Background Paper 5

Research and Technology

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Research and Technology and the Multifunctional Character of Agriculture and Land. Background Paper 5: Research and Technology.

INTRODUCTION

The primary role of agricultural research is to heighten knowledge and improve technology. It heightens understanding of the interactions and interdependence between production systems and farming communities. This requires a holistic and interdisciplinary approach to problem identification, analysis and solution-finding. This paper examines the relationship between the multifunctional character of agriculture and land (MFCAL) and research. In particular, it explores the extent to which an awareness of one can strengthen the other. The discussion focuses on both conceptual issues and concrete examples. Evidence is provided by a review of a number of activities of International Agricultural Research Centers (IARCs) and members of the Consultative Group on International Agricultural Research, henceforth the CGIAR system in general. The CGIAR System furnishes an excellent example of the relationship between MFCAL and research. It was established in 1971 to support productivity-oriented research, in response to food needs of near-famine proportions in the South. The research objectives, partnerships, and institutional structure of the CGIAR have evolved over time, in keeping with the challenges confronted by the world's poor and disadvantaged. Today, productivity improvement and natural resource management are the twin pillars of CGIAR research on food crops, conservation of genetic resources (biodiversity), forestry and agroforestry, livestock management, aquatic resources, soil and water nutrients, water management, and agriculture-related policies, as well as in its endeavours to strengthen scientific capacity in developing countries.[71]

THE MFCAL APPROACH

The paper draws heavily from the so-called MFCAL Approach. This is a descriptive framework that captures the multifunctional character of agriculture and land. The approach recognises that the first and foremost role of agriculture remains the production of food. It stresses however, that agriculture and related land use activity can also deliver a wide range of non-food goods and services, influence the natural resource system, shape social and cultural systems and can contribute significantly to economic growth. The approach also focuses on the trade-offs and synergies that can exist between these different functions.

The first dimension of the multifunctional character of agriculture and related land use concerns food production and the contribution that this makes to food security. Food security has been defined by FAO as a situation in which all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. There are three dimensions implicit in this definition: availability, stability and access. Adequate food availability means that, on average, sufficient food supplies should be available to meet consumption needs. Stability refers to minimising the probability that, in difficult years or seasons, food consumption might fall below consumption requirements. Access to food draws attention to the fact that, even with bountiful supplies, many people still go hungry because they are poor and unable to produce or purchase the food they need. In addition if food needs are met through exploiting

[71] CGIAR, 1998. *Third System Review of the Consultative Group on International Agricultural Research (CGIAR)*. October 8, 1998. Washington DC: CGIAR System Review Secretariat

non-renewable natural resources or degrading the environment there is no guarantee of food security in the longer-term.

Current concerns for food security stem from both the unacceptability of current levels of food insecure people (at least 800million people) and the recognition that agriculture will have to feed an increasing human population, forecast to reach 8 000 million by 2020, of whom 6 700 million will be in developing countries. In most developing countries, the majority of the poor live in rural areas and depend on agriculture for their livelihoods. Expanding food production to feed this increasing population, while alleviating poverty through gainful employment in agriculture, is a formidable challenge.

In addition to food production and the vital contribution that it makes to food security, the MFCAL Approach recognises three further broad functions 1) environmental 2) economic 3) social.

The Environmental Function. Agriculture and related land use can have beneficial or harmful effects on the environment. The MFCAL approach can help to identify opportunities to optimise the linkages between agriculture and the biological and physical properties of the natural environment. The environmental function of the MFCAL Approach is relevant to a number of critical global environmental problems including biodiversity, climate change, desertification, water quality and availability, and pollution.

The Economic Function. Agriculture remains a principal force in sustaining the operation and growth of the whole economy, even in highly industrialised countries. Valuation of the various economic functions requires assessment of short, medium and long-term benefits. Important determinants of the economic function include the complexity and maturity of market development and the level of institutional development.

The Social Function. Both the maintenance and continuing dynamism of rural communities are basic to sustaining agro-ecology and improving the quality of life (and indeed, to assuring the very survival) of rural residents, particularly of the young. On another level, the capitalisation of local knowledge and the forging of relationships between local and external sources of expertise, information and advice are fundamental to the future of existing rural communities. Social viability includes maintenance of cultural heritage: for we know that in many instances, societies still identify strongly with their historical origins in agrarian communities and rural lifestyles.

APPLYING THE MFCAL APPROACH TO THE WORK OF THE IARCS

For the purposes of this discussion, research at IARCs is divided into four broad themes: food security, natural resource management, institutional strengthening and socioeconomics (alternative for this term) and policy. There are complex and interdependent links between these themes, which all contribute towards the primary goal of food security and poverty alleviation in developing countries.

Food Security

Although the rate of population growth is decreasing steadily, the increase in absolute numbers of people to be fed may be such that the carrying capacity of agricultural lands could soon be reached given current technology. Research can contribute to long-term food security through both the transfer of new and improved technology to farmers and by finding ways of helping increase household income and purchasing power. Similarly, the capacity of farmers to manage risks can be improved by the diversification of household incomes and the evaluation of alternative investment opportunities in terms of both security and potential financial return. Nonetheless, agriculture will continue to provide the main income stream

and source of livelihoods to the majority of the rural poor throughout the developing world. Importantly however, agricultural income streams are both seasonal and variable. Long-term food security therefore requires, in part, that productive resources are shifted from good years to bad ones, or from locations of surplus to those of deficit. There can be little doubt then, that food security remains a basic foundation of any process of substantial long-term poverty alleviation and ultimately, political stability.

At the national level, food security policies frequently include initiatives directed at raising the level of self-sufficiency through domestic production and storage, promoting farmer education and training, encouraging decentralised food production as a safeