of employment and land management is underlined. Non productive functions such as environmental protection are becoming a priority, with some financial compensation backed up by voluntary compliance.

An alternative question is whether France (and Europe) should try to reverse current trends and reinforce international raw and intermediate product competitiveness, as proposed by French wheat producers, and also improve the efficiency and competitive advantage of their food exports.

EU proposals to maintain the competitiveness of European agriculture based on price reductions and simplification and unification of the subsidy system meet with strong opposition from producer countries such as France, their main argument being that the European deficit in rapeseed or peas should receive support to limit US soybean imports. From this perspective, according to French agricultural policy, the main aim of the CAP should change from an emphasis on increasing production and exports to recognition of the multi-functionality (economic, social and environmental) of agriculture. All those functions have to be rewarded, so subsidies and support are not exclusively focused on, and determined by, production. The CAP support system should be modified within the perspective of the next round of WTO negotiations. However the powerful French wheat growers oppose this approach.

Netherlands

The Dutch government is generally supportive of Agenda 2000 particularly on the reduction of price support but it is more critical of the low levels of compensation (the shift to decoupled income support is unfavourable to intensive farming and Dutch rural areas are probably not eligible for support). The government is also in favour of EU enlargement and trade liberalisation, the latter being conditional on respecting national standards for environmental protection, food quality and human health. Innovation and technological development are seen as major tools for maintaining and enhancing international competitiveness of the Dutch agrofood sector. Government policy thus aims to promote a market-oriented approach to agriculture at national and EU levels, with the parallel aim, based largely on self-regulation, that it should remain ecologically sound. There are also subsidies for organic production..

Dutch agriculture has limited natural advantages and the Ministry of Agriculture emphasises that the sector has to increase profits by marketing new products and solving problems (environment, animal welfare) better and earlier than competitors. The sector thus depends on innovation to maintain its competitive edge.

Denmark

Denmark has been a net beneficiary of the CAP, and reforms involving the reduction of subsidies and decoupling of income support are against agricultural interests. However, national policies support liberalisation of world trade accompanied by higher environmental standards at the EU level. The need for such reform to be gradual is stressed to protect farm incomes.

Spain

CAP reform and WTO agreements involving market liberalisation and reduction of production subsidies will force Spanish agriculture to increase its competitiveness in international markets. Farmers can reduce production costs by using cheaper inputs and increasing negative environmental impacts or they can incorporate technological innovations and diversify their product range. The resulting changes in agricultural systems could produce overexploitation of water resources. However, product diversification and incorporation of technological innovations could have positive impacts on sustainability through, for example, the use of higher quality seeds adapted to specialised conditions enabling reduction in the use of other inputs.

Agricultural policy has been facing a contradiction between the need to improve and update farming units to improve productivity and competitiveness of the sector, and the imposition of restrictions to production levels. CAP reform has affected the continental (interior) farming systems but not the Mediterranean ones. The duality between traditional, less competitive units and modern, highly capitalised, very competitive units has been reinforced.

Overview and international issues

Governments increasingly operate in an international context and national freedom of action is diminishing. Nevertheless, as the information from the national policy reports referred to here shows, there is considerable variation of emphasis on regulatory and policy issues in different European countries.

Support for proposed CAP reforms and removal of production-related farm support mechanisms is strongest in the UK, France and Spain, as these countries believe that large sections of their farming community will be able to survive and perhaps even prosper in a free market economy. However, in all countries there is also support for retaining the current systems.

Denmark and the Netherlands, among the countries studied, have the longest history of policy development to restrict pesticide use and to encourage the development of more environmentally sustainable chemicals, often in advance of EU level policies. However, even in these countries many farmers recognise that commercial farming will always need to rely on pesticides to some extent. Concerns about pesticide use are more subliminal in the UK, France and Spain, but in France and Spain, sustainability of the water supply and use for irrigation purposes are major issues.

Public concern about GM crops has been increasing rapidly in most European countries in the past two years, most notably in the UK and France (Tait, in press). The policy responses to these concerns across European countries have also become increasingly out of step with the intentions of EC Directives and the prospect of EU harmonisation of biotechnology policies is receding (Levidow *et al.*, 2000). Spain has so far had lower levels of concern than other European countries but even here it is growing. There are also indications that these concerns are spreading to other parts of the world, particularly the USA, where they could have more immediate impacts on the plans of agrochemical and seeds companies.

In the EU, reforms to the CAP have been motivated, among other things by the General Agreement on Tariffs and Trade (GATT) and subsequently by the WTO as part of the global trade liberalisation agenda. Support for crop production *per se* will be phased out and alternative mechanisms will need to be found to avoid damage to the non-food benefits of agriculture. The agricultural agenda for these talks, and also within the OECD, has been shifting to include non-food

concerns and multifunctionality (OECD, 1998). However, public concerns about globalisation have remained, including sustainability of food production systems, the increasingly rapid pace of technological innovation and the power of the multinational companies that increasingly control agricultural trade (Tait and Bruce, 2000). Public groups concerned about these issues were major contributors to the disruption of the 'Millennium Round' of negotiations at the World Trade Organisation (WTO) talks in Seattle in December 1999 (Kyriakou, 2000).

Giddens (1999) has advocated development of better public means of engaging with science and technology, which would not necessarily do away with the quandary of 'scare mongering by pressure groups versus cover-ups by risk generators and regulators' but which might allow us to reduce some of its more damaging consequences. Patten (2000) in the first of a series of BBC Reith Lectures on sustainable development raises questions about the role of non-governmental organisations (NGOs), as representatives of public concerns at negotiations such as those of the WTO. At the same time, Agenda 2000 proposals (CEC, 1998) have given environmental agencies and interest groups a more legitimate role in the debate on whether the dual objectives of improving competitiveness and protecting the rural environment can be combined in a set of integrated policy measures, or whether they are incompatible and have to be addressed separately.

In this climate, the companies developing innovative products for agriculture can expect to face a period of considerable turbulence both in the regulatory environment and on the public opinion front for some time to come. Delays and uncertainty in the regulatory and policy environment are likely to affect the nature and timing of companies' investments, in both pesticides and biotechnology.

The impact of policy on industry strategies

If the market for new technology is uncertain and regulatory systems are in a state of flux, industry will in the long run be discouraged from investing in innovation. However, this is likely to be a delayed effect as, particularly in the case of pesticides and genetically modified (GM) crops, companies are used to operating with lead times of 15-20 years which make short term market and policy fluctuations less relevant to their decisions.

The second stage of the PITA project, following the policy analysis, has involved a series of interviews with senior managers in companies developing pesticides, biotechnology and seeds. Analysis of these results is not yet complete but some preliminary findings relevant to the issue of overall agricultural sustainability are emerging, for example on the development, production and use of pesticides and the future of GM crops.

STI policies

Government policies to support innovation, particularly in the agricultural biotechnology area, could lead to faster development of a range of technology options with the potential to improve the sustainability of farming systems by reducing the use of pesticides and improving the quality or yield of the crop. There is little doubt about the need for, and benefits from, public support for fundamental research and for training highly qualified scientists, engineers and managers. However, it is difficult to envisage how public investment beyond the fundamental research stage for new or existing small companies will lead to corresponding public benefits under current circumstances. Research carried out some years ago showed that small and medium sized enterprises (SMEs) in agricultural biotechnology are not able to innovate independently of the strategies of multinational

companies (MNCs) and indeed if they are successful innovators, their most likely fate is to be taken over by an MNC (Chataway and Tait, 1993).

The 'barrier to entry' for small firms in the agrochemical and biotechnology industries arises from the strong regulatory regimes in these areas – only large companies can tolerate the long market lead times and can afford to build up the expertise needed to deal with regulatory systems world-wide (Tait and Williams, 1999). New entrants into a technology area are not inhibited by a (perhaps) inappropriate organisational culture and an existing portfolio of products to defend; they are therefore more likely to change industry trajectories, perhaps in directions that would favour products offering greater farm sustainability. Under current circumstances, given that regulatory regimes are, if anything, becoming stricter and more complex, the contribution of SMEs to innovation in pesticides and biotechnology for sustainable farming is likely to be channelled through MNC strategies.

Thus, government STI policies have little impact on R&D strategies of MNCs and, although they may offer short term support to SMEs, there is so far no evidence of this support having a direct impact on the types of products available to farmers. A more radical and integrated approach to STI policies is needed if the aim of developing innovative products for agriculture, more rapidly, is to be achieved.

Pesticides

The pesticide regulatory regimes of the EU have so far been unwilling or unable to move ahead of scientific evidence of harm and to withdraw existing approved chemicals on a precautionary basis. According to our discussions with EU policy makers, one aspect of pesticide regulation which has been holding up the development of regulatory approaches which discriminate in favour of environmentally benign products is the lack of agreed indicators by which to judge the potential environmental harm from individual pesticides in use.

However, US regulators seem to have successfully circumvented this problem and, from information provided by the companies we interviewed, the US Food Quality Protection Act (FQPA) 1996 has dramatically changed this situation. The FQPA amended the Federal Insecticide, Fungicide and Rodenticide Act and the Federal Food Drug and Cosmetic Act and changed the way the Environmental Protection Agency (EPA) regulates pesticides. There is a new safety standard – reasonable certainty of no harm – that must be applied to all pesticides used on foods and also a system which expedites the approval of safer pesticides (www.epa.gov/oppfead1/fqpa).

The latter feature was mentioned by some of the companies we interviewed as the policy measure that had most significantly affected their strategies. They described it as leading to greener products rather than products directed to a specific market. The result is that companies compete on product performance and lack of restrictions on use. There is a 'risk cup' and once it is full there is no more room for 'me-too' products. In R&D planning companies therefore need to look at how their new product will shunt out others (their own and other companies'). These factors also have a knock-on effect on the rest of the world given the US influence on import tolerance levels. Safer products are registered faster which gives them a market advantage and, just as important, the breadth of the label will give such products a commercial advantage. A compound which has 'safer' status will knock out or limit the impact of products already on the market.

The EC Drinking Water Directive (80/778) which sets a limit of 0.1 µg/litre for contamination with pesticides was, on the other hand, widely seen as insufficiently discriminating, given that the threshold level of contamination bears no relation to the toxicity of the chemicals

concerned. Companies do not have problems complying with the Directive, but it is used by them as a criterion for rejecting chemicals at an early stage of the R&D process – any pesticide with the potential to leach from soils is rejected. The result is that chemicals with potentially attractive features from a sustainability point of view are being eliminated from further consideration. The fungicide azoxystrobin which was the first product to be registered under the EPA's Reduced Risk Pesticide Scheme was a marginal candidate for rejection in the R&D pipeline because of anticipated problems with the EC Drinking Water Directive.

Despite the regulatory success of the FQPA, managers made the point that a new pesticide on the market will not necessarily knock out older and more damaging products, particularly if they are much cheaper. Farmers may need to be given an incentive to take up new technology. Pesticide taxes have had support from some policy makers and environmental groups but they are generally seen by industry and economists as inefficient and largely ineffective. Regulatory review, if done in consultation with industry, was seen as a more effective method of encouraging change.

Biotechnology

From the industry point of view, biotechnology regulation in Europe was seen as having a potentially serious impact on the R&D strategies of companies, particularly those with their main R&D facilities in Europe. The regulatory uncertainty may drive them to relocate elsewhere, but would not necessarily have an effect on decision making for world markets where companies still see GM crops as having enormous potential benefits for the sustainability of farming systems. To give just a few examples: 'low phytate' animal feeds and feeds tailored to the nutritional needs of different species would reduce the environmental impact of animal husbandry systems; GM insect and disease resistant crops would reduce, but not eliminate, the need for pesticide applications; and if fewer pesticides are applied the number of chemical factories (with attendant point source pollution problems and health risks to workers) can be reduced and there will be less wastage of fossil fuels in transport and application of chemicals. There is a view in industry that GM crops could have a considerably greater and more rapid impact on pesticide usage levels in agriculture than any conceivable policy or regulatory initiative.

A policy consensus is nevertheless emerging that GM crops have been introduced with undue haste and perhaps with insufficient attention to the need for public reassurance (based on widely available evidence of safety) and also public choice (based on clear labelling). An international forum, similar to the Intergovernmental Panel on Climate Change has been proposed to provide Governments with a state of the art assessment of scientific knowledge and to set this in the context of society's broader concerns (Krebs, 2000).

The need for policy evolution

This paper has given an overview of one part of the current regulatory and policy environment within which new approaches to the development of technology for sustainable farming systems are emerging. It only has a partial coverage of a very large area but several important points are clearly beginning to emerge.

- There are policy and regulatory initiatives that can have a major and rapid influence on the innovation processes relevant to sustainable farming systems, but they are infrequent and their value and significance may not be recognised.

- It is more usual to find that policies and regulations emerging from one policy area have unexpected effects in other areas or are counteracted by constraints which were not previously recognised.
- Public arena decision makers can most effectively focus on creating a policy and regulatory environment which is enabling in the desired direction, rather than being constraining and restrictive.
- Faced with businesses operating on a global scale, globally organised environmental and other public pressure groups and rapid information flows using the internet, policy makers need to be better informed and better integrated. This will imply building on new national and international transboundary regulatory systems and developing a body of policy makers with new, interdisciplinary skills.

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Annex 1

SNH Tibre Project
Targeted Inputs for a Better Rural Environment

Sustainable development and Scottish agriculture

In intensively farmed lowland areas, conservation agencies have tended to focus on the creation and improvement of small, peripheral areas of wildlife habitat such as hedgerows, ponds and small woodlands. Due to the impact from the surrounding intensively farmed areas, these peripheral wildlife habitats are often less biologically diverse than SNH would wish. However, this does not necessarily mean that the intensive farming systems themselves are unsustainable in agricultural or economic terms.

Despite numerous predictions to the contrary, intensive farming systems in the UK have largely managed to avoid collapsing into a degenerative ecological spiral. They have therefore remained sustainable from the agronomic point of view, partly as a result of technological inputs, aided by financial support measures. In other parts of the world where farmers have seen clear evidence of the unsustainability of their farming systems, for example because of run-away pest problems, it has not been difficult to persuade them to change their attitudes and their practices. However, in the UK, such changes have been much more difficult to achieve.

The TIBRE project is only one component of SNH's overall approach to the sustainable development of agricultural systems. In many parts of the country, where the agricultural system itself supports the wildlife habitats and landscapes that we would like to see encouraged, SNH has a range of programmes to foster the systems themselves, as in crofting and hill farming regions. In intensively farmed lowland areas, where farmers are willing to make the necessary changes, we will continue to support conversion to organic and lower input integrated farming systems. However, we have good reason to believe that the largest and most intensive farmers will not willingly go down this route.

The TIBRE project was therefore set up to enable these farmers to contribute to the environmental sustainability of Scottish agriculture, while at the same time continuing to contribute to its agricultural sustainability. We felt that this could be achieved through the uptake of technological innovations in the areas of chemical technology, biotechnology, engineering and information technology.

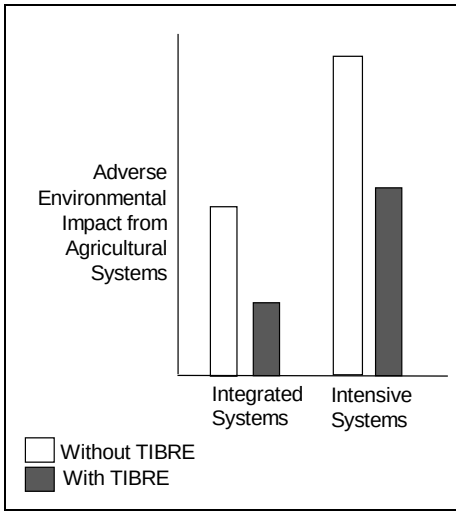
TIBRE rationale

The TIBRE project offers a practical and constructive approach which deals with the complex issues relevant to intensive lowland agricultural systems:

- the possible withdrawal of financial support for farmers through the CAP could lead to greater reliance on cheaper and more environmentally damaging technology;
- it will become progressively harder for expensive, new, more environmentally sustainable technology to gain a toe-hold in the market in competition with this cheaper technology;

- industry will be less likely to spend money on research and development for new technology under these market conditions;
- policies designed to reduce surplus production, such as "set-aside", are likely to be reversed as EU prices approach those of the world market;
- the use of productive land for alternative, non-food crops, some of very high value, will increase the pressure to maximise food production on the remaining land area;
- a return to a situation of maximum food production on most of the available land which would result from increased demand on world markets could be very damaging to the environment if it relied on increased use of the current generation of technological inputs.

Although targeted primarily to intensive farming systems, TIBRE will also be applicable to the integrated systems being advocated by a range of initiatives in the UK such as Linking the Environment and Farming (LEAF), the Government's R&D LINK programme and the Scottish Agricultural College Sustainable Farming Systems Programme. The figure below illustrates the potential environmental benefits from TIBRE for integrated and intensive farming systems.



The overall aims of the TIBRE project are as follows:

- to improve the environmental sustainability of integrated and intensive agricultural systems through the uptake of new technology;
- to reduce the environmental impacts on productive areas of farms and to minimise the impact on the non-farmed wildlife habitats;
- to encourage commercial companies to speed up the development of new technology with improved environmental performance and with no loss of agronomic performance;
- to influence policy so as to foster appropriate technological innovation;
- to implement TIBRE through working with relevant partners in the UK and in other EU countries.

Phases 1 and 2 of the TIBRE Project

The project has been under way in SNH since June 1993 and considerable progress has been made with its development.

First we undertook an *initial consultation* in order to gauge the reaction of a wide range of interested parties to the project and to assess how it might be developed further. Consultees included research institutes, universities, voluntary bodies, agrochemical companies, the National Farmers' Union of Scotland and the Scottish Office Agriculture and Fisheries Department. There was general support for the idea, particularly from farmers, farming organisations, agricultural researchers and the agrochemical industry. Reservations were, however, expressed by some nature conservation bodies who placed more emphasis on the need to encourage environmentally sensitive farming by traditional methods in areas which are already rich in wildlife.

The major part of the work involved an *option appraisal* of relevant technological developments. We looked at products which had recently become available on the market, were soon to be available or were in the early stages of research and development, in the areas of chemical technology, biotechnology, information technology and agricultural engineering. A series of detailed reports was prepared by external contractors and a summary of these reports is being prepared for publication in the RASD Reviews Series.

An *Inter-Agency Working Group* was set up involving the research community, farming advisers and consultants, the agrochemical industry, policy makers and voluntary conservation organisations. These bodies will have a crucial role to play in implementing the ideas and proposals which we are developing. The advice from the first meeting of this working group helped SNH to take forward the options identified by the initial surveys and to set up the initial consultations with farmers.

We then undertook a *technology assessment* to provide further evaluation of the innovations identified by the option appraisal. Products were considered from the point of view of their potential beneficial influence on the natural heritage arising from: a reduction in the load of a known toxin; substitution of a safer alternative; protection of ground or surface waters; protection of natural habitats; protection of the soil resource, e.g. through reducing nutrient load; or a reduction in gaseous nitrogen loss. We also considered the availability of the innovations, economic and agricultural factors likely to influence farmers' attitudes, and the possibilities for synergistic interactions among existing and new developments. Overall this assessment showed that many products, which are already available on the market, have the potential to offer a direct or indirect environmental advantage over present agricultural technology.

We then undertook a *consultation* with approximately 20 arable farmers who have an influential position in the farming community and who are motivated to a high degree by business concerns. Some of these farmers are known also to have an interest in the environment, but this was not a factor in the choice. These farmers were asked to discuss the long list of products which had been identified by the option appraisal and the technological assessment as being of possible environmental benefit and to rank them according to their perceived attractiveness for use on their farms. The resulting shorter list of technological options will form the basis for the set of demonstration and advisory packages to be taken forward in the next phase of the TIBRE project.

Phase 2 of the project is now underway and is due for completion in the Autumn of 1996. It has the following main components:

- an extension of Phase 1 work in the arable sector to develop partnerships with farmers, farmers advisors, policy makers, industry and the retail sector, at the Scottish, UK and European Union levels;
- an extension of the coverage of TIBRE into lowland intensive animal husbandry;
- a communications plan to gain widespread publicity for the TIBRE initiative;
- planned transfer of major activity on TIBRE to our partners in a third phase, with retention of a less resource intensive, but still influential role for SNH.

TIBRE benefits and advantages

The TIBRE approach is in keeping with modern thinking on constructive approaches to environmental improvement through technological innovation. Examples include the Technology Foresight initiative of the Office of Science and Technology, the European Commission Fourth Framework Programme, and the Research and Development strategies of many commercial companies. Many non-government organisations are also increasingly supportive of this approach.

TIBRE is in keeping with the attitudes and natural inclinations of large, intensive farmers. It is therefore more likely to gain a ready acceptance than alternative approaches which require farmers to change their attitudes and their farming systems. It is also more likely to be self-supporting in the long term as it will not require continual reinforcement through a system of state subsidies and training programmes.

The focus on products and on collaboration with industry will lead eventually to a situation where there are commercial incentives to promote the TIBRE approach. In the early stages of implementation, public support may be necessary to encourage early uptake of the new technology, but it should be possible to phase out such support as the technology becomes more widely adopted. It is therefore likely to be less demanding on the public purse in the long-term than alternative approaches.

The TIBRE approach is also considered more environmentally robust than alternative approaches to agricultural sustainability. Many current initiatives focus on the perceived over-production of food in the European Union and attempt to reduce inputs with the joint aims of reducing production and also reducing environmental impacts. If there should be a change in the policy environment and a return to maximising outputs, this will be much more sustainable if it is done from an improved technological base, rather than with current environmentally damaging technology.

Achievements to date

As outlined in Section 7, a series of papers on TIBRE has been presented at conferences recently. Presentations at conferences usually generate considerable interest and follow-up publicity in the farming and environmental literature and also on radio. An information leaflet on TIBRE has also been prepared.

A major achievement must be that SNH is now regarded in a relatively favourable light by many who are influential in the farming community. Examples are given in Section 7.

We are already in discussion with the Scottish Agricultural College over the possibility of the TIBRE approach becoming a component of their advisory programme, and we would expect this

to come to fruition in two to three years time. We hope that SNH Regional and Area staff will want to be involved in any regional demonstrations, but this will not be essential.

Future plans

A Review Paper will be published summarising the innovations proposed by the contractors as suitable to contribute to a TIBRE approach, including details of the subsequent assessment by ourselves and by farmers. We will also continue to produce publications for conferences and for the non-specialist press as opportunities present themselves.

In addition to the work with SAC, we will be discussing TIBRE with other advisors in Scotland, including the commercial sector with a view to the setting up of demonstrations of the economic and managerial feasibility of the approach on working farms.

We plan to present our ideas to English farmers with a similar status to those in our Scottish group. We are also in discussion with MAFF with a view to linking the TIBRE approach with its Action Plan for the Responsible Use of Pesticides.

With a view to influencing the agrochemical industry we have been offered an opportunity to present details of the TIBRE approach to a meeting of the British Agrochemicals Association which will be attended by the Chief Executives of most of the multi-national agrochemical companies operating in the UK.

We also to plan to make presentations to staff from the European Commission and also to members of the European Parliament to encourage a Europe-wide consideration of the opportunities presented by the TIBRE approach and of the policy developments which it may stimulate.

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Annex 2

Policy Influences on Technology for Agriculture: Chemicals,Biotechnology and Seeds (PITA)

Project funded by the EC Targeted Socio-Economic Research Programme (TSER), DGXII

Project outline

Technological innovation in the agrochemical, biotechnology and seeds industries and in associated public sector research establishments (PSREs) has the potential to deliver more socially and environmentally sustainable farming systems and to improve the quality of life in Europe. This is particularly true of farms on the most fertile land.

However, although policies developed in different areas may all aim to improve the quality of life, in practice, in their influence on company and PSRE strategies, they frequently counteract one another and so attenuate the desired effect.

Market-related factors also influence decision making in industry and PSREs, the most important for this project being the policies of food processors and distributors and also public attitudes and opinion, which often set more demanding standards than those of national governments and the EU.

The PITA project will first develop an integrated analysis of policies and market-related factors relevant to the agrochemical, biotechnology and seeds sectors. The core of the project which follows will be an investigation of the impact of these factors on the strategies and decision making of companies and PSREs and the downstream implications of these decisions on employment, international competitiveness and environmental benefits. The range of policies and other influences studied will include:

- policies to stimulate innovation in the agrochemical, biotechnology and seeds industries;
- purchasing policies of food processors and distributors;
- policies for international trade liberalisation;
- policies for the regulation of industry and farming (for environmental protection and public health and safety, particularly for pesticides and biotechnology);
- agricultural and farming support policies, particularly for crop production;
- policies to promote environmental sustainability and wildlife biodiversity in arable farming areas;
- public opinion and attitudes.

Project objectives

The overall aim will be to contribute to the development of sustainable industrial and farming systems and an improved quality of life by encouraging the development and uptake of 'cleaner' technology for intensive agriculture. The project structure is summarised in Figure 1

Objective 1: To develop an integrated analysis of policies and market-related factors relevant to technological innovation in the agrochemical, biotechnology and seeds sectors, to study their interactions and to develop hypotheses about their impact on strategic decision making in industry and PSREs.

Objective 2: To study the influence of policies and market-related factors on innovation strategies in the agrochemical, biotechnology and seeds industries and PSREs, and their impact on decisions about product development, levels of investment and location of investment.

Objective 3: To study the outcomes of the industry decisions investigated under objective 2, in their effects on employment, on international competitiveness and on their potential to deliver environmental benefits.

Project outputs

We will provide feed back to policy, research and commercial decision makers to give them an improved information base for future decisions on policy development and product innovation by the following means.

- Reports on policy and market-related factors, their interactions and their projected influence on industry and PSRE decision making;
- Reports on strategic decision making in industry and PSREs on product development, investment levels and location of investment, as influenced by policies and market-related factors;
- Integrated overall report;
- PITA database;
- Information packs for policy makers and industry and PSRE decision makers;
- Series of meetings with relevant stakeholders.

Partnership

Partners have the necessary spectrum of expertise in policy analysis and technology management and interdisciplinary working as follows:

- **UK (Co-ordinators):** Open University: David Wield, Edinburgh University: Joyce Tait.
- **Netherlands:** Agricultural Economics Research Institute, The Hague, Jos Bijman;
- **France:** Institut National de la Recherche Agronomique, SERD, Grenoble, Pierre-Benoit Joly; and QAP Decision, Gerald Assouline.
- **Spain:** University of Seville, Carlos Roman, Jose Carlos Cuerda.
- **Denmark:** South Jutland University Centre, Villy Sogaard.
- **Additional Partners:** Anthony Arundel (MERIT, NL).

The countries have been chosen to illustrate a range of policy approaches to the issues being studied and to include a significant proportion of the companies and PSREs to be involved in the research. National level policy studies will be carried out in these countries, along with an EU-level analysis.

For the industry-based research, we will include all the major multinational companies operating in Europe, including those based in Switzerland, all relevant trade associations, PSREs and small companies, where appropriate, regardless of location in Europe.

Overall co-ordination was carried out by the UK team. The project operated from December 1997 to July 2000.

Annex 3

PITA Policy Reports
December 1998

Villy Søgaard and Jesper Toft (South Jutland University Centre (SUC)) *Denmark National Policy Report*.

Isabelle Jorge, Pierre-Benoit Joly and Stéphane Lemarié (INRA-SERD) and Gerald Assouline (QAP Decision) *France National Policy Report.*

Jos Bijman, Floor Brouwer, Freek de Meere and Siemen van Berkum (Agricultural Economics Research Institute) and René von Schomberg (International Centre for Human and Public Affairs) *Netherlands National Policy Report.*

José Carlos Cuerda García-Junceda, Alejandro García Hermenegildo, Ana Goitia Charneco and Esther Grávalos García (Instituto de Desarrollo Regional) *Spain National Policy Report.*

Nick Barnes, Susan Carr, Joanna Chataway, Les Levidow and Dave Wield (Open University) and Joyce Tait (SUPRA, University of Edinburgh) *United Kingdom National Policy Report.*

Jos Bijman (Agricultural Economics Research Institute, The Hague) and Joyce Tait (SUPRA, University of Edinburgh) (Eds.) *European Union Policies on Agrochemicals, Biotechnology and Seeds.*

IMPROVING DISSEMINATION OF TECHNOLOGICAL INFORMATION TO FARMERS

Peter Gæmelke[1]

Introduction

Improving the dissemination of technological information to farmers is a challenging task; how this task will be accomplished will depend on the country and the farming system in question. This workshop provides an opportunity to relate my experiences in Denmark[2] in comparison to experiences found in other countries. In order to improve farmers' access to and their use of new technologies in sustainable farming, we need solutions that are *well targeted* to a specific country and farming system.

What is sustainable agriculture?

The great majority of farmers manage their land in a responsible and sustainable manner and their management practices are generally in line with the traditional notion of sustainability. That is, farmers want to pass on the farmland to the next generation in the same — or preferably, in a better — state than they received it.

There is no consensus about the definition of sustainable agriculture, even in a small country such as Denmark. The range of views is wide with some people considering only organic farming to be truly sustainable. I do not share this view. Agriculture can remain sustainable through the judicious use of fertilisers and pesticides.

Farming will always have an influence on the landscape and the environment, but land can be farmed without degrading soil resources or causing excessive nutrient run-off to the environment. This can be achieved by combining experience and common sense with the application of new technology and research results.

Countries have different ways of defining "sustainable agriculture". In Denmark, farmer organisations have developed guidelines on how to achieve environmental sustainability at the farm level while maintaining economic sustainability. Codes of good agricultural practice provide practical guidelines to farmers. The main objectives for codes of good agricultural practice are:

- to produce high quality food and fibre,

1. Chairman, Danish Farmers' Union, President, Danish Agricultural Council.

2. I have been a farm-owner and operator since 1983. I own today 240 hectares of land used for winter wheat, winter barley, rye, winter rape, rye grass, spring barley, peas and grassland. I also own 60 hectares of forest and produce 4 000 slaughter-pigs a year.

- to use sustainable and profitable production methods,
- to reduce adverse effects on the environment, and
- to use ethically justifiable production methods.

These objectives can be achieved through:

- focusing on the quality of agricultural products,
- optimising the nutrient balance,
- judicious use of pesticides,
- improving animal welfare and health,
- improving feed quality,
- maintaining cultural landscape values,
- improving energy efficiency,
- adequate work safety measures, and
- Appropriate farm management practices.

The purpose of the guidelines, disseminated through extension services, is to help set standards for individual farmer's management practices. In addition to the codes of good agricultural practice, these practices are also influenced by various government regulations on sustainable farm management. Adopting sustainable farm management practices often requires farmers to make investments. In some cases, these investment costs can be covered through higher prices for their products at the market, but this can occur only if the consumer is aware of the shift to a more sustainable production method and is willing to pay a premium for such products. Farmers, however, are still not successful at getting this information across to consumers. When farmers do a good job in improving their farm management practices, they should inform the public about it. So it is important to improve communication.

New technologies available to farmers

Farming methods are undergoing significant technological changes. New government regulations and the demand for more advanced and labour-saving technological solutions are among the driving forces behind the change. To give a practical example, some of the important changes on my own farm in the past ten years include:

- animal waste storage capacity increased to one year,
- manure spread while crops growing and better spreading equipment used,
- total plant nutrient balance calculated,
- nitrogen and phosphorous content in animal feed minimised,
- pesticide use optimised with help of a computer programme,
- pesticides sprayed at the optimal time (very early in the morning), and
- better spraying equipment used and spraying equipment cleaned in a safe place.

The choice of farming technologies will continue to increase in the future. One problem, however, is the price of new technology, which is often high. Adopting new technologies can thus require making significant investments and farmers are only willing to invest money when it is profitable for them to do so. This can require expanding the scale of the farm operation through buying more farmland or livestock. Thus new technologies are a major driving force behind structural change resulting in fewer and larger farms, more machinery used on farms, and less manpower needed to run the farm.

Examples of technologies that can enhance the environmental performance of agriculture and contribute to sustainable farming, are:

- reduction in the reliance on pesticides through
  - increasing mechanical weed control;
  - wider application of biological pest control methods; and
  - increasing precision in calculating thresholds and improving warning systems.
- reduction in the loss of plant nutrients through:
  - improving the quality of feed without using excessive amounts of nitrogen and phosphorous fertilisers; and
  - "precision farming" based on the global positioning system and advanced tool control technologies that enable farmers to optimise with accuracy nutrient use and crop treatment at the field level.
- application of modern biotechnology
  - the most far-reaching changes can be expected from the application of modern biotechnology and genetic engineering of crops. These are controversial issues at the moment. However, in order to meet the increasing global demand for food in a sustainable way, it is necessary to explore the possibilities of modern biotechnology.

The system of knowledge dissemination

The key questions related to knowledge dissemination in Denmark, as well as in other countries, are:

- how to get the information out to farmers; and
- how to help *individual* farmers to find out what are the good, practical and economically feasible solutions for them.

I will start by describing how the dissemination of information is organised in Denmark. For more than a century, farmer organisations have organised the knowledge dissemination process in a way that maximises the benefit to individual farmers. First, they have a major influence on farmers' training and education levels and, secondly, the organisations work together with applied research institutes. Thirdly, a comprehensive advisory service is in place as the central information source for

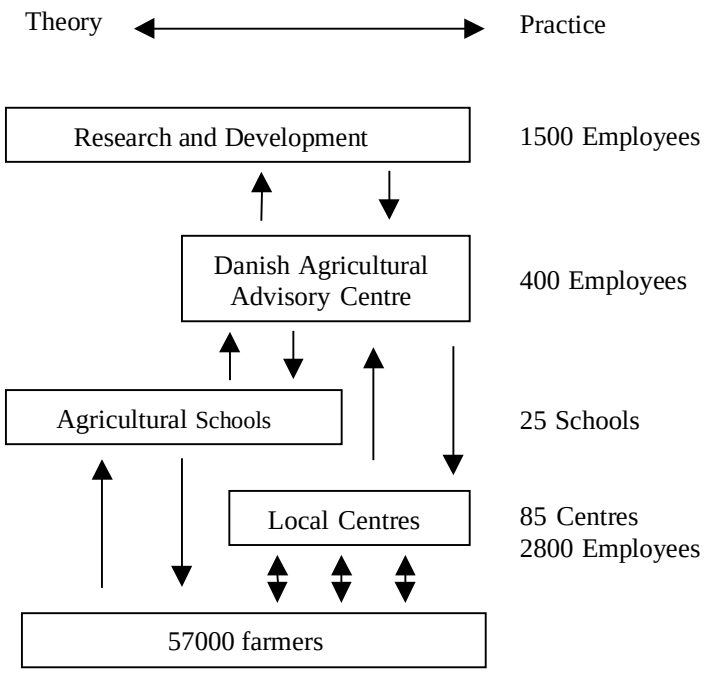
farmers. The way in which the dissemination of information is organised in Denmark may not be ideal for other countries, but it corresponds well to national objectives. The objectives state that the advisory service:

- should be readily accessible to every farmer;
- it needs to be objective (independent of commercial interests); and
- it needs to be at the forefront in gathering and processing information and developing practical tools for farm management.

The main features of the Danish Agricultural Advisory Service are that:

- it is managed by farmers through farmer organisations;
- it is supported by the government;
- it is officially and universally recognised as neutral and independent of commercial interests;
- it provides advisory services covering all production branches;
- it operates at local and national levels; and
- it does not carry out farm inspections on behalf of the government.

Figure 1. The Danish Model



Today, the Danish Agricultural Advisory Service mostly works under market conditions providing services on a commercial fee-for-service basis. The government pays 10% of total costs and the users — the farmers — pay 90%. The Danish advisory service employs one professional for every 20 farmers, which indicates a high level of service and personal contact.

The local level of the service includes 85 advisory centres with almost 3000 advisors and assistants. These centres are organised and run by local farmers' unions and associations. The advisors provide guidance and services tailored to the farmer's needs. A local centre typically provides guidance for 500-2000 members and has 20-70 employees.

At the national level, the Danish Agricultural Advisory Centre provides local centres with the latest information on both Danish and foreign research. It also has its own research programme and a number of development projects. The national centre has a permanent staff of 360 persons. The professional staff includes more than 200 agricultural experts highly specialised in various technical and economic fields.

How to improve the dissemination of information

We have now at our disposal excellent means of compiling and disseminating information. Satellite communication, computer technology and the Internet are examples of information dissemination tools. New technologies and opportunities are developing so quickly that we can be sure of only one thing: that tomorrow there will be still more information technology available.

About 50% of Danish farmers are currently connected to the Internet. This share is increasing rapidly and in the future nearly all farmers will be connected. This development is about to revolutionise the traditional dissemination of information as most farmers will be able to obtain information through the Internet. For example, farmers will be able to look up information on new legislation and regulations, engage in professional debates with other farmers and advisers, participate in electronic conferences and discussion groups, and fill in applications and requests on-line.

These new developments do not necessarily make it easier for the advisory service to help farmers as it is not just the quantity of information that matters. Farmers can be flooded with information that is biased, irrelevant or motivated by commercial interests, creating confusion as they try to find the "right" information. The main challenge is the transformation of information into relevant and practical know-how. In my view, the strategy in the future will not be very different from the current strategy in Denmark:

- first, farmers must receive a good basic education that enables them to ask the right questions and search for answers in the right places;
- second, we need independent research institutes to develop and test new technologies;
- third, the advisory service network must remain as an independent and credible source of guidance and information for individual farmers.

I also believe that in the future, most farmers will prefer to meet their information needs through personal contact and a network of advisers and fellow farmers. Some farmers will certainly use the Internet actively to build their personal networks by, for example, joining discussion groups that include farmers in other countries. In the coming years, however, most farmers will continue to prefer human contact because that is the easiest and most pleasant way to convert basic information into practical know-how.

I want to emphasise the importance of reaching all farmers. As chairman of a farmers' union, I do not want to be serving only the biggest and most technologically advanced farmers. I certainly want my own — that is, the advisory services' — databases and Internet-resources to be the preferred sources of information for the vast majority of farmers. In addition, I want to promote unity and co-

operation among my fellow farmers, who are becoming increasingly individualistic. For many reasons I see my information strategy as one combining traditional personal contacts with the optimal use of new information technology.

Sustainable agriculture implies that all farmers understand what sustainable agricultural practices are and that they apply them. Although the trend is increasingly towards commercialisation of dissemination of information, farmer organisations and governments continue to have the biggest responsibility for helping farmers choose appropriate farming practices.

Appropriate farming practices are those which at once contribute towards making the agriculture industry more sustainable as well as contributing to the farmer's personal success, that is his income and working conditions.

In a world where government and the general public have placed so many demands and restrictions on farmers, government must take an interest in and financially support an efficient information service geared to the farmers. Anything less would be irresponsible.

I hope the workshop will focus on the following aspects in discussing farmers' information needs in the future:

- What assistance and services can the farmer expect to help him comply with the demands for sustainability?
- What are the government's obligations towards the farmer?
- What are the obligations of farmers' organisations?
- What strategies should be adopted to improve the current system of disseminating information in OECD countries?

THE ADOPTION OF SUSTAINABLE AGRICULTURAL PRODUCTION PRACTICES: RESULTS FROM THE U.S. DEPARTMENT OF AGRICULTURE AREA STUDIES PROJECT

Margriet Caswell[1]

Abstract

The United States Department of Agriculture Area Studies Project was designed to characterise the extent of adoption of sustainable nutrient, pest, soil and water management practices and to assess the factors that affect adoption for a wide range of management strategies across diverse natural resource regions. The project entailed the administration of a detailed field-level survey to farmers in 12 watersheds in the U.S. to gather data on agricultural practices, input use, and natural resource characteristics associated with farming activities. The data were analysed by the Economic Research Service using a consistent methodological approach with the full set of data to study the constraints associated with the adoption of micronutrients, N-testing, split nitrogen applications, green manure, biological pest controls, pest resistant varieties, crop rotations, pheromones, scouting, conservation tillage, contour farming, strip cropping, grassed waterways and irrigation. In addition to the combined-areas analyses, selected areas were chosen for study to illustrate the difference in results between aggregate and area-specific models. The unique sample design for the survey was used to explore the importance of field-level natural resource data for evaluating adoption at both the aggregate and watershed levels.

Keywords: Technology adoption, conservation

Introduction

The United States Department of Agriculture (USDA) has many programs encouraging the use of practices and technologies designed to conserve resources and reduce flows of potentially harmful substances into the environment. Most programs rely on voluntary means, such as technical assistance, education, demonstration and cost sharing, to induce the adoption of sustainable agricultural practices. The effectiveness of these programs in influencing the diffusion of targeted technologies has varied. This paper describes an effort by the USDA Economic Research Service (ERS) to determine the natural resource, human capital and policy factors that influence the choice of sustainable technologies and how that influence differs across cropping systems, geographic regions and types of technology.

The USDA Area Studies Project entailed the administration of a detailed field-level survey to farmers in selected watersheds in the United States to gather data on agricultural practices, input

1. Chief of the Production Management and Technology Branch, Resource Economics Division, Economic Research Service, United States Department of Agriculture.

use, and natural resource characteristics associated with farming activities. A full discussion of the project can be found in Caswell *et al*. (2000, *forthcoming*). Ten of these watersheds were identified as having potential agriculture-induced water quality problems and had sufficient data to provide statistically reliable estimates. The objective of the ERS analysis was to use a consistent methodological approach with the full set of data to study the constraints associated with the adoption of selected farming practices that may avoid or reduce environmental damages. In addition, the unique sample design for the survey was used to explore the importance of field-level natural resource data for evaluating adoption at both the aggregate and watershed levels. We used the same unified econometric framework and set of core variables to analyse the adoption of technologies and practices in four key management categories: nutrients, pests, soil and water.

Background

The U.S. Water Quality Initiative was created in 1989 in response to public concern about agricultural chemicals in groundwater. Later studies revealed that nutrients and sediments from agriculture are the leading source of impairment of U.S. rivers, streams, and lakes (U.S. EPA, 1995, 1998). Many of the management practices developed to reduce agricultural nonpoint source pollution were believed to be inexpensive to implement and, once implemented, would raise farmers' profits (U.S. Congress, OTA, 1995). These pollution-reducing practices were not being adopted at a rapid rate, however. The Economic Research Service (ERS) was given the lead responsibility and funding to build a database on ago-chemical use and associated farm practices to assess the extent of adoption of preferred practices and to identify the most important determinants of technology use. The Area Studies Survey was one of three primary data efforts, and was designed to provide a link between natural resource characteristics, farm production practices and water quality at a local level.

The Area Studies Project was based on the growing body of work showing the need to link economic models of agricultural production with models of the physical environment. Site characteristics will influence the choice of many production practices and will determine the environmental consequences of that choice (Opaluch and Segerson, 1991; Antle and Capalbo, 1991; Just and Antle, 1990). For example, soil permeability may affect a producer's choice of irrigation system and fertiliser application method. The permeability of the soil will also determine the speed and distance chemical residuals will be transported and if they will reach an environmentally sensitive resource. When the effectiveness of practices is correlated with natural resource assets used on the farm, the spatial pattern of practice use will be determined by the distribution of those physical characteristics (Caswell, 1989, 1991). The distribution of physical characteristics will also determine the relative vulnerability of natural resources to agricultural nonpoint pollution (Shoemaker, Ervin and Caswell, 1993). Early work on identifying groundwater resources that were potentially vulnerable to agricultural chemical degradation was published in Kellogg *et al.* (1992).

The two fundamental categories of site characteristics are *(1)* those that have impacts on a grower's choice of production practices and *(2)* those that will determine the impact of the production choices on environmental quality. These are not mutually exclusive sets of characteristics. For example, the organic content of the soil at a site may be a factor in a farmer's choice of tillage practice and the irrigation system that is used. The organic content will also be a factor in erosion and deep percolation of chemicals that can be affected by tillage and irrigation choices. Each site is associated with a combination of characteristics in the *production-impact* and *environmental-impact* categories.

Policy changes that affect practice adoption will alter the spatial pattern of environmental effects, so information is needed on management practices and the environmental attributes of the land in production (Antle *et al*., 1995). Heterogeneous land and climate conditions will determine both

agricultural production and environmental impacts of policies (Just and Antle, 1990). Wu and Segerson (1995) have shown that if one uses aggregate data and ignores site characteristics in analysing the impacts of agricultural activities on water quality, one's conclusions may be subject to five potential sources of bias. These sources can be categorised in two types: "*(1)* Those relating to incorrectly estimating pollution per acre and *(2)* those relating to incorrectly estimating the number of polluting acres" (Wu and Segerson, 1995).

The Area Studies survey was developed to test the hypothesis that differences in productivity caused by physical characteristics of farmland will determine the distribution of adoption behaviour for some agricultural practices. The production-impact component of site characteristics can be analysed with economic models. Evaluation of the environmental-impact factors requires physical modelling of the fate and transport of residuals that result from the choices of practices and technologies. The amount of information needed to construct a fully integrated economic and physical model can be daunting, however, even for a small geographic region. Much of the early discussions about developing the Area Studies Project centred on identifying the minimum data needs to estimate the integrated model parameters.

Theory of adoption behaviour

There is an extensive body of literature on the economic theory of technology adoption. The understanding of the driving forces of adoption is important for the development of pollution-reducing technologies because the effectiveness of the technology will depend on where and when it is used (Stoneman and David, 1986).

The adoption of technology for natural resource management and conservation, such as soil conservation, integrated pest management, soil nutrient testing and irrigation management, are considered apart from the use of conventional inputs such as agricultural fertilisers and chemicals. While decisions on the amount of conventional inputs to apply are made on a seasonal or annual basis, the adoption of new technology represents a significant shift in a farmer's production strategy. The decision to adopt new technology is analogous to an investment decision. The decision may involve substantial initial fixed costs, while the benefits accrue over time. The initial costs may include the purchase of new equipment and of learning the best techniques for managing the technology on the farm. A producer may perceive the non-monetary costs of change to be very high.

An individual's assessment of the new technology is subjective and may change over time as a farmer learns more about the technology from neighbours who have already adopted it, the extension service, or the media. When a technology first becomes available, uncertainty about its performance under local conditions is often high. Significant adaptation of the technology may be necessary before it performs well in the local production environment. Over time, as some farmers in an area adopt and gain experience with the new technology, the uncertainty and cost of adoption fall. Some farmers may fail to adopt the technology altogether if they determine that it simply does not perform well under their resource conditions, or if the size or type of their farm operation is not suited to the technology in question (Griliches, 1957).

A new technology or innovation will change the marginal rate of substitution between inputs in a production process. Some changes may be perceived as large by a potential adopter. Early studies of adoption were based on the assumption that individuals were resistant to change and that resistance had to be overcome (Nowak, 1984). There is a distinct difference, however, between a producer who is unable to adopt versus one who is unwilling to adopt. In other words, nonadopters can be characterised as *(1)* those for whom adoption would not be more profitable than continuing with

current practices, and *(2)* those for whom adoption would be more profitable but who choose not to switch technologies due to other barriers. Policies designed to encourage adoption would need to be targeted differently for these two groups.

The current economic theory of adoption is based on the assumption that the potential adopter makes his or her choice based on the maximisation of expected utility subject to prices, policies, personal characteristics and natural resource assets. A discrete choice of technology is made that leads to a level of input use and profit. If the benefits associated with the use of a conservation technology accrues primarily beyond the farm, producers would not be expected to include those benefits in their decision to adopt the technology. Many of the recommended practices are designed to reduce off-site environmental impacts (externalities) rather than to increase on-site productivity. The total benefits of switching to these technologies may outweigh the costs by a large margin, but if those gains are not realised by the farmer who bears the costs, the voluntary adoption of preferred technologies may not occur.

Since neither farms nor farmers are identical, there will be differences in whether a particular technology is adopted or when. Farmers will differ in their ability to understand and adapt to innovative methods, and in the quality of the land they control. The farmer is aware of these factors and uses that knowledge to assess the expected gain of adoption. The distribution of the underlying heterogeneous factors will determine the pattern of practice adoption. When one of the heterogeneous factors is associated with natural resource characteristics, the adoption pattern can be defined spatially.

The effectiveness of policies designed to improve water quality or other environmental assets through promoting the adoption of conservation technologies and sustainable management strategies will depend on an understanding of how farmers choose their production practices. The Area Studies Project was designed to characterise the extent of adoption of nutrient, pest, soil and water management practices and to assess the factors that affect adoption for a wide range of management strategies across diverse natural resource regions.

Data and empirical framework

The Area Studies Project was a collaborative effort between USDA agencies (Economic Research Service (ERS), National Agricultural Statistics Service (NASS), and the Natural Resource Conservation Service (NRCS, formerly Soil Conservation Service, SCS). In addition, there was extensive interaction with the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (EPA). The link between the enumerated survey data and the natural resource base came from the sampling frame, which was based on the NRCS Natural Resource Inventory (NRI) sites. Each observation was identified with a sampled NRI point that provided the physical data, such as soil erosion and leaching potentials, and productivity, that represented the farm operator's resources. Many of the site's production-impact and environmental-impact characteristics are included in the NRI database and its links. Regional temperature and rainfall data also were added to the data set.

The Area Studies survey data that we analysed were collected in 10 U.S. watersheds over the period 1991 to 1993. The chosen areas were part of the U.S. Geologic Survey National Water Quality Assessment Program (NAWQA) that was initiating an extensive water quality monitoring effort. Each area is defined by watershed boundaries that do not necessarily correspond with state or county borders. The areas surveyed in 1991 were the Central Nebraska River Basins, White River Basin in Indiana, Lower Susquehanna River Basin in Pennsylvania, and Mid-Columbia River Basin in Washington. The areas selected for the 1992 Area Studies survey were the Albemarle-Pamlico Drainage in Virginia, Georgia Coastal Plain, Illinois/Iowa Basin and Upper Snake River Basin in

Idaho. The 1993 regions selected for the survey and for which sufficient data were gathered were the Southern High Plains in Texas and the Mississippi Embayment that included parts of Arkansas, Kentucky, Louisiana, Mississippi, Missouri and Tennessee.

The Area Studies survey instrument was designed to collect detailed information on the use of cropping systems, agricultural production technologies, and chemical use at both the field and whole-farm level. A personal interview was conducted with the farm operator. Information was gathered on the crops and livestock produced and the size of the operation. Questions were asked about the cropping and tillage practices used in the survey year as well as the two previous years. Data were also collected on the type of soil conservation practices used over the three years. Farmers were asked about government program participation and whether they had crop insurance. Farm operators were asked about a wide range of practices used for the management of nutrients, pests, soil, and water. Data were gathered on soil testing, manure applications, source of fertiliser information, and the amount of fertiliser applied. Farmers were asked about their use of biological and chemical pest control methods. The irrigation and drainage section of the survey contained questions about the irrigation technology used, water source, drainage systems, and who advised the operator about when to irrigate. Demographic information about the farm operator was collected on tenure status, age, education, years of experience, and the number of days worked off the farm. Since age and years of experience were highly correlated, only experience was used in the analysis. We were not, however, able to obtain data on costs and prices, which greatly handicapped the economic analysis.

The objective of the econometric analysis was to identify the principal constraints to the adoption of resource-conserving technologies in agriculture and to compare these factors across technologies, cropping systems, and geographic areas. We assume that a farmer adopts a new technology if the utility or profitability of adoption will be greater than what he or she would experience by not adopting. In most cases, the technology adoption decision is simply a yes/no rule, *i.e.* either to adopt or not adopt. In these cases, we used a binomial logit model to estimate the probability of adoption. If a farmer was faced with a choice among several competing alternatives, we used a multinomial logit model. We recognise that more sophisticated empirical methods exist, but due to data limitations none were suitable for comparing results across technologies and areas — a primary motivation for this study.

We analysed the adoption of soil conservation practices including conservation tillage, crop residue use, chiselling and subsoiling, contour farming, conservation cover or green manure crops, grass and legumes in rotation, strip cropping, terracing, grassed waterways, filter strips, grade stabilisation structures and critical area planting. The pest management practices studied were the use of rotations, destruction of crop residues, biological controls and pheromones, and professional scouting. We included modern nutrient management practices such as N-testing, split nitrogen applications, and micronutrient use as well as the more traditional practice of planting legumes in rotation. The decision of whether to irrigate was analysed as well as the choice of irrigation technology.

Each adoption study used the same core set of variables in order to compare the effects of human capital, policy, farm, and natural resource characteristics on the adoption of several management practices. The data from all the watersheds were combined for each analysis, and then the analysis was conducted on selected individual areas to assess potential aggregation bias. In other words, would factors that strongly influenced adoption in individual watersheds be “averaged out” in the combined model and appear to be unimportant?

Results

The focus of the Area Studies analysis was on technologies that help to conserve natural resources by improving the efficiency of chemical or mechanical inputs used in agricultural crop production. Many of these sustainable technologies involve using more intensive management methods or information technology in conjunction with chemical inputs. By making more judicious use of conventional inputs, it may be possible to reduce or mitigate potential environmental consequences of agricultural production while at the same time improving farm productivity and profitability. Each of the four major management categories was studied using all areas combined, and then selected areas were assessed to see whether important site-specific factors would be missed by aggregating across areas. Several factors emerged as important influences for conservation technology adoption across many agricultural management practices that we studied. Table 1 summarises the findings for the combined-area models.

Education (*i.e.* whether the respondant attended college) has a significant positive effect on the adoption of information-intensive technologies, such as the use of biological pest control or nitrogen testing. The increasing complexity of emerging technologies is a factor that agencies or technology providers should consider when targeting potential adopters. Technical assistance, demonstration, or consulting services may be necessary to promote adoption of certain preferred practices.

Information-intensive practices are less likely to be adopted by an experienced farmer, which may imply either that such operators have the knowledge they need to farm successfully or that they are less willing to change practices than younger, less experienced farmers.

Ownership of the surveyed field had less of an impact on practice adoption than we initially expected based on the hypothesis that landowners would be more likely to invest in new practices than renters. Most practices included in this study, however, were not structural. Investment in irrigation technologies, which have high initial costs, was more likely for owners rather than renters, but the difference was small.

An enterprise with a livestock component was less likely to adopt information-intensive nutrient management practices, such as soil testing, split nitrogen application or micronutrient use, and more likely to use manure. This expected result may change in the future if livestock operations are required to implement nutrient-management plans that include restrictions on application of manure to land.

Investment in irrigation had a significant positive effect on the adoption of all pest and nutrient management practices that we considered. Water is the primary transport mechanism for chemicals to leave a root zone and travel to ground or surface water. Therefore, water and chemical management are expected to be complementary. Water management is less predictable for rain-fed agricultural production, so the use of chemical management strategies by such farms may be less effective than for farms that are irrigated.

Both government program participation and the use of expert advice had strong positive influences on the adoption of virtually all the preferred soil, pest, and nutrient management technologies. The Area Studies Survey was conducted when conservation compliance was a condition of receiving benefits from a number of USDA programs. Farms with an erosion potential in excess of a critical level were required to adopt conservation practices to be eligible to participate in the programs. The availability and use of technical assistance appear to be significant influences on the decision to use the set of practices reviewed in this study. It is likely that those subject to conservation

compliance used some resource-conserving practices, but the significance of a farmer's use of advice suggests that technical assistance influenced the choice of the particular practices. The result is an affirmation that extension and education efforts are important components to effect technological change in agriculture. In particular, these activities have an impact on the adoption of information-intensive technologies and on those practices designed to provide offsite benefits.

In the combined-area model for most practices, a regional dummy performed as well as the more precise resource characteristics. The greater significance of the dummies in the combined-area model should be expected because of the usual result that dummies absorb many indistinguishable effects. In the single-area models, however, the resource variables were often significant determinants of adoption, confirming the idea that site-specific information is critical to modelling and explaining resource-conserving efforts. The resource measures that we chose may not have captured the important resource characteristics expected to influence the adoption of all technologies in all watersheds. We did not expect generic resource characteristics we used would play an important part in a farmer's choice of pest-management strategy. An estimate of pest infestation is a critical resource characteristic in this case. We had hoped, however, that constructing site-specific indices would improve the aggregate modelling of adoption for soil, nutrient, and water management practices. We conclude that the value of using field-level resource data is in the single-area or watershed-level modelling efforts. In addition, the chosen index should reflect the environmental circumstances of the specific area and technology, rather than a one-size-fits-all index. For example, in modelling the decision to irrigate, the single attribute, slope, had more explanatory power than did the index of soil productivity.

Assessing the influence of resource characteristics on adoption (*i.e.* the *production-impact*) was only one reason to include site-specific resource information in the Area Studies Survey. These data were gathered to provide the link between the economic and physical fate and transport models. That work has not been completed, so it is still unclear whether the micro data are useful to assess aggregate models. The site-specific resource information at the watershed level is important for both production-impact and environmental-impact analysis.

The combined-area models represent the aggregation across distinct watersheds. From a policy perspective, these results can be misleading. For example, for the adoption of soil-conserving practices, a farmer's experience and whether he or she works off-farm have significant positive effects in the Susquehanna River Basin, but the aggregate model results show no significant effects of these factors. A policy decision to encourage adoption of conservation technologies in Susquehanna would be more efficient if based on site-specific information. On the other hand, in some cases the combined-area model results are dominated by a single area. The data allow fairly precise environmental-policy modelling to use for targeting. The unified modelling approach that we used shows that important information can be lost in the process of aggregation. Incentives developed to address factors identified in the aggregate model may be appropriate for only one area and counterproductive for others. We recognise that this averaging problem exists for all policies to some extent. However, our comparison of the combined-area and single-area models illustrated the magnitude of the differences between the Area Studies regions.

Conclusions

The Area Studies Survey data set offered a unique opportunity to assess the usefulness of conducting a field-level survey linked to site-specific resource characteristics. The richness of the data set allowed a wide range of analyses. The lack of data on costs and prices, however, greatly handicapped the study. The greatest contribution of an Area Studies survey based on field-level

characteristics could be to help answer a watershed-specific question. A unified modelling framework was used to compare the results of aggregate and regional studies. Resource characteristics are an important component of producers' decisions. The analyses of farming systems (combinations of agricultural practices) also will be enhanced by site-specific resource data. Both economic and physical modelling efforts can be supported with the data that is produced through the survey. Agricultural water-quality problems are inherently site-specific. Surveys designed to capture national (or even state) averages are not as useful for analysis as ones that sample extensively in an area of interest. For environmental problems, analyses will be most efficient if conducted at a geographically relevant scale whenever possible. The Area Studies Project succeeded in developing and conducting a survey that has contributed to our understanding of agricultural-practice adoption and of survey design.

Table 1. Change in predicted adoption: combined area models

Variables	Any Soil Cons.	Soil - Water Quality	No-Till	Rotat.	Resid.	Biolog.	Scout	Modern Nutrient	N Test	Split N	Legumes	Manure	Decision to Irrigate
College	+ *				- **	+ **	+ **	+ **		+ **			+ **
Experience					- **	- *	- *	- **	- **				- **
Workoff			+ *		+ *			- **		- **		- **	- **
Tenure	- **			- *			- **				- **	+ **	+ **
Acres	+ **		+ **			+ **	+ **	+ **	+ **		- *	- **	- **
Rotation	+ **	+ **	+ **	na	na	na	na	na	na	na	na	na	+ **
Rowcrop	+ **	+ **	- **	+ ** soy	+ ** cotton	+ ** cotton	+ ** cotton	+ **	+ **	+ *	na	+ **	+ ** corn
Grain	- **			- **	- **	+ ** frt/veg	na		- ** sm-grn	+ ** rice/soy	na		+ ** frt/veg
Manure		+ **	+ *	na	na	na	na	- ** animal	- ** animal		- ** animal	+ ** animal	na
Irrigation			- **	+ **	+ **	+ **	+ **	+ **	+ **	+ **	+ **	+ **	na
Program		+ **	+ **	+ **			+ **	+ **	+ **	+ **	+ **		+ **
Advice	+ **	+ **	+ **	+ **	+ **	+ **	+ **	+ **	+ **	+ **			na
Insure	+ **						+ **	+ **	+ **		- **		
Slp				- **				+ **	+ **		- **		+ **
Pisoil	+ **	+ *		+ **			- *		+ **	- **	+ **	+ **	- ** slope
Eroton		+ ** RKLS		na	- **	na	na	+ *				+ *	+ ** wind
Rain	+ **	+ *	+ **		+ **			+ **		+ **		na	- **
Temp	+ **		+ **		+ **	+ **				+ **	na	- **	+ **

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

Source: Economic Research Service.

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POLICY-TECHNOLOGY INTERACTIONS FOR INTENSIVE FARMING SYSTEMS: SOME EXPERIENCES FROM THE NETHERLANDS

Floor Brouwer[1]

Abstract

Numerous technological advancements have been adopted in the Netherlands during the past decade to meet environmental requirements for intensive farming systems. This report provides empirical evidence on the adoption of new technologies by agriculture in the Netherlands, focussing on the arable sector and its objectives to meet environmental policy targets on crop protection products and on greenhouses to improve energy-efficiency. Such technologies play a vital role in meeting more stringent environmental policy targets by intensive farming systems and the achievement of sustainable production methods in agriculture. The key driving forces to provide incentives to the introduction of such technologies are in the domain of public policies, commonly supported through market initiatives. Public policies have contributed to achieving major environmental progress regarding use of crop protection products in arable production and improving the efficiency of energy consumption by greenhouses. Private actors have played a vital role in managing for the provision of technologies needed in achieving such policy objectives, including new agrochemicals, which allow for more targeted use and require lower dosages. Innovations have also been introduced to improve energy efficiency in greenhouses.

Key words: Crop protection products, arable production, energy, greenhouse, technology.

Introduction

Following a general overview on agriculture and environment in the Netherlands, this section focuses on two sectors: the arable sector and greenhouses. The first case study examines arable production and its response to policies to reduce usage of crop protection products. It examines the response by the agricultural sector in meeting the requirements of the Multi-Year Crop Protection Plan (MYCPP). Linkages are made on how government policies have induced the adoption of more sustainable farming practices. The available technologies (*e.g.* authorisation of crop protection products entering the market) have contributed to achieve policy objectives. The second case study examines greenhouse horticultural production and the introduction of technologies to improve energy-efficiency in this sector, which is highly dependent on energy. Such technologies reflect the importance of improving energy-efficiency in meeting the requirements agreed to under the Multi-Year Agreement on Energy in Horticulture under Glass (MJAE). Finally, some conclusions are drawn regarding strategies for the development and implementation of innovations in intensive farming

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systems. In addition, relevant data and indicators on the efficiency of inputs used by intensive farming systems are provided. A set of agri-environmental indicators, which could measure progress on the adoption of more sustainable technologies in agriculture, is considered to be a valid tool in achieving policy objectives.

Since the scope of the workshop is on technologies for sustainable farming systems, the focus is on environmental concerns that would require the adoption of technologies (mainly the quality of water, soil and air). Other concerns (*e.g.* biodiversity and landscape) are not examined in full detail since they are less dependent on technological innovations and mainly rely on the adoption of well-targeted public policies which reflect societal preferences.

Agriculture and environment in The Netherlands

The Netherlands ranks among the smaller countries in the European Union (EU); it is slightly smaller than Denmark, but bigger than Belgium and Luxembourg. The total size of the country is 41 026 km^2 and almost half of its territory is used agriculturally. The population is currently 15.6 million, making it one of the most densely populated in the world. The rural countryside covers about 80% of the land area and includes almost 40% of the total population. Land is a limited resource used for a wide range of competing functions, such as housing, infrastructure, industry and services, recreation, nature conservation, as well as agriculture. The price of agricultural land is generally increasing due to greater competition amongst these alternative uses, and currently exceeds NLG 50 000 - 60 000 per hectare in most of the country. Prices increased during the 1990s in response principally to the demand for agricultural land to meet nutrient control measures and the high demand from non-agricultural activities (housing and recreational activities).

The Netherlands is second behind the United States in terms of export surplus in agricultural products; about 80% of exports are with other member countries of the European Union. It has one of the most intensive farming systems with high output levels supported by a considerable use of agrochemicals. Both internal and external conditions have contributed to this trend. Nationally, the constraints on the availability of agricultural land have given incentives to increase the intensity of agricultural production over time. In addition, the Common Market has also contributed to free internal trade within the European Union and has provided incentives to increase production in regions where competitive advantages existed. Intensive farming systems with high levels of output are commonly characterised by a high usage of inputs (agrochemicals like plant protection products and fertilisers, as well as resources such as energy and water). Land, labour and capital resources (*e.g.* machinery) are key limiting resources used in an intensive manner, with high output generated per unit of labour supplied. In such circumstances, technologies are vital in meeting environmental constraints.

Farming is practised on approximately 100 000 holdings utilising almost 2 million ha of land. Gross value of agricultural production in is about NLG 35 billion per annum. Horticultural production is the largest sector and currently has a share of 40% of total gross production value, followed by cattle farming and intensive livestock production which both have a share of around 25% of gross production value. Arable production has a share of some 8%.

Major issues of environmental concern that result at least in part from agriculture include (Brouwer and Van Berkum, 1998):

- pollution of groundwater, surface water and coastal waters (*e.g.* eutrophication) from nitrates and phosphates. The percentage of observations where the concentration of nitrate in the groundwater exceeds 50 mg per litre (at the depth of 5-15 metre below ground level) is around 20% at the sandy soils used agriculturally;
- emissions of ammonia and their impact on acidification of soils, water, nature areas and forests. Emissions of ammonia have been reduced considerably during the 1990s, mainly because manure had to be applied on a low-emission basis;
- effects of crop protection products on the quality of soils and water. The norms for pesticides are exceeded for some pesticides in some pumping stations;
- emissions of greenhouse gases and their possible effects on global warming. The horticulture sector is very energy-intensive as it covers less than 1% of the land used agriculturally, but uses almost 80% of total energy consumption by the agricultural sector. Agriculture currently accounts for about 11% of the emissions of greenhouse gases, with the share of agriculture in total emissions of CO_2 at 4.5%.Shares are much larger for the other emission categories. The relative share for CH_4 are 41%, and for N_2O they are 33%;
- desiccation of nature areas through high use of water from groundwater resources, drainage and land consolidation programmes. Groundwater tables are reduced by up to 40-120 cm in the eastern and southern part of the country, mainly due to former land consolidation programmes;
- biodiversity and landscape issues, which mainly concern important bird areas (especially those important for breeding and/or migratory birds), semi-natural grasslands (usually managed by nature conservation organisations) and areas rich in natural features (*e.g.* hedges). Although direct management issues for biodiversity and landscape are not dealt with here, the other environmental themes (*e.g.* eutrophication, crop protection products and desiccation) also have an impact on farmland or adjacent nature areas. The use of crop protection products, for example, had a major impact on raptors and water birds in the 1960s, although the situation has since improved. The issue of biodiversity and landscape is part of the environmental benefits of agriculture, as discussed in detail during the OECD Helsinki Seminar in 1996 and subsequently discussed in the JWP. Apart from the proceedings of the Helsinki seminar and subsequent documents of the JWP, a Dutch case study on these issues was produced for the Helsinki seminar and is available upon request.

Some key figures on environmental pressures from agriculture are depicted in Table 1.

Table 1. Environmental pressures from agriculture in The Netherlands

	1985	1990	1995	1998
Emissions of carbon dioxide (CO_2), millions of kg	5.6	8.6	9.4	8.6
Emissions of methane (CH_4), millions of kg	527	507	479	438
Emissions of dinitro-oxide (N_2O), millions of kg	24	22	28	26
Total emissions of greenhouse gases (CO_2 equivalent)	24.0	26.1	28.0	25.8
Emissions of ammonia (NH_3), millions of kg	239	220	141	166
Discharge of phosphorus (P) to soil, millions of kg	57	87	71	63
Discharge of nitrogen (N) to soil, millions of kg	527	426	509	450
Use of crop protection products, millions of kg	21.0	20.3	12.6	12.7

Source: National Institute of Public Health and Environment (RIVM).

All sectors need to meet environmental restrictions which, since the end of the 1980s, have been embodied in policies:

- Dairy production is a major agricultural activity based largely on the available land resource. This sector takes about half of the available land resource. Nitrogen surpluses of dairy producers on a per hectare basis exceed on average 300 kg. A major reduction on nutrient surpluses is needed. Structural features and farm management practices are vital to adopt more sustainable production methods. Measures included are better fertilisation and feeding regimes, restricted use of fertilisers and feed concentrates, low levels of milk production per cow and per hectare, as well as reducing stocking density of livestock production.
- Intensive livestock production units (mainly pigs and poultry). This sector contributes to large environmental problems (*e.g.* nitrate pollution problems of groundwater and surface waters) due to an insufficient area of land available to apply the livestock manure. A large number of measures have been introduced over the past decade to reduce nutrient losses to the environment. Measures taken have contributed to reducing phosphate surpluses. Mineral efficiency of feed has been increased, in part by the addition of the enzyme phytase to feed for pigs. The reduction of nitrogen surpluses has been far less successful. Technologies have been adopted to reduce emissions of ammonia from intensive livestock production units, both through housing systems with lower emissions and through improved means to apply livestock manure.
- Arable production is largely a rotation of cereals, potatoes and sugarbeet. Growing cereals is part of a narrow cropping plan with a considerable acreage devoted to sugarbeet and potatoes.
- Horticulture under glass is a very energy-intensive sector, with increasing concern about the effects of CO_2 emissions on climate change.

Awareness of environmental pressures has increased since the late 1980s and legislation has been introduced to achieve sustainable production methods. Environmental control measures were introduced in the 1990s. Examples are the Multi-Year Crop Protection Plan (MYCPP) to reduce harmful environmental effects of crop protection products (*e.g.* arable production) and sectoral policies to improve the efficiency of energy consumption (*e.g.* Multi-Year Agreement on Energy in Horticulture under Glass). Figure 1 shows the gross value added of arable production since 1990 and the use of crop protection products used by this sector. The use of crop protection products was

reduced largely, whereas the gross value added of arable production mainly showed inter-annual variations due to price fluctuations of arable products. In addition, Figure 2 shows the gross value added from greenhouses since 1985 and the amount of energy consumed in this sector. The gross value added of greenhouses increased by more than 50% and the increase of energy consumption remained lower during this time period.

Figure 1. Gross value added and use of crop protection products in arable production

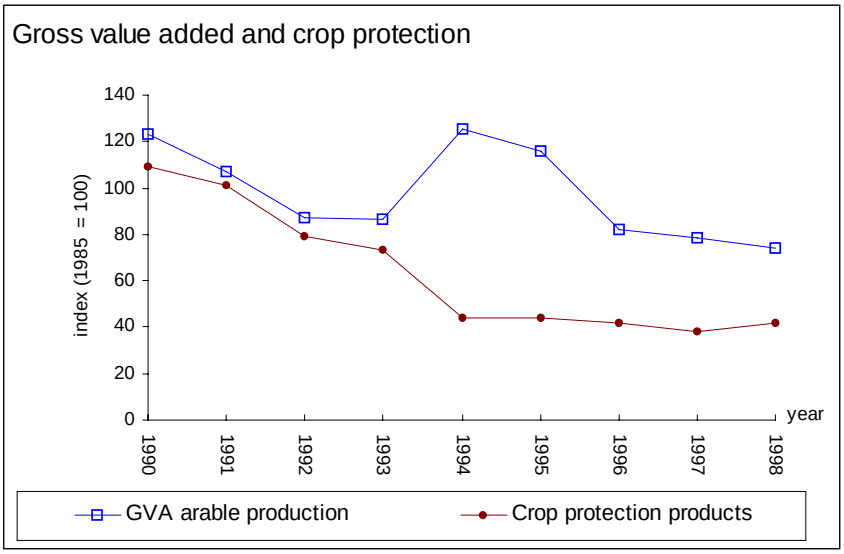
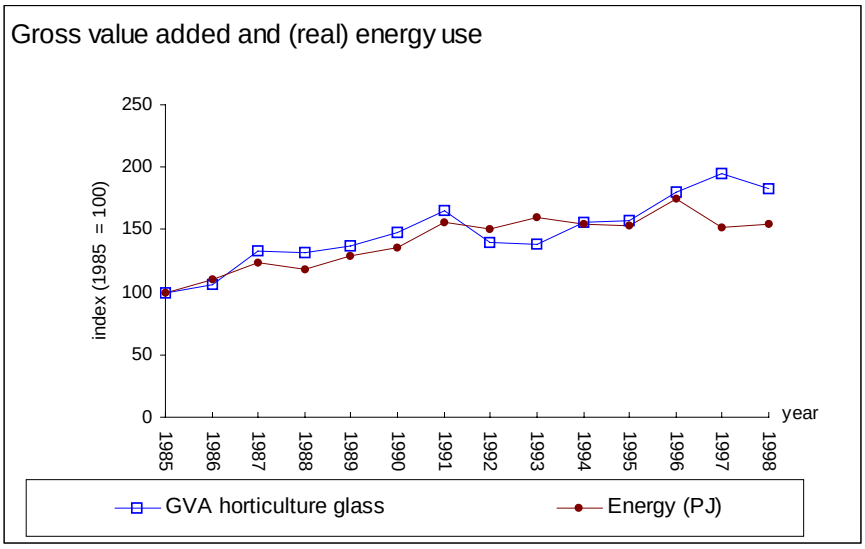


Figure 2. Gross value added and energy use by greenhouses



The authorisation of crop protection products is the duty of CTB (*College Toelating Bestrijdingsmiddelen*). The total number of products authorised for agricultural use increased until the 1980s, but has gradually diminished since the first half of the 1990s (Table 2). Decisions on the

authorisation of crop protection products are taken within the framework of the relevant rules and legislation.

Table 2. Crop protection products authorised for agricultural use in The Netherlands

Product group	1970	1980	1990	1995	1998
Insecticides/acaricides	76	87	85	88	96
Fungicides	67	79	74	78	85
Herbicides	72	85	93	90	87
Other compounds	51	72	72	60	50
Total	259	307	305	296	286

The incentives to increase environmental production methods are not provided solely by public policies. Market initiatives also stimulate the environmental awareness of producers. Several sectors have responded in a pro-active manner to requirements by policy regulation as well as consumer preferences to environmentally friendly products. The Horticulture Environmental Programme (*Milieu Programma Sierteelt*), for example, stimulates environmental awareness in the cultivation of flowers, plants, bulbs and nursery stock products (MPS, 1999). The programme essentially requires producers to keep records on their use of crop protection products, fertilisers and energy. Approximately 3 000 producers are listed as part of the system. The use of crop protection products has been reduced by some 25% in a few years time and similar efforts exist for other sectors (*e.g.* bulb growing and tree cultivation). In addition, retailers increasingly demand the use of environmentally-friendly conditions in production methods used in primary production.

Technologies and usage of crop protection products

The objectives of crop protection policy in were developed in 1991 in the Multi-Year Crop Protection Plan (MLNV, 1991). The main achievement for the period 1991-2000 was reducing the dependence on crop protection products in agriculture and horticulture, together with the elimination of harmful external effects caused by the use of these products. Three objectives have been quantified. First, the plan includes a long-term, multi-objective oriented approach to reduce usage levels and an overall reduction in the use of crop protection products is to be achieved by the year 2000 relative to the period 1984-1988. Second, emissions need to be reduced. Finally, the third objective is to reduce dependence on the use of crop protection products. The following points should be noted:

- An overall reduction in the use of crop protection products needs to be achieved by 2000 compared to the period 1984-1988. Policy targets to reduce use of crop protection products are formulated according to product group. Use of crop protection products in total needs to be reduced by some 56%. More specifically, the reduction targets are formulated by a group of active ingredients. The largest reductions are required for nematicides (-68%). The use of herbicides, insecticides, fungicides and other active ingredients needs to be diminished by close to 40%.Reduction targets are formulated for each agricultural sector.
- In addition to reduction targets on use of crop protection products, their emissions to the environment also need to be reduced. Air emissions need to be diminished by 50%,

whereas the emissions to soils and groundwater are to be reduced by 75%, and the emissions to surface water even by 90%;

- The dependence on the use of crop protection products needs to be reduced. No specific reduction targets are formulated on this item.

Emphasis is also given to research, extension, education and fiscal incentives. An agreement was signed between the national government, the agricultural business sector and the pesticides industry to meet the targets of the Multi-Year Crop Protection Plan (*Bestuursovereenkomst Uitvoering Meerjarenplan Gewasbescherming*). As a result, the achievement of the Plan's objectives became a joint responsibility of these three partners. Additional instruments might be introduced (*e.g.* tax on pesticides) if the objectives are not met with the existing instruments.

MYCPP has formulated reduction targets for the years 1995 and 2000. The use of crop protection products in arable production shows a declining trend during the 1990s. New active ingredients have entered the market.

The application of biological control remained limited in arable production, although significantly increased in the production of flowers and vegetables. Over the past ten years, the integrated control of insects, for example, is practically standard in the production of tomatoes, where there has been a significant reduction in the use of crop protection products. The prevention of pests and diseases increasingly include the natural resistance of plants, differences in soil conditions and the impact of crop rotation. Also, reductions could be achieved through the adoption of more technical means in production. The application of the Minimal Lethal Herbicide Dosage (MLHD) approach (allows for an approximate 50% reduction in the use of herbicides. New equipment has been introduced in arable production to improve the effectiveness of treatment against insects and diseases.

The use of crop protection products in arable production diminished from 15 million kg (1990) to less than 6 million kg active ingredients (since the mid-90s, Table 3). There has been a significant reduction in the use of nematicides since 1993 due in principal to the introduction of regulations that same year. Since then, soil disinfection is only allowed once every four years and requires prior approval by Plant Health Services. The use of fungicides diminished during the first half of the 1990s through substitution by compounds requiring lower dosages, although it increased between 1996 and 1998. Poor weather conditions combined with high rainfall during the 1997 and 1998 growing seasons required a high use of fungicides to protect potatoes against fungi.

Changes in farm management practices (through improved application technologies and the use of Integrated Crop Management practices) and national mandatory reduction schemes have contributed to the lower use of crop protection products. In addition, new compounds requiring lower dosages have entered the market. We will examine the use of compounds for arable production in 1990 and 1998 in order to examine changes in the compounds used.

Table 4 shows the use of crop protection products, including at least one active ingredient, that have a share of at least 1% of total use by arable production. A comparison is made between use of crop protection products in 1998 and 1990. The use of crop protection products was reduced by more than 50% during this period. In 1998, 16 compounds accounted for 70% of total use of crop protection products. In 1990, 11 compounds accounted for a similar share of total use of crop protection products.

Table 3. Use of crop protection products in arable crop production (1 000 kg)

Year	Insecticides	Fungicides	Herbicides	Nematicides	Additives	Other	Total
1990	261	3 009	1 926	9 491	628	169	15 485
1991	188	2 959	1 901	8 840	390	129	14 407
1992	204	2 662	1 612	6 217	376	138	11 209
1993	136	2 382	1 504	5 459	804	105	10 390
1994	120	2 257	1 517	1 649	607	93	6 234
1995	116	1 960	1 553	1 784	566	241	6 220
1996	174	2 062	1 477	1 378	624	191	5 905
1997	90	2 473	1 455	613	540	241	5 411
1998	96	3 028	1 502	575	556	141	5 898

Source: LEI.

Table 4. Use of crop protection agents on arable farms in 1990 and 1998
(in kg of active ingredients; between brackets is given the relative shares in total use of arable production)

		1998	1990
Mancozeb (68.00%),cymoxanil (4.50%)	Fungicides	528.299 (11)	340.849 (3)
Chloorthalonil (37.50%),propamocarb-hydrochloride (37.50%)	Fungicide	374.961 (8)	0 (0)
Fentin-acetaat (11.50%),maneb (34.00%)	Fungicide	222.677 (5)	610.970 (6)
Mancozeb (67.00%),dimethomorph (7.50%)	Fungicide	181.763 (4)	0 (0)
Maneb (38.00%),zineb (41.00%)	Fungicide	155.596 (3)	53.195 (1)
Fluazinam (50.00%)	Fungicide	150.798 (3)	0 (0)
Maneb (80.00%)	Fungicide	143.846 (3)	302.679 (3)
Fentin-acetaat (9.00%),maneb (62.50%)	Fungicide	143.199 (3)	272.182 (3)
Metiram (64.00%),cymoxanil (4.80%)	Fungicide	75.496 (2)	13.479 (0)
Mineral oil (86.00%)	Additive	486.578 (10)	278.040 (3)
Metam-natrium (51.00%)	Nematiciden	303.437 (6)	2.902.894 (29)
Cis-dichloorpropene (116.00%)	Nematiciden	180.391 (4)	0 (0)
Dichloorpropene (118.00%)	Nematiciden	12.493 (0)	2.778.844 (28)
Glyfosaat (42.00%)	Herbiciden	217.127 (4)	92.922 (1)
Diquat dibromide (20.00%)	Herbiciden	78.670 (2)	28.821 (0)
Metamitron (70.00%)	Herbiciden	75.369 (2)	108.214 (1)
Prosulfocarb (80.00%)	Herbiciden	75.056 (2)	0 (0)
DNOC (20.00%)	Herbiciden	20.037 (0)	151.080 (2)
Other		1.486.821 (30)	2.102.113 (21)
TOTAL		4.912.615 (100)	10.036.280 (100)

Source: LEI

The composition of active ingredients changed during the 1990s:

- Total use of nematicides in arable production was almost 0.6 million kg (1998), which however was as much as 9.5 million kg in 1990. In 1990, two active ingredients (metam-natrium and dichloorpropene) in total accounted for almost 60% (or 5.6 million kg) of total use of crop protection products by arable production. Each of them account for more than a quarter of total use of crop protection products in 1990. Both products showed very large reductions during the 1990s, and the use of cis-dichlorpropene increased substantially. Crop protection agents that include cis-dichlorpropene only entered the market in 1990 and 1991. The use of di-chloorpropene became marginal.
- In addition to the reductions achieved in using nematicides, changes have also taken place in the composition of fungicides used. Fentin, maneb and mancozeb are the leading active ingredients to protect potatoes against fungi. The active ingredient fluazinam was authorised for use in 1996, whereas the combination of mancozeb and dimethomorph is authorised for use since 1997. Other fungicides, which are largely based on maneb, zineb and other active ingredients, are commonly applied in crop protection products that are authorised several decades ago, or might be relatively new. The authorisation of crop protection products that are composed of fentin-acetaat and maneb, will expire in the nearby future. Compounds, which are composed of metiram and cymoxanil have been authorised in 1993, and currently take about 2% of total use of active ingredients in arable production.
- The authorisation of new active ingredients entering the market, and the expiration of other active ingredients, also affects the use of herbicides. Use of the active ingredient prosulfocarb is authorised in two crop protection products since the end of 1990 and 1996, and currently accounts for about 2% of total use of crop protection products in arable production. The use of crop protection products with DNOC (20%) will also expire, and its use has been reduced largely during the 1990s.
- Several active ingredients have been authorised for agricultural use and entered the market in the 1990s. In part, they replaced active ingredients for which authorisation expired.

Improving energy-efficiency in greenhouses

Total energy consumption of greenhouses has steadily increased over the past decades as a result of strong production growth; this sector currently uses about 60% of total energy consumed by agriculture in the Netherlands. It has a share of more than 85% of total agricultural use of natural gas (3.7 billion m^3). The price of natural gas used in greenhouses is approximately 26 cents (situation 1998). This price is inclusive of charges, which are part of the energy policy aimed at greenhouses. However, prices are lower than the prices paid by consumers, due to a deduction granted to large consumers, including the chemical industry, aluminium production and greenhouses. The greenhouses sector is considered to be a large-scale user of natural gas. The price development over time is also influenced by the world market development of fuel oil prices. The reduced prices for natural gas apply to all holdings which consume more than 30 000 m^3 of natural gas. Energy accounts for a large share of total costs in greenhouses, ranging between around 18% (vegetables) and 13% (flowers).

This section examines trends in energy consumption in greenhouses, emissions of carbon dioxide and the amount of energy used per unit of agricultural produce. This will contribute to examining technical means in improving energy efficiency, which corresponds to the amount of

energy required to produce one unit of product. This indicator is, therefore, affected by a combination of energy consumption and production level.

Policies related to energy consumption in greenhouses mainly aim to achieve an improvement in energy-efficiency for producing horticulture products. No explicit reduction target exists for the emissions of carbon dioxide from greenhouses. A Multi-Year Agreement on Energy in Horticulture under Glass has contributed to the Netherland's energy policy. This agreement was aimed to achieve an improvement of energy efficiency by 40% in 1995 compared to the reference year 1980. By 2000, it was anticipated that energy efficiency will have been improved by 50% compared to 1980.

The sector has succeeded in achieving the intermediate objective for 1995 (Figure 3). The efficiency in energy use has improved by 40% between 1980 and 1995. Energy-efficiency was supposed to be improved by another 10% for the remaining period of five years. It is unlikely that the eventual target of 50% will be achieved. Meanwhile, an improvement of energy efficiency is agreed to be achieved by the year 2010. By that time, it should be improved by 65%, relative to the base year 1980.

Figure 3 shows the trend on emissions of carbon dioxide and energy-efficiency in greenhouses. The reduction in the emissions of carbon dioxide was primarily achieved through the delivery of residual heat from energy utility companies. This was a negligible factor during the mid-80s, but it already had a share of more than 10% of total energy consumption by greenhouses in 1998. The emissions of carbon dioxide increased up to the mid-90s, and have diminished gradually since then. Three factors have contributed to this trend:

- the expansion of the area of greenhouses until 1993, the gradual reduction during the period between 1993 and 1996, and the limited increase since then;
- intensification of production, in terms of energy consumption and volume of production per unit of land area; and
- trends in energy-efficiency.

As part of the Kyoto Protocol, the European Union agreed to reduce the emissions of greenhouse gases by 8% during the period until 2008-2012, relative to 1990. The Netherlands has agreed to reduce their emissions by 6%. Nevertheless, a substantial reduction in total emissions of greenhouse gases is needed, essentially because they have increased by 7% during the period 1990-1998. Key instruments to alter this trend are arrangements with the different target groups (*e.g.* industrial sectors), the provision of subsidies for investments, fiscal measures and an increase of energy taxes.

The tendency to increase the intensity of energy is reflected by measures taken to intensify the application of measures to control production and climatic conditions. Means to control dosage of carbon dioxide and the use of assimilation lightning are increasingly adopted, not only in vegetable production, but in ornamental plant production as well. Using dosages of carbon dioxide during period when horticultural systems do not need to be heated have intensified during the first half of the 1990s.

Figure 3. Energy efficiency and emissions of carbon dioxide from greenhouses

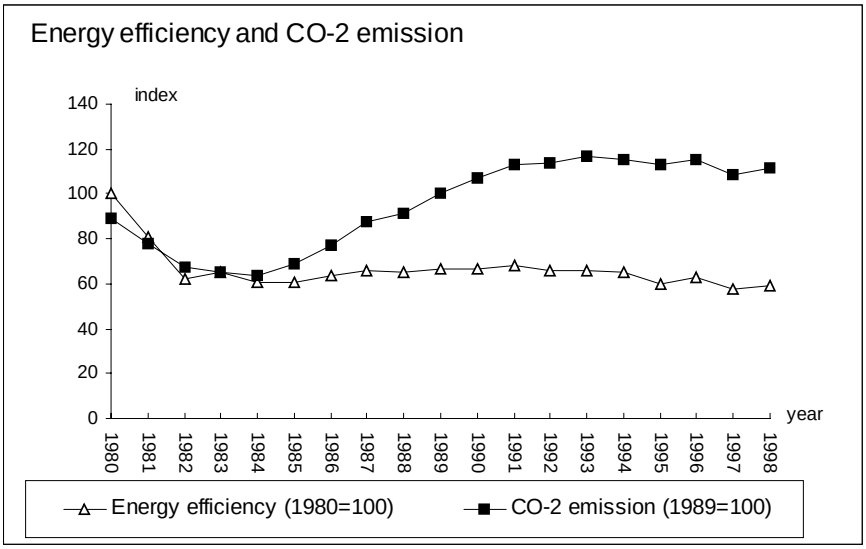


Table 5 summarises the investments in durable equipment made between 1991 and 1996 by greenhouses. Approximately 10% of all investments in durable equipment contribute to energy saving in greenhouses. The investments made over time are largely dependent on trends in profitability. Investments tend to increase with a rise in profitability. Bakker *et al.* (1998) have estimated the energy saving achieved with the available equipment. The available options allowed achieving a 2% saving of energy per annum during the first half of the 1990s.

Table 5. Investments in durable equipment by greenhouses
(million NLG)

Equipment	1991	1992	1993	1994	1995	1996	Total
Climate computer	24	29	12	7	9	20	101
Condenser	5	9	5	5	3	3	30
Heat buffer	5	11	10	3	1	24	54
Thermal screen	62	90	43	32	48	49	324
Sub total	96	139	71	46	61	95	508
Total	1 144	1 113	740	580	647	772	4 995

Concluding remarks

The following concluding remarks derive from the above analysis on the importance of technologies for intensive farming systems in the Netherlands.

- There is good evidence on the importance of keeping records on the inputs used by farmers in meeting policy objectives. It increases the awareness on the environmental effects of farming practices applied. Such records are considered to be an important tool in changing the behaviour of individual farmers, and subsequently to contribute to sustainable production methods.

- Public policies provide incentives to farmers seeking innovations to meet the requirements of policy. Mandatory national policies with a broad range of reduction targets, for example, have been the major incentive to reduce the use of crop protection products in the Netherlands, and have also contributed to control the application of crop protection products. Investments have been made in more-advanced equipment to apply crop protection products and reduce drift. The authorisation procedure altered the composition of active ingredients available for agricultural use and essentially contributed to reduce total use. Such technologies, however, need to be available and private actors play a vital role in managing for the provision of such technologies. The chemical industry, for example, supplies new crop protection products, allowing for more targeted use and requiring much lower dosages. Similar observations have been made in greenhouses. The availability of technologies has also been an important factor in meeting public policies in this sector. In addition, innovations also are needed for the supply of technical equipment to improve energy efficiency in greenhouses.
- Efficiency indicators are relevant in the context of the adoption of technologies by intensive farming systems in their attempt to meeting environmental policy targets. Essentially, environmental policy standards can result in improve efficiency of production, for example a better use of crop protection products and energy, potentially cutting costs and increasing gross margins. Such indicators allow balancing environmental constraints with the economic performance of individual producers. Policies to improve energy-efficiency, for example, have given incentives to increase the efficiency per unit of agricultural output.
- Innovations and the adoption of technologies are vital for intensive farming to meet environmental policy targets and contribute to a sustainable and viable agricultural sector. Such technologies may increase flexibility in selecting the means by which individual producers can achieve environmental objective targets, and subsequently limit costs of meeting environmental policy objectives.
- Public policies and private actors have interacted during the 1990s in their attempt to promote the adoption of innovations in intensive farming systems. Market initiatives increasingly respond to public policy and contribute to sustainable farming systems.

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EVOLUTION AND INSTRUMENTS FOR THE IMPLEMENTATION FOR WHOLE FARM ENVIRONMENTAL MANAGEMENT PROGRAMME IN SWITZERLAND

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and
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Abstract

There was growing evidence during the late 1980s of the need for Swiss agriculture to consider more widely the principles of sustainability and market demands. Various initiatives were taken by different groups in the agricultural sector which led to the implementation of a national program for a whole farm environmental management. This became part of the whole concept of multifunctionality in agriculture. Today, 85% of Swiss farms participate in this program.

This section presents the evolution of this national strategy, starting with the initial idea of integrated pest management and how the implementation was accelerated by the shift to a new system of direct payments that are environmentally targeted. The roles of research, extension and agricultural policy are described as well as the instruments applied. In addition, some examples of the adoption of environmental friendly production techniques are presented. The program has already shown some positive effects on total use of mineral fertilisers and pesticides as well as on the area of semi-natural habitats on farmland dedicated to the conservation of biodiversity. This section concludes with reflections on the need to differentiate between the standards for farming activities according to regional environmental goals and the need to enhance international co-operation.

Keywords: integrated production, ecological farming program

Introduction

Growing pressure on Swiss agriculture during the 1980s promoted a reform of agricultural policy and the development of a national program for a whole farm environmental management. This national program, for integrated production (IP) with reduced input on the one hand and for organic farming on the other was launched in 1993. In 1998, 85% of Swiss farm land was cultivated according to this program. The first elements of this process were *a)* to separate the policy on prices of agricultural products from the policy on farmers income, and *b)* the step-by-step development of the agronomic concept from integrated pest management to the integrated production at farm level. Substantial financial incentives and the contributions of applied research and extension services played

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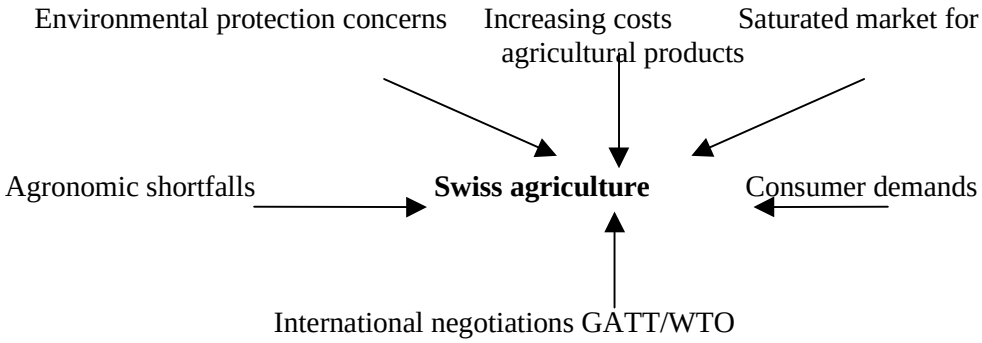
a key role in the implementation of the program. Experimental and pilot farms provided most valuable information for the definition of suitable national standards for the IP program that corresponds with many objectives of the Decision 3/11 of the third Conference of Parties to the Convention on Biological Diversity (UNEP/CBD 1996). The first effect of the ecological farming program observed was a reduction in the national annual use of pesticides, nitrogen and phosphorus-fertilisers. In addition, the proportion of semi-natural habitats on farm land showed a clear increase. To further improve sustainability of farming systems, steps at the national and international levels are proposed.

Growing pressure on Swiss agriculture in the 1980s

The situation of Swiss agriculture drastically changed during the 1980s. After three decades of slow but continuous intensification and rationalisation, some agricultural and environmental problems of the actual farming system became evident. Frequent use of pesticides and simplification of crop rotations had produced resistance of some pests and weeds to chemical control, and increased soil erosion was observed for crops such as maize. Some cases of contamination of surface and ground water with nutrients and pesticides raised the question of sustainability of the actual production systems in a period of growing public interest for nature conservation and pesticide-free products. The intensified production has also led to saturation of the market for some products like milk or cereals. The to maintain farmers' income in parity with Swiss workmen by product-related subsidies increased every year, setting off a national discussion about tasks and financial support of Swiss agriculture. In addition, there was growing international pressure for less protectionism for national agricultural products from the Uruguay round of GATT on (Figure 1). This situation stimulated initiatives of different groups within the agricultural sector that resulted in the implementation of a national program for a whole-farm environmental management.

Figure 1. Factors exerting pressure on Swiss agriculture in the late 1980s

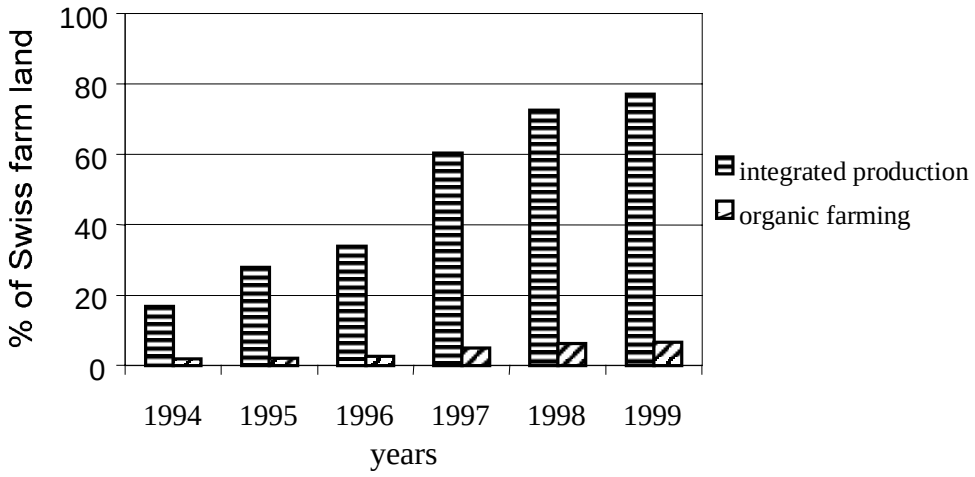


Evolution of integrated production (IP) in Switzerland as a tool for whole-farm agronomic and environmental management

The official program for whole farm integrated production with reduced input and the one for organic farming in Switzerland were started in the year 1993. The proportion of Swiss farm land cultivated according to the standards of the official program for integrated production increased from 17% in 1994 to 77% in 1999 (Figure 2). During the same period, the proportion of organic farming

increased from 1.8% to 6.7%. This development was achieved by the joint efforts of a reform in Swiss agricultural policy and the collaboration of farmers, extension services and applied research.

Figure 2. Evolution of the proportion of Swiss farm land managed according to the Federal program for integrated and organic farming



Source: Bundesamt für Landwirtschaft, 2000.

Reform in Swiss agricultural policy

It was the vote of 1986 on the promotion of domestic sugar production that saw a majority of citizens refusing for the first time a further increase of financial support for Swiss agriculture. The beginning GATT negotiations also clearly demonstrated the need for a reform of Swiss agricultural policy. As a result, the Swiss Federal Office of Agriculture appointed in 1987 a second expert commission on direct payments in agriculture. In 1990, this group presented a proposal to stop government measures and subsidies aimed at maintaining high prices of agricultural products to ensure farmers' income (Popp, 1990). Instead, the future government direct payments should make environmentally friendly management practices on the farm more profitable. This same commission introduced the term "multifunctional agriculture" in the Swiss discussion and claimed direct payments to farmers for performances of public interest. Against this background, the *Seventh National Report on Agriculture* was published in 1992 and met with very good political acceptance. To put this reform into practice, new measures were needed. In 1992, a new Article 31*a* was added to the Federal Agricultural Law and became the basis for direct payments by the government. These measures took due account of the multifunctional character of Swiss agriculture. According to the constitutional article on agriculture approved in 1996, the main functions of Swiss agriculture are:

- Conservation of natural resources.
- Tending the cultural landscape.
- Decentralised settlement of the country.
- Secure food supply for the population.

In a next step, Article 31*b* was added. It defines the governmental contributions for special ecological performance of farms above the level of Article 31a and allowed already in 1993 to launch the national program for integrated or organic whole farm management. This program is an actor-

oriented approach and participation in its sub-programs is voluntary. The incentives motivate farmers to adopt minimal official farm management standards facilitating environmentally compatible farming and they intend to compensate costs of additional work or yield losses.

The official minimal requirements for the program of "integrated production with reduced input" (Article 31*b*), in addition to the law for environmental protection, were the following in 1996:

- diverse crop rotation (more than four crops, cropping breaks);
- high index of soil cover during autumn and winter. Measures to prevent erosion, if necessary;
- balanced nutrient budget of the farm for N and P not exceeding 10% surplus. Analysis of soil nutrient contents at least every ten years;
- restrictions for some applications of chemical plant protection products; apply the principle of economic thresholds. Technical control of spraying equipment;
- dedicate at least 5% (since 1999, 7%) of farm land to ecological compensation (semi-natural habitats) and establish buffer strips along rivers and roads;
- livestock husbandry has to meet defined standards of "animal friendly" conditions as an example of minimal number of days outdoors,
- farmer must participate in group extension activities, document main farming activities and tolerate controls.

These farming standards evolved from intensive discussions, following the experience of a relatively large pilot farm network (started in 1991), and system comparison trials. Instead of a normative approach based on environmental ideals, they were designed in a rather empirical way in order to encourage the largest possible number of Swiss farmers to use environmentally compatible farming practices.

The legal norms for organic farming are the same as for IP, but extended by a complete renunciation of synthetic fertilisers and pesticides. Organic farms must fulfil the directives of the Swiss ordinance of organic farming as well as meet most regulations of the European Union concerning organic farming (EU 2092/91).

In both farming systems, the farm is considered an ago-ecosystem with internal nutrient flows and complex interactions. Therefore, the whole farm (with the exceptions of vineyards and orchards) must be managed according to the system concerned to obtain direct payments. In other words, sectorial IP and organic farming do not obtain support from the government. As shown in Table 1, the amount of direct payments for ecological farming systems are substantial.

Table 1. Amounts of direct payments per year for participating in the official Swiss programs for whole farm integrated and organic farming, respectively (1998)

	Payments for integrated farming	**Payments for organic farming**
Special crops (fruit, vegetable, and wine yards)	750 Euro / ha	1125 Euro / ha
Arable crops	500 Euro / ha	875 Euro / ha
Rest of farm land	270 Euro / ha	330 Euro / ha

Fulfilment of these minimum requirements is controlled by an officially accepted organisation, in most cases by the cantons, some of which added more ambitious requirements to the program.

In 1996, Swiss voters approved a new constitutional article on agriculture by a majority of nearly 80%. They explicitly acknowledged the multifunctional character and role of Swiss agriculture and confirmed the chosen direction to reform Swiss agricultural policy. In 1999, after minor changes, the environmentally targeted requirements of the official integrated farming program, according to Article 31*b*, were declared the minimum ecological standard for all farmers wishing to obtain governmental direct payments. Farms fulfilling these standards obtain an equal financial support as before. Further ecological measures, such as organic farming, establishment of ecological compensation areas on farm land, or special measures for animal friendly livestock husbandry are also paid.

An evaluation of the program was initiated by the Swiss Federal Office of Agriculture in 1996 which instructed its research stations to perform an evaluation study of the program. Through the recently imposed political obligation of an annual report on sustainability of Swiss agriculture, the Ministry also takes a leading role in communicating progress on environmental, economic and social issues of Swiss agriculture.

To implement the reform of Swiss agriculture in practice, the Swiss Federal Office of Agriculture declared clear priorities of suitable instruments already in the report of 1992. Research, education and extension are considered the most important instruments. Their task is to enable farmers to understand and to efficiently carry out the environmentally friendly whole-farm management. Direct payments are a second instrument that helps to make ecological management activities more profitable and also promotes voluntary participation of farmers in the ecological programs. Prohibitions and penalties, however, scored lowest in motivating farmers for ecological objectives, but they are necessary to maintain a common minimal legal standard for all farmers.

Role of research and extension

A small group of pioneers of applied research and extension first noticed the appearance of agronomic problems due to intensified agricultural production in the 1970s and started to search for solutions. The process began in the sector of fruit growing. The intensive application of plant protection products and fertilisers resulted in agronomic problems, for example the control of spider mites led to a spiral of increasing input of ago-chemicals. They became aware that a long-term solution to these problems demanded a new approach instead of further optimisation of isolated measures. So the concept of integrated pest management (IPM) was developed for fruit growing in Switzerland (Steiner *et al.* 1977; Baggiolini 1978). Special attention was paid to understanding and utilising natural regulation mechanisms like control of pests by their predators. A similar development followed in arable crops, where undesired effects of intensification of cultivation were also observed. In plots with repeated maize growing, some weed species had become resistant to or escaped the action of the commonly used herbicide triacine and endangered the harvests (Ammon and Beuret, 1984). In addition, neighbouring countries reported severe attacks with secondary pests like aphids or spider mites in large maize plots after their natural antagonists had unintentionally been eliminated by the control of the European corn borer with non-selective insecticides (Mestres and Cabanettes, 1985; Naibo and Foulgocq, 1985; Leisner *et al.*, 1987). These experiences promoted the idea of IPM in arable crops. Extension and education services and researchers worked together to provide farmers with the necessary information on economic thresholds for direct plant protection measures and how to use natural regulation mechanisms or mechanical control for IPM.

In a further step, applied researchers and extensionists also included the integrated nutrient management in the concept and broadened it to become an integrated farming system (for a definition see Heitefuss, 1990; El Titi *et al*,. 1993) by considering the whole farm as an ago-ecosystem (Häni *et al.*, 1989). In the year 1988, a working group of the Swiss association of agricultural and food engineers (SVIAL) published the first complete guidelines for the integrated production in arable crops. In 1992, their third edition was extended also to grassland (Niklaus *et al.*, 1992).

To gain practical experience with this new approach, several system comparison trials were immediately established by research stations on experimental farms (Häni, 1990; Fried *et al.*1998) or strip trials at agricultural schools and extension centres (overview in Häni and Vereijken, 1990). Based on a mandate by the Swiss Federal Office of Agriculture, the official extension services initiated a network of integrated pilot farms in 1991 (Nationale Projektgruppe Öko-Pilotbetriebe, 1998). These on-farm tests in the German speaking and the francophone part of Switzerland provided good demonstrations for farmers, as well as the urgently needed first experience and figures for the implementation of the official IP-program of 1993 and for its later adjustments. These figures also served for the step-by-step development of the common belief that integrated farming had to be more than "good agricultural practice" in order to deserve recognition as a special ecological performance (Blum and Roux, 1996).

Since the beginning of IP, the official research stations and central and cantonal extension services have supported farmers free of charge, often in joint actions, by developing adapted techniques and procedures, by providing information, thresholds and varieties, etc., to carry out the integrated management. It was the main task of the extension and education centres to acquaint farmers with the idea of multifunctionality and to provide new knowledge needed for IPM and IP. They also stimulated group extension about ecological farming and organised the administration of direct payments and control for IP and eco-management in most cantons. For the evaluation of environmental effects of the program, the Swiss Federal Office of Agriculture appointed in 1996 mainly the Swiss Federal Research Stations. The research stations also work in a national and international context on indicators of sustainability and on tools to facilitate a directed eco-management of each farm in the future.

Role of farmers and market for the adoption of IP in Switzerland

As shown in Figure 2, the proportion of Swiss farm land cultivated according to the national standards of integrated management increased quickly after 1993, despite the initial scepticism of many farmers due to a supposedly higher input of labour. Farmers also feared that significant problems in plant protection or plant nutrition would develop due to the restrictions of pesticide and fertiliser use. Those with plots of fruit, vegetable or wine-growing hesitated to adopt the whole farm management program, but the growing experience with IP and the incentive of substantial direct payments in a situation of decreasing product prices made them join the program. Conversion to organic farming was stimulated by direct payments which are about 50% higher than for IP. Dairy farms in mountain regions, which were already working at low intensities, converted quickly to organic farming. Today, in regions like the mountainous canton of Grisons, 35% of the farms fulfil the requirements for organic farming. An important element for the quick adoption of the IP program in Switzerland was the fact that most Swiss farms were still working at an intermediate input intensity in comparison to intensive growing areas in Europe. As an example, mean annual nitrogen-input in winter wheat of conventional Swiss farms from 1991 to 1996 was about 139 kg N per hectare (*Nationale Projektgruppe Öko-Pilotbetriebe*, 1998). The voluntary participation and the possibility to choose the degree of ecological performance in the national program met well with the farmers' self-image as free entrepreneurs. They also showed increasing understanding for environmental concerns

such as the protection of ground and surface water, although they feared that a tax would be imposed on fertilisers and pesticides for ecological reasons. The need of semi-natural habitats on farm land to conserve biodiversity in rural areas, however, is still not appreciated by farmers in general.

The market had little importance for the implementation of IP in Switzerland. A national IP market label was created in the year 1989, but it had little market acceptance nor did it achieve higher product prices until recently. Consumers also had difficulties in understanding the meaning of IP. In contrast, organic products, especially vegetables and fruits, have had a widely accepted market label since 1980 and obtained higher prices, which promoted the conversion of farms to produce organically. The positive image of organic farming in the public opinion inspired supermarket chains recently to promote and sell organic products on a larger scale. Due to its success, one supermarket chain started to promote products with IP-label.

Examples for technologies recently developed and adopted for sustainable farming systems

One objective of IP is the more focused use of pesticides. For *Phytophtora infestans* control in potatoes as an example, a decision support system (DSS) was developed with an epidemiological model based on national registration of the occurrence of the disease (monitoring) and meteorological data. This system has been shown to enable farmers to protect their crop more specifically against the fungal disease and to make considerable savings in routine fungicide applications in years of rather low disease pressure (Steenblock, 1999).

Another successful approach to replace unspecific pesticide application is the implementation of biocontrol of the European corn borer in Switzerland by mass release of the parasitic wasp Trichogramma brassicae (Bigler, 1986) in maize fields.

Problems with soil erosion and compaction in maize fields triggered applied research to study conservation tillage and underseeding of clover grass in maize fields under humid Swiss conditions (up to 1100 mm precipitation per year). Adapted to Swiss dairy farms with a high portion of clover grass in the crop rotation, the new system with rotary band seeding of maize in a living mulch gives a much better soil and water protection than the traditional system with bare ground after ploughing, with comparable costs and yields (Ammon *et al.* 1995). This cultivation system is now applied on about 8% of the total Swiss maize area.

For the application of farmyard slurry, applied research also produced useful results. Choosing suitable weather and soil conditions for slurry application can reduce ammonia losses by 10 to 40%. Improved application techniques may reduce this loss even by 30 to 90% (Frick and Menzi, 1997).

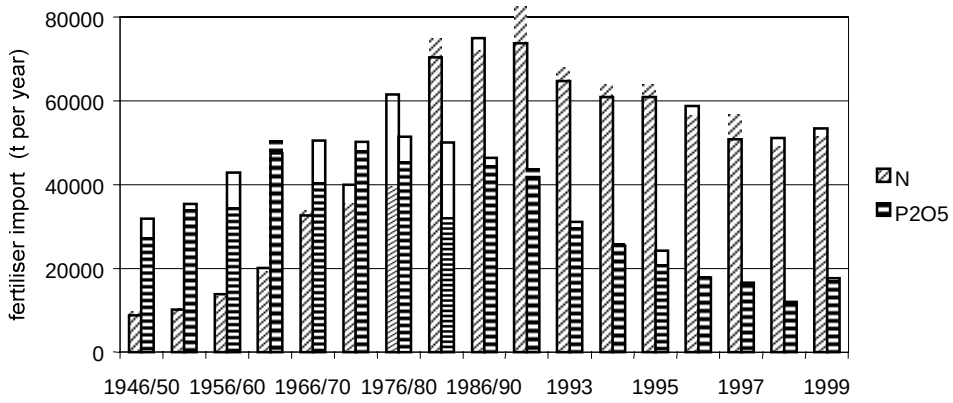
For ecological compensation on arable land, special wild flower mixtures were designed that have some competitive strength against weeds and provide a big floristic diversity during the succession over several years. Such seed mixtures contain suitable plants for flower-visiting insects and are at an intermediate level concerning seed costs (Heitzmann 1994; Schaffner 1998).

Such techniques or measures have proved to be valuable components of a more sustainable agriculture. Their adoption is facilitated where there is good advice by extension services and some kind of obvious and immediate advantage for the farmer. It is also important that they are well imbedded into the whole farming system and that farmers have the skills necessary to adopt them into their daily work on the farm. There remain, however, many other questions about technologies for sustainable farming that need to be worked on at a national and international level.

Examples of first effects of the national program

Switzerland is almost completely dependent on imports of mineral fertilisers. Therefore, such imports are a good indicator of Swiss fertiliser use. Figure 3 shows the development of the import of mineral nitrogen (N) and phosphorous (P2O5) fertilisers since 1950. Import of P2O5 reached a maximum in the period from 1976 to 1980. It then decreased in the 1980s due to the adoption of recommendations to reduce mineral P2O5 supply in case of elevated P-contents of the soil and to take into account also the P-content of organic fertilisers applied. This led to a more efficient use of different P-sources by the farmers. For nitrogen fertilisers, the reduction of imports occurred later, namely in the 1990s when IP started to become established in Switzerland and imposed standards for the nitrogen-use on each farm.

Figure 3. Evolution of the amount of nitrogen and phosphorous fertilisers imported by Switzerland

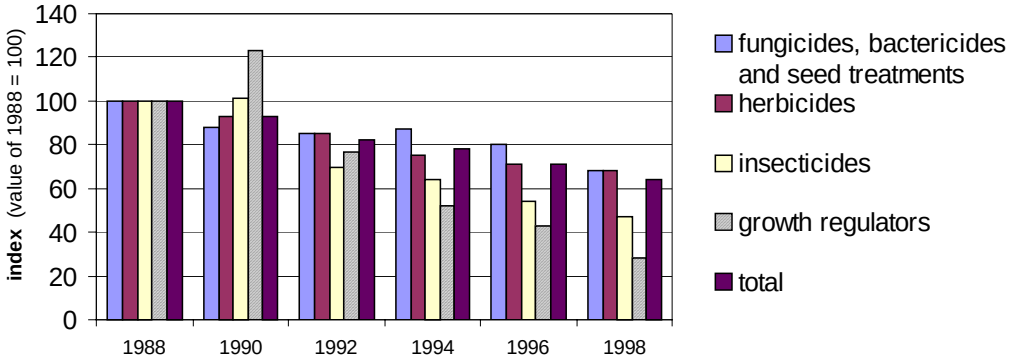


Source : Bundesamt für Landwirtschaft, 2000.

For plant protection products, there have been some changes in the Swiss market has during the last ten years. In comparison to 1988, the quantity of pesticides used per year shows a clear decline (Figure 4). Even though some modern herbicides are applied at much lower doses than traditional products, this decrease in pesticide use is mainly due to a more focused use as well as to a program with subsidies which promotes fungicide, insecticide and growth regulator-free cereal growing.

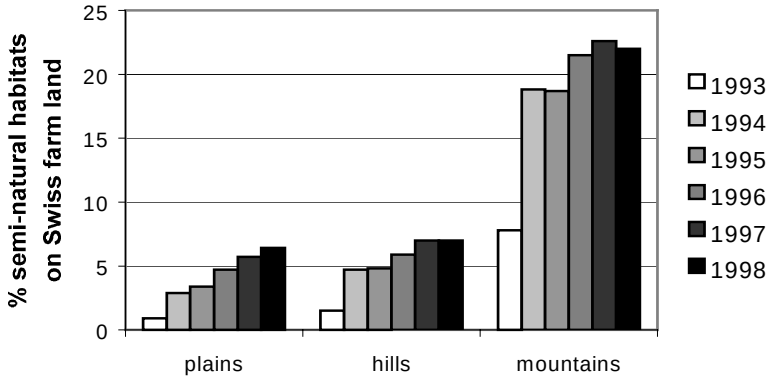
The obligation of the IP program to establish at least 5% of the farm land as ecological compensation area and the subsidies paid for the establishment of specific types of semi-natural habitats had a clear effect on the percentage of farm land dedicated to promote biodiversity. Starting at a rather low level in 1993 in the plains, this area increased to 6% in 1998 (hedges, wildflower strips, etc.). In the mountain area, extensive and medium intensive meadows existed already in 1993 to a greater proportion than in the plains. Nevertheless, the registered area showed a further increase until 1998 in this zone.

Figure 4. Evolution of the sales of different plant protection products (amount in 1988 = 100%)



Source: Bundesamt für Landwirtschaft, 2000.

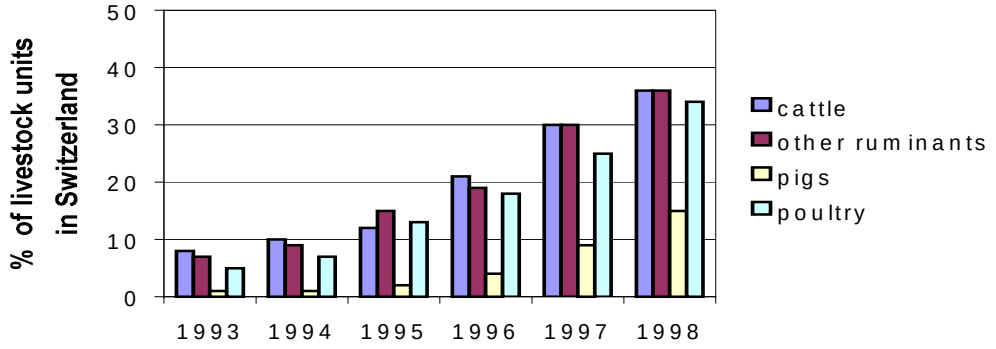
Figure 5. Evolution of the proportion of semi-natural habitats on farm land in different zones of altitude



Source: Bundesamt für Landwirtschaft, 2000

The evolution of participation of Swiss farmers in the additional voluntary program called "RAUS" for animal-friendly rearing systems is shown in Figure 6. "RAUS" is a program with the objective that animals do not remain always in the stable but be put out to pasture in summer and stay at least 13 days per month outdoors also in winter. An other ordinance promotes particularly animal-friendly indoor rearing systems of animals. The livestock are kept in groups and move about in the stable and on straw. As this program often requires reconstruction of older stables, it will be adopted by farmers more slowly.

Figure 6. Evolution of the proportion of Swiss livestock participating in the RAUS-program



Source: Bundesamt für Landwirtschaft, 2000.

Central bookkeeping of representative farms indicates a decreasing income per working day for Swiss farmers during the period 1991 to 1995 (Meier, 1998). Thereafter, the income per working day slowly recovered as the situation on the meat market improved. The mean income per working day during the years 1994 to 1998 was about 5% lower than in the period 1991/1992 for integrated farms in the plains and 15 % lower for conventional farms. For organic farms, this reduction was about 3% (Hilfiker 1998; Anonymous, 1998; Anonymous, 2000).

The importance of environmentally targeted direct payments is also evident in a concrete example for arable crops. In the system comparison trial on the mixed farm Burgrain in central Switzerland, a conventional, an integrated and an organic system are run side by side with the same crop rotation (Fried *et al*,. 1998). Of the 12 plots of the experimental farm, five are planted each year with clover grass. Net profit II of the seven arable crops was calculated as crop value at conventional prices minus labour, machine and direct costs for production. Without any direct payments and at conventional product prices, the integrated and organic farming of the seven arable crops produced a mean annual net profit that was lower by CHF 418 and CHF1 012, respectively per hectare than the conventional system. When environmentally targeted payments were included, both less intensive systems obtained a net profit about CHF650 / ha higher than the conventional system, demonstrating the importance of direct payments. If the organic system succeeds to sell its products at the full price of organic products, it obtains an even better economic result.

Table 4. Mean differences in relative yield and net profit of arable crops of the integrated and organic farming systems at the experimental farm Burgrain*

	Units	Integrated	Organic
Yield difference in % of conventional farming of arable crops	%	- 12%	- 17%
Difference in net profit II to the conventional system without any subsidies and conventional product price	Euro / ha	- 260	- 630
subsidies for pesticide-free cereal growing	Euro / ha	+ 166	+ 166
direct payments for environmentally friendly farming systems	Euro / ha	+ 500	+ 875
Difference in net profit II to the conventional system with subsidies and direct payments	Euro/ha	+ 406	+ 411

* Including subsidies and direct payments, in comparison to the conventional system 1997-1999
Source : Fried *et al.*, 2000.

Factors contributing to the successful implementation of the whole farm program

Pressure built up on Swiss agriculture during the 1980s was the driving force for the reform of Swiss agricultural policy and the development of the new agronomic concept of integrated whole farm management at a reduced input level. Substantial financial incentives for participation in the program could be provided by the change from the product-oriented subsidy system towards environmentally targeted direct payments. Another important aspect for farmers to join the national IP program was that participation was voluntary and that several different levels of commitment to ecological performance could be chosen. The necessary information and advice for more ecological farming was provided free of charge by extension services and applied research. The agronomic concept from integrated pest management to good agricultural practice to IP and later to whole farm ecological management had evolved continuously over time (Baggiolini, 1998). The same occurred for the discussion of multifunctionality of agriculture and direct payments for public services of farmers like ecological performance. This step-by-step evolution and the experience from the rather large network of pilot farms allowed the quite fast implementation of the federal program after 1993. Agreement on the ecological standards for the Swiss IP program was not too difficult to reach, as most Swiss farms still work with a lower input intensity (Anonymous, 1991) and more diverse crop rotations than in many European regions. Nevertheless, the general acceptance was mainly the result of the experience collected in system comparison trials on experimental farms and in the network of IP pilot farms allowing to select an appropriate level of federal standards and the procedural rules for a wide participation of Swiss farms in the ecological farming program. The “holistic” whole farm approach assured that not only single problems were tackled but a general improvement towards sustainability was stimulated.

Future questions and steps

At the national level, there is an urgent need for further evaluation of the Swiss environmental whole-farm program to improve efficiency and effectiveness of the direct payments where necessary. As an example, semi-natural habitats on farm land have not yet always shown an increase in biological diversity. Therefore, an assessment of selected quality traits and a funding system based on the observation of minimal quality standards are in discussion. Furthermore, a differentiation of environmental objectives corresponding to demand for non-food outputs and its derived restrictions in farming activities between different regions is currently under discussion in Switzerland (OECD, 1999). Special measures in zones with elevated nitrate leaching risk, regional goals for conservation of biodiversity as well as specific measures on the landscape level according to a regional development program are also under discussion.

At the international level, a commitment to common standards for sustainable agriculture is necessary. Trading agricultural products at their “real costs” by also internalising their costs of environmental pollution or energy consumption and multilateral environmental agreements with standards recognised by WTO are needed to orient the market more towards sustainably produced goods. Through an obligatory international labelling showing the production method of products, the consumers could obtain the information needed for their choice. To improve sustainability of agricultural production, international knowledge transfer for the development and implementation of environmentally friendly production techniques should be facilitated. In addition, more exchanges of experiences and procedures to design and implement sustainable farming systems are needed and the question of how to cope with conflicting interests within such systems must be addressed.

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ANNEX

SUMMARY OF THE WORKSHOP

Jacques de Graaf[1]

Setting the scene

Ewoud Pierhagen, Director of International Affairs opened the workshop on behalf of L.J. Brinkhorst, Minister of Agriculture, Nature Management and Fisheries of the Netherlands. Mr Pierhagen briefly introduced Dutch agriculture and emphasised that the Netherlands is a small, densely populated country and that the pressure on land and the environment is high. Agricultural production is important in the Netherlands and the farming systems are relatively intensive: 40% of agricultural production consists of horticultural products, 20% is intensive animal husbandry systems and arable cropping systems represent 10%. Several reasons contributed to the development of Dutch agriculture, such as favourable soil conditions, geographical position, research and extension, trading and a competitive market oriented approach to agriculture. However, agriculture has created several environmental problems during the last decades. Therefore, it is necessary to rethink the role of agriculture. Research efforts focus, amongst others, on intensive systems and their environmental sustainability. Mr Pierhagen noted that technological innovations can be of great importance in combining intensive farming with high environmental standards. He also suggested that world agricultural production should be increased due to population growth and that intensive agricultural production systems could contribute to sustained growth. Agricultural production will globally become more intensive.

Gérard Viatte, Director of the Food, Agriculture and Fisheries Directorate of the OECD presented an overall OECD perspective on agricultural development and sustainability. He noted that globalisation, liberalisation and the impact of rapid advances in technologies will present new challenges and opportunities to all countries. Also, the fast changing information technology will have an impact on agricultural development and economic growth and will require new methods of organising work and trade to harness the benefits of globalisation. Therefore, major challenges relate to the design of policies and the search for coherence between different policies. Synergies between trade, environmental and research policies in a world-wide context would require attention by those actors involved in the agricultural development process. Mr Viatte referred to the importance of technological advancement and the adoption by farmers of new technologies. Farmers adopt new technologies when it is beneficial for them to do so. Agriculture would have to respond to civil society and production should take place in an environmentally sound manner. Issues such as international competition and the quality of food and feed need to be addressed. He noted that sustainability has several dimensions. This concept requires that attention is paid to the national resource base, the economic returns of production and the management of knowledge intensive systems. He called for a dialogue between the various actors such as scientists and farmers and stressed the importance of

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policy coherence. Mr Viatte noted that the workshop is of great importance because results could be used as input to other OECD work in the area of sustainable development.

The farmers' perspective on the adoption of technologies for sustainable farming systems was presented by Gerard Doornbos, President of the International Federation of Agricultural producers (IFAP/FIPA). Mr Doornbos noted that technological change is one of the most important factors affecting agricultural production and argued that new technologies (such as biotechnology) are often debated in international agricultural trade policy negotiations. There are challenges in addressing issues such as globalisation and international competition especially with a view to sustainable farming systems. He noted that adoption of new technologies depends on many factors and that national and international policies affect the decision making process at farm level. Mr Doornbos mentioned that market forces may lead to intensification of farming systems because low costs and high yields need to be pursued in order to compete successfully. However, this has had detrimental effects on the environment. Mr Doornbos referred to the Netherlands as a good example on how tangible results can be achieved in combining intensive agricultural systems with high environmental standards thereby contributing to the sustainability of farming systems. He noted that in the last decade or so the use of pesticides dropped by 50% in the Netherlands while water is used more efficient and no tillage systems and direct seeding have become common practise. Also precision farming techniques have been developed and adopted by some farmers. Mr Doornbos, further noted that there are several dimensions to sustainability and that this concept is differently employed in developing countries than in OECD countries. In his function as president of the world farmers organisation IFAP, he said that in developing countries high priority should be given to food security while in OECD countries food quality is high on the agenda. He called for increased consistency and coherence in policies. Referring to the international research efforts, he mentioned that multinational companies tend to increasingly dominate the research agenda and partly determine what happens; he therefore called for more government support to public sector research, such as universities. According to Doornbos, multifunctional demands on agriculture by the civil society also require publicly funded research. He further mentioned that farmers do adopt new technologies if it is (financially) beneficial for them to do so.

The public interest perspective on adopting technologies for sustainable farming systems was presented by Takashi Shinohara, Director General of the National Research Institute of Agricultural Economics, Ministry of Agriculture, Forestry and Fisheries, Japan. Mr Shinohara gave an overview of Japanese agriculture. Japan significantly imports more agricultural commodities and products than it exports. Feed grains from the U.S. are imported mainly for pork production. Food security is a very important issue in Japan and much emphasis is placed on producing food on Japanese soil. Mr Shinohara referred to the concept of "food miles" suggesting that transport costs and pollution may be reduced in food self-sufficient societies. Agriculture has contributed to environmental pollution in Japan. Mr Shinohara noted that environmental sustainability is high on the political agenda. The public perspective in Japan is that of attaining environmentally sustainable production systems. Rural areas are perceived to be in symbiosis with the natural environment. Mr Shinohara noted that multifunctionality is an important and interesting concept and that research and extension efforts should look more closely at this concept. New technologies should be developed to achieve the highest level of sustainability taking into consideration economic, social and environmental aspects. Mr Shinohara also noted that Japanese consumers are concerned about genetically modified organisms. However, it should be noted that life sciences will play an important role in the future development of farming systems.

In the general discussion, several delegates reflected on the presentations and addressed the issue of sustainability. There is a need to reconcile food security concerns with trade and environmental issues and to find a balance between agricultural production and environmental

concerns, given the diversity between farming systems around the world. Developing countries often have different policy objectives, there aim is to achieve self-sufficiency, and consequently the concept of sustainability is viewed differently in these countries. A synergy is needed between the market, sustainability and agricultural policies with regard to the preservation and use of natural resources. While some countries noted that sustainability is linked with extensification of production systems, others suggested that intensification is often needed to meet the increasing demand for food in the world. Biodiversity was mentioned as an important aspect of sustainability. Consumer concerns were also discussed and the fact that consumer concerns are not reflected in the prices paid to farmers. There is a need to define concepts such as multifunctionality and good agricultural practices more clearly. The role of the government in achieving sustainable growth was emphasised.

Arie Kuyvenhoven, Head of Development Economics Group, Department of Social Sciences, Wageningen University presented a paper on assessing sustainable technologies in developing countries. He noted that the Green revolution has been of great importance to Asian countries, but of less importance to Africa. New challenges emerged with a view to improving productivity, achieve sustainability and reduce poverty. The development, adoption and diffusion of sustainable farming systems require appropriate markets and institutional arrangements. Mr Kuyvenhoven argued that policy effects may be quite limited in Africa because the majority of small farmers on this continent are partly integrated in the economy. Cash crop production may be important in facilitating economic growth. Attention should be paid to farm household economics, extension, market development, land rights, financial systems and institutional development.

Trends in technologies and markets

Margriet Caswell, Chief of the Production Management and Technology Branch in the Resource Economics Division, Economic Research Service, United States Department of Agriculture elaborated on some of the present developments in U.S. research institutes. She argued that the research paradigm should shift from a transfer of technology model to that of a holistic model in which more emphasis is given to participatory research methodologies. Unfortunately, research budgets have become increasingly tighter in the United States, while the management demands of institutions increased due to the higher level of accountability. She argued that in the U.S. many real problems are not fully addressed, such as the environment and food safety, mainly because of *ad hoc* research planning. Research should become interdisciplinary, problem-based while the total impact of technologies should be assessed in the wider economic, social and environmental context.

Josef Hoppichler, an Austrian researcher at the Federal Institute for Less-Favoured and Mountainous Areas, also suggested that a paradigm shift is required to attain sustainable development. He discussed technological development from a social and economic perspective. He argued that organic farming is an important trend in integrated farming systems and suggested that holistic rather than reductionist approaches should be pursued in agricultural research efforts. He suggested that a new research sector should pay attention to economic, social, ethical and environmental impacts of technological innovations. New methodologies would have to be developed and besides questionnaires, Delphi methods should be considered as well as, for example, expert hearings in parliaments and the organisation of consensus conferences.

Claus Sommer from the Institute of Production Engineering and Farm Building Research of the Federal Research Centre of Agriculture (FAL) in Germany discussed the importance of agricultural engineering in the search for new technologies and discussed soil tillage systems. He noted that technologies such as no-tillage could contribute to making farming more sustainable.

Technological innovations should be economic viable, appropriate, applicable and accessible to the user.

Atsuhiro Meno, Deputy Director of the Japanese Office of Sustainable Agriculture, Agriculture Production Bureau, Ministry of Agriculture, Forestry and Fisheries, presented and discussed the structure of the National Foresight Program and Japans' technology forecast. The National Foresight Program operates at three levels, *i.e.* macro level (Ministerial), meso level (groups of companies) and micro level (individual companies). In Japan, the basic orientation of research in the field of agriculture, forestry and fisheries is that of developing sustainable environmentally sound systems. Work is ongoing in the field of plant nutrient management by improving fertiliser application rates and soil productivity and in the area of integrated pest management. Mr Meno noted that rural communities need to be revitalised by enhancing the multiple functions of agriculture, forestry and fisheries. This will require the development of suitable evaluation methodologies on the multiple functions including land, biodiversity and environment.

Eric Claassen, Research Director, Institute for Animal Science and Health, ID-Lelystad, The Netherlands, discussed some issues related to the question of how Dutch agriculture would be in 2015. He noted that the Dutch agricultural sector entered into agreement with civil society (license to produce) and that the sector is in a continuous dialogue with policy makers, NGO's, and other actors. A broad range of system innovations are required, ranging from programmes in the area of environment, animal husbandry systems and information technology systems. Professor Claassen noted that biotechnology could play an important role in the further development of preventive and curative medicines for animals. In addition, the origin of the product will become more important in the future as consumers, at least those in Europe, want to know the origin of the food they consume. Registration systems for animals would therefore need to be further improved.

After the presentations, the expert panel discussed future projects for new technologies in agriculture. The New Zealand delegate mentioned that much was said on the development of new technologies, but less on the development of markets. This would require more attention. The Dutch delegate (Professor Meester) wondered which technologies are really in the pipeline for enhancing sustainable development. The panellists came up with several answers such as precision agriculture (site-specific), robots (target oriented), but also mentioned were large GMO free areas to facilitate organic seed breeding. Other technologies mentioned were biotechnology, nitrogen fixation processes, xenotransplantation and the development of new farming systems in general. This suggests that technology is widely defined.

Bernard Lehmann, of the Swiss Institute of Agricultural Economics, Swiss Federal Institute of Technology, then presented how developments in the agri-food chain could affect farming technologies and systems. He discussed the external context and the relevance of the agri-food chain as well as developments upstream and downstream of the farmgate. He presented a case study on GMO-use in Swiss agriculture. The main conclusions were that farming has to fulfil an increasing set of criteria in market concerns and non-market concerns. Public funded research remains important with a view to objectivity and technology development should be driven by the needs of the stakeholders.

Innovation, adoption and dissemination

Joyce Tait of the University of Edinburgh, United Kingdom, presented her view on how governments may influence innovation and uptake of technologies for sustainable farming systems. According to Professor Tait, policy measures can have great and rapid influence on the development

of more sustainable agricultural systems. The policy measures are, however, infrequent and not always recognised. They can also have unexpected consequences for other policy fields. Therefore, policy makers should be better informed and make use of more interdisciplinary skills in addressing the development and use of more agricultural systems. Professor Tait further noted that the Food Quality Protection Act in the U.S. has introduced a so-called fast track allowing approved and environmentally safe products to be marketed faster. This has stimulated the development of pesticides that are environmentally friendly. In addition, Professor Tait noted that biotechnology could contribute to the development of specifically tailored animal feed and foods with consumer attractive products (novel foods). She mentioned that EU legislation with regard to biotechnology is very complex.

Peter Gaemelke, President of the Danish Agricultural Council and Member of the Executive Committee of the International Federation of Agricultural Producers (IFAP/FIPA), addressed the issue of improving the dissemination of technological information to farmers**.** Mr Gaemelke noted that not only organic farming could be sustainable, but that intensive farming systems with good management, especially in response to social (civil society) and environmental demands, could be as well. He discussed the importance of Good Agricultural Practices for sustainable agriculture. Although this concept should be further defined, Mr Gaemelke suggested that four dimensions could be attributed to this concept, *i.e.* agriculture should produce healthy foods, be profitable, limit environmental effects and be ethically sound. Therefore, attention should be given to improving the quality of the products, manage the nutrient balance, minimise the use of pesticides and concern for animal health and welfare. He suggested that technologies help in achieving certain objectives (such as reducing pesticides), but that farmers adopt technologies only when it is profitable to do so. He expressed some concern about the developments in the field of agricultural research and extension service and the relation between farmers' organisations, governments and big multinational companies in agro-food industry, such as Monsanto. These multinational companies have an increasing influence on research agendas and, consequently, there is a need for independent research organisation. Mr Gaemelke stressed the important role of advisory services in the dissemination of technologies. He also discussed the importance of the retail sector as large companies have an increasingly important role in deciding what farmers must produce.

Bringing the themes together

Wilfrid Legg, Head of Policies and Environment Division, Directorate for Food, Agriculture and Fisheries, OECD explained that the aim of this session was to highlight the lessons learned, discuss factors that help or hinder the adoption of sustainable technologies and the potential roles for the governments. Each of the five[2] panellists briefly summarised their main observations and lessons learned. The panellists covered a broad range of issues. The importance of technological innovations and that of sustainable development in general was revisited by some of the speakers. Key observations related to integrating agricultural and environmental policies, interdisciplinary approaches, the importance of international trade, etc. Other important remarks concerned the role of communication, research, extension and trade policy. Attention was given to the issues relating to

2. Mr. Utpal Vasavada, Chief Environmental Indicators and Resource Accounting Branch, Economic Research Service, United States Department of Agriculture. Mr. Jyri Ollila, Counsellor, Agriculture and Rural Development, Delegation of Finland to the OECD. Mr. Terence McRae, Chief, Environmental Information and Analysis, Environment Bureau, Policy Branch, Agriculture and Agri-Food Canada. Mr. Joseph Racapé, Chargé de Mission, Direction de la nature et des paysages, Ministère de l'Aménagement du Territoire et de l'Environnement, France. Mr. Jacques de Graaf, Department of International Affairs, Ministry of Agriculture, Nature Management and Fisheries, The Netherlands.

achieving synergy between environmental and research policies and to aspects related to policy coherence, the role of the governments and interactions between various systems properties and systems levels (national, regional and international).

The last plenary session was devoted to the conclusions and recommendations. In line with other OECD workshops, the conclusions were not formally adopted but submitted to the OECD Joint Working Party on Agriculture and Environment with a recommendation that they be included in the published proceedings.

Several delegates emphasised the importance of information exchange covering both new and old technologies. They stated that the OECD could play a role in facilitating and co-ordinating such information exchange.

REPORT OF THE WORKING GROUP ON TECHNOLOGIES

Jyri Ollila
and
Outi Honkatukia[1]

Introduction

Assessing farming technologies requires a multidisciplinary approach, an old truth emphasised by several members of this working group. The group consisted of academics and policy-makers with wide ranging areas of expertise, including precision farming, soil science, irrigation, animal welfare, organic farming, pest control, energy use, construction of farm buildings, and management of less favoured areas.

Agricultural practices and technologies, including novel applications of existing technologies, and their effects on sustainability at the farm level were discussed, as were studies comparing the benefits — particularly with respect to environmental performance (or "eco-efficiency") — and the costs of technologies. The group agreed on the importance of distinguishing between economic costs and benefits to a country or society and the financial costs and benefits measured at the farm level, although it noted that this comparison was difficult to do in practice.

Case studies

A number of case studies were presented as a basis for discussion. The Italian case study analysed opportunities to change from conventional or traditional farming practices to environmentally sound practices, both in term of profitability and environmental considerations, while taking into account farmers' perceptions on agri-environmental issues. The evaluation of the different farming systems was formulated on the basis of three methodological steps: *(i)* collection of detailed information on farming practices, with special reference to the factors of production used; *(ii)* economic analysis of the production of cereals, vegetables, grapes, olives and livestock products; and *(iii)* environmental impact analysis of different production processes. The study highlighted the trade-off between profitability (with and without public support) and the environmental impacts of the different production processes.

The Spanish case study showed that the primary agro-climatic data used to estimate the water requirements of Spanish agriculture is inaccurate because the measuring stations are not optimally located and generally do not collect the type of information needed by farmers. A new agro-climatic network, currently being tested, provides more accurate climatic parameters to calculate the

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water requirements therby facilitating optimal management and use of the water resource. When a suitable method to calculate the water needs has been developed, the information should be included in automated and remote controlled irrigation systems. The paper described such an irrigation system, including the computer programme used to manage the system.

The case study from The Netherlands provided empirical evidence on the adoption of new technologies by agriculture. It focused on achieving environmental policy targets for the use of crop protection products in the arable sector and for improving energy efficiency in greenhouse horticulture. Such new technologies play a vital role in meeting more stringent environmental policy targets for intensive farming systems and in shifting to more sustainable production methods in agriculture. Government policies and market initiatives are the key driving forces behind the adoption of such technologies. The private sector has played a vital role in providing the technologies needed to achieve such policy objectives, including new agrochemicals, which allow for more targeted use and require lower dosages. Innovations have also been introduced to improve energy efficiency in greenhouse horticulture.

The German case study examined the construction of animal housing for pigs and cattle that would minimise emissions. There were several examples of conflicting demands on construction engineering and management practices for environmentally-sound pig and cattle farming. The study also discussed different solutions for reducing emissions, including electronic animal identification systems, animal specific feeding techniques and control of feed intake in group husbandry systems (pigs, beef cattle and dairy cows), construction of floors and lying areas in group husbandry systems, construction of stables (closed or open), and manure storage facilities. The study concluded that: 1) the analysis of the emissions should be based on products and animal units; 2) the use of individual feeding, sensor and monitoring techniques can eliminate many causes of emissions in group husbandry systems; 3) emissions from buildings can be reduced or eliminated if manure is not stored for a long period of time; 4) air quality can be improved and emissions reduced by removing liquid and solid manure separately from the building; 5) open stables can be constructed in a way that makes them environmentally friendly; and 6) liquid and solid manure should not leak from the building and cause soil or water contamination even when stored for a long period of time. Using dairy cattle husbandry as an example, the study also found that increasing per-animal productivity usually reduces emissions per product unit and that electronic animal identification systems can improve products and increase resistance against epidemics. More research and development is needed to measure emissions from open stables.

The Japanese case study described the recent methodological developments in evaluating the environmental benefits of agriculture and examined the adoption of technologies that reduce environmental pressures from agriculture, in particular experiences in adopting of environmentally-benign nitrogenous fertiliser. The study showed that simple traditional technologies combined with modern monitoring systems can help to achieve sustainability in agriculture. It also emphasised the need for farmers to understand the environmental externalities of agriculture and the role of the public sector in adopting technologies to reduce the environmental pressures of agriculture.

Discussion

Sustainable farming systems

In a sustainable farming system all inputs, including environmental and natural resources, are used optimally. This can be difficult to achieve when externalities are not fully internalised and

some resources are not priced correctly by the market. Farmers can make optimal decisions only when input prices reflect both on-farm and off-farm effects, such as impacts on groundwater.

Both extensive and intensive farming systems can be sustainable. Intensive farming can be locally sustainable under certain site-specific factors and local conditions. Some of these factors relate to the endowment of natural resources (*e.g.* soil fertility), socio-cultural factors, geography and local conditions (*e.g.* slope and soil type). In order to remain sustainable, intensive farming systems often require technologically more sophisticated solutions than do extensive farming systems. It is important to assess sustainability not only in terms of the economic and environmental aspects, but also to consider the social aspects and find a balance between the three dimensions of sustainability.

Technologies

The term *technologies* can be defined loosely to include farm management practices. The range of technologies used in sustainable agriculture is wide, ranging from simple to sophisticated, and from conventional farming technologies to organic, integrated and precision farming.

While existing technologies already have an established regulatory framework, some new emerging technologies (that introduce entirely new production systems, such as the use of biotechnology) may need special attention from the government, *e.g*. introducing new guidelines, legislation and regulations.

Technologies can be characterised as either production-oriented or non-commodity-oriented. Technological spill-overs from other sectors to agriculture are important because the agricultural sector is not itself paying the research and development costs. Information technologies are increasingly used in agriculture, where they can help to reduce geographical handicaps. The relative impact of information technologies is greater on agriculture than on the other sectors of the economy.

Economic, environmental and social considerations should be taken into account when evaluating technologies. In addition to assessing the technical and economic efficiency of the technology, it is important to evaluate how well the technology is accepted by farmers and civil society (social acceptance).

Information needs

The group agreed that countries can learn from sharing experiences about technologies and farming systems. This exchange of information is useful even though a technology or farming system used to achieve sustainable agriculture in one country does not automatically lead to similar results in another country.

Both data and indicators are needed to assess sustainability. Data availability is often a problem, although new information technologies can be used to overcome this problem. Data is usually available for specific case studies, but it is difficult to draw general conclusions based on site-specific data. For example, it may be possible to rank sustainable farming systems for a local region, but one should be cautious in generalising these results and applying them at the national level. While it is relatively easier to obtain data on the profitability and cost of a specific technology, it is considerably more difficult to assess the environmental effects of technologies. More efforts should be put in assessing the environmental and social impacts in monetary terms.

Barriers to the uptake of technologies

Factors hindering the adoption of appropriate technologies for sustainable farming systems include:

- economic profitability of the technology;
- farmer's financial constraints and access to credit;
- farmer's familiarity with the technology, and his knowledge and education levels;
- uncertainty about agricultural support policies and world market prices;
- conservative attitudes of farmers and local authorities (which can make them slow adopters);
- local/ site-specific conditions;
- structural factors such as size of the farm — for example, precision farming is good for large farms, but expensive for small farms that could benefit from semi-precision farming instead);
- cost of new technology to farmer — new technologies are often expensive when they are first introduced, thus penalising early adopters;
- scale of production for the technology — technologies produced in small quantities have difficulties to get market access.

Role of governments

The group discussed how governments influence the adoption of farming practices and technologies through policies and what difficulties they face in designing these policies. Agri-environmental programmes have been introduced in most OECD countries and governments are using specific policies favouring particular farming systems (*e.g.* organic farming) or practices (*e.g.* conservation tillage) to influence farmer behaviour. Governments are also supporting research and demonstration farms that can contribute towards the adoption of technologies. However, rather than giving out payments for farmers for adopting of a certain technology or farming system, it may be better for governments to pay farmers to meet an environmental standard. In other words, governments should not automatically favour the adoption of some specific technologies over others.

Given the diversity and complexity of farming systems, it is difficult for governments to know which technologies and farming systems they should encourage, and this for two reasons. First, governments are not all knowing and secondly, their support can reduce innovations overall. Consequently, governments should be favouring voluntary approaches to technology adoption for the following reasons:

- government should not be in the business of pushing some technologies because one size does not fit all and governments simply do not know what is best in all contexts; and
- farmers prefer voluntary approaches to compulsory regulations because market-based approaches are often more efficient and regulations discourage innovation due to locked-in technologies.

Although the government is primarily responsible for achieving sustainable agriculture, the role of the private sector is important too, for example, in the promotion of sustainable farming

technologies. Profit is the main motivation for the private sector to promote these technologies, but image and public relations reasons also play a role.

Quick and slow adopters

The group emphasised the importance of extension and education, and considered that public efforts to encourage the adoption of technologies should benefit both quick and slow adopters. Farmers can be slow adopters for various reasons. For example, adopting the new technology may not be profitable to them, in which case they may prefer to wait until the price of the technology decreases as a result of market developments or government policies. Another reason for slow adoption can be the different attitudes to risk. Some farmers will always be risk averse and governments should try to influence farmer attitudes to risk. Governments can, however, introduce regulations and cross-compliance requirements for environmental reasons in order to change the behaviour of slow adopters. For quick adopters, it may be sufficient if the government promotes the technology through extension. In all cases, governments should apply a good mix of policies.

There can be a trade-off between promoting a simple and reasonably effective technology, such as crop rotation, and a complex but more environmentally beneficial technology or farming system, such as precision farming. The trade-offs are not automatic and even when these exist, the relationships are not always linear. Both simple are complex technologies need to be applied in order to achieve sustainable agriculture.

Cultural and economic factors influence the rate of adoption of particular technologies. Other factors affecting the rate of adoption include the efficiency of the extension service and the overall level of economic development.

Trade-offs in early adoption

One risk in early adoption is that capital will be "locked in place" when it could have been used more efficiently had the technology been allowed to mature further. If there is a high uncertainty about agricultural and other policies, promotion of early adoption may result in investing in the "wrong" technologies. On the other hand, stimulating adoption may help accelerate the learning curve and ensure that the economies of scale are fully exploited sooner in the manufacturing of the technology than they otherwise would be.

Another risk in early adoption is that consumers may not be ready to accept the technology. For example, farmers in some countries began to grow genetically modified crops before consumers were willing to buy genetically modified agricultural products. There may be social conflicts, especially in small farming communities, where some farmers switch to organic farming but others do not. Farmers should benefit from investing in human capital: sophisticated, new technologies that require a higher education level should be profitable so that the quick adopters can also enjoy the profits.

Economies of scale

There are economies of scale in manufacturing and applying technologies as well as in using farming practices. These economies of scale exist at the farm, technology and market levels, and depend on the characteristics of the technology.

When adopting a sustainable farming technology involves a large capital investment, large farms are in a better position to adopt it than are small farms However, not all new technologies require large investments and small farms may in fact be in a better position to adopt certain technologies. In some cases, it is possible for small farms to invest together or to buy the service from an outside provider, and thus avoid making large capital investments. Sometimes combining basic, conventional farm management practices with sophisticated environmental monitoring systems can be the best way to achieve sustainability in agriculture.

Technologies originally developed for sectors other than agriculture can be interesting where agiculture can adopt these technologies without having to pay the development cost. Examples of these kinds of technologies are new information technologies and technologies using Global Positioning and Geographical Information Systems.

Modern technological solutions could be used to produce non-commodity outputs from agriculture. Enhancing biodiversity and maintaining semi-natural habitats and agricultural landscapes should not automatically mean that only old technologies and farming practices can be applied. The use of new technologies in this field could be an area for more public research funding.

REPORT OF THE WORKING GROUP ON INSTITUTIONS

Terence McRae
and Ronald Steenblik[1]

In seeking to influence and increase the uptake of more-sustainable farming technologies, policy makers need to take into account the great diversity across farming systems, technologies, farmer attitudes and the environment itself, as these factors will have a profound affect on how different technologies are perceived and at what rate they are being adopted.

New technologies often raise new issues for the environment, public health, etc. When broad public issues are take, governments should engage civil society in a dialogue to discuss these issues and their implications. A participatory approach is needed to involve the public in identifying desired outcomes and assessing tradeoffs. Taking their views into account is crucial to securing their support.

The case studies

Seven case studies were presented and discussed in the working group. The group included people from academia, scientific research institutes and economists. The main focus of discussions was on how to boost the capacity of institutions to evaluate the implications of new technologies and to decide where they should be focussing scarce resources across research, education and training.

The case study from the United States reported on a comprehensive study that characterises the extent of adoption of nutrient, pest, soil, and water-management practices and assesses the factors that have influenced adoption across diverse regions. The project entailed the administration of a detailed field-level survey to farmers in 12 .S. watersheds which gathered data on agricultural practices, input use, and natural resource characteristics associated with farming activities. These data were then analysed by the Economic Research Service (ERS) using a consistent methodological approach. Among the key findings were that: education has a significantly positive effect on the adoption of information-intensive technologies; the increasing complexity of emerging technologies is a factor that needs to be considered by agencies or technology providers when targeting potential adopters; and technical assistance, demonstration, or consulting services may be necessary to promote adoption of certain preferred practices. However, from a policy perspective, some of the results obtained can be misleading. The unified modelling approach used by the ERS shows that important information can be "lost" in the process of aggregation. For example, adoption incentives developed to address factors identified in the aggregate model may be appropriate for only one area and counterproductive for all others.

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The case study from Switzerland discussed the steps leading up to the development of a new national strategy that considers more widely the principles of sustainability and market demands. The study describes how it developed from the idea of integrated pest management and evolved into a national program for whole-farm environmental management. Implementation was accelerated by the shift to a new system of direct payments that are targeted at environmental outcomes. The roles of research, extension and the instruments of agricultural policy are described. In addition, some examples of the adoption of environmental friendly production techniques are presented. The program has already shown some positive effects on total use of mineral fertilisers and pesticides, as well as on the area of semi-natural habitats on farmland dedicated to the conservation of biodiversity. The study concludes with reflections about the need to differentiate the standards for farming activities according to regional environmental goals and to enhance international co-operation.

The European Commission reported on the implementation of its Fifth Research Framework Programme, which forms an integral part of its strategy to support more-sustainable agriculture. The Commission is today taking a multidisciplinary approach to research and is requiring that funded research projects respond to criteria that are oriented more towards quick implementation of results, especially those that help achieve Community socio-economic objectives (*e.g.* employment creation, competition). Programmes at the European Community level add value through the creation of multinational and trans-frontier partnerships, including those with countries associated with the EU or in the course of EU-accession, and through the possibilities they create for collaboration at international, Community, national and regional levels. The annual evaluation of the implementation of the programme of work by groups of independent high-level experts allows the programme to evolve and adapt in such a way that it can respond quickly to changing priorities.

The case study from Poland described the changes that have taken place since 1989. In addition to experiencing major structural change, Polish agriculture is also beginning to promote organic agriculture and various agri-environmental programmes.

The case study from Japan (also presented in Working Group I) examined the role of public and private institutions, their possible relationships with other relevant factors, including labour-saving technological developments, and major impediments with respect to the development and adoption of an environmentally-benign practices. Municipal governments have played a significant role in promoting initiatives to enhance the environmental benefits of agriculture. The case study shows that institutions enabling co-ordinated action at the local level may be needed in order to obtain the desired outcomes from new technologies — especially those, like organic pest control, that require high local rates of adoption to be effective.

The case study from Turkey described some of the challenges currently facing Turkish agriculture. The country hopes to increase the adoption rate of technologies for more sustainable farming systems, but because the country's inheritance laws perpetuate the existence of small and fragmented farms, most farmers can neither afford nor apply many of the technologies and practices that are needed.

Climate change and the world response to emissions of greenhouse gases (GHG) was the topic of the case study from Canada. Getting broadly based buy-in from the public at large is a major challenge faced by all governments that are signatories to Annex 1 of the Kyoto Protocol. The case study explained the Canadian approach to developing a strategy for the agricultural sector as a component of a comprehensive national strategy. Given the need to change behaviour throughout the industry, a broad-based consultative process was employed to lend legitimacy to the process. The highlights of this process were discussed, recognising that many uncertainties (scientific and policy) remain that must be addressed prior to being able to win broad-based support. For example, it must

still be demonstrated that technological change at the farm level can eventually lead to achieving national GHG-reduction targets. Many potential win-win type solutions were identified which have encouraged continued stakeholder participation in the process. Development of a national policy to address climate change is still a work-in-progress that will require the active involvement of all components of the agri-food system. It will also require great flexibility and adaptation on the part of Canadian institutions which must link internally as well as externally to institutions working on the same issue.

Discussion

Links between institutional arrangements

- Synergies between institutional players and tools is vital; key players must work together. Achievement of desired technology modification and behavioural change requires support from the public, industry, research community, extension services, etc. In Switzerland, for example, several levers were used to shift behaviour toward adoption of more-sustainable farming technologies.
- Existing institutions often take too narrow a perspective on issues relating to technology, typically focussing on a particular issue or sector. Mechanisms need to be developed to ensure that the broader public interest is taken into account. This also applies to research, which needs to evolve beyond a reductionist approach to also consider a broader systems approach.
- Some environmental problems are highly localised, but require collective action. Such collective action may necessitate involving community-based groups. One important tool at their disposal is peer pressure.

Data / indicators / information

- Institutional analytical capacity is needed to provide policy-makers with information on the costs and benefits of various policy and technological options. For example, we need to get better at conducting *ex-ante* analysis of the risks of particular technologies. That capacity has declined in many countries in recent years at the same time that the rate of technological development, and the need to undertake new investments, is increasing.
- Integrated, multi-disciplinary analysis is needed to understand the biophysical, social and economic implications of technologies and their trade-offs. Comprehensive information packages need to be put forward to decision-makers.
- Information, such as that provided by indicators and model-based analyses, are needed to guide policy design and determine whether technologies are being adopted as expected, and whether desired outcomes are being achieved. Governments need to ensure access to detailed data, while at the same time respecting the rights of those who supply the data to confidentiality.
- We need to better understand who pays and who benefits from new technologies and systems, and take such information into account in the policy-making process.

Barriers to uptake

- Advisory support to farmers wishing to adopt new technologies and systems is key; if lacking, adoption rates will suffer.
- Farmer education and management expertise are also key, especially as agriculture continues to shift to more-sophisticated systems and technologies. There is a considerable potential to better utilise new technologies for disseminating information to farmers and in general influencing the adoption of more-sustainable technologies.
- Farm structure matters. It can present both barriers to and opportunities for the adoption of technologies, especially where technologies exhibit economies or diseconomies of scale.
- Inertia, and resistance to change due to risk and uncertainty, are factors that have to be managed. There is a need to build public and industry awareness and support on the need for change, and on the changes to be made.
- Finally, we need to bear in mind that the best technology is not always a new technology. There are many examples of old technologies that remain relevant to addressing today's challenges. Often, modern science can be enlisted to help fine-tune old technologies (such as crop rotation) in ways that enhance their contribution to sustainability.

How governments have influenced adoption

The papers demonstrated that governments have used a wide variety of measures to influence the uptake of environmentally-sound farming technologies, including:

- research;
- extension;
- cross-compliance measures;
- education and awareness, information dissemination; and
- engaging the public through consultation mechanisms.

As disucssed in the paper by Joyce Tait, environmental regulations are also (increasingly) influencing technology development and adoption. At the same time, policies and programmes may need to be better targeted at those regions or clients that are in need of priority attention and better tailored to their requirements. At the international level, there is a need to consider both the spill-over effects on other countries and the broader international outcomes of national approaches to agricultural technologies. Government resources may need to be increased if the capacity to assess impacts is not sufficient to keep up with technological developments.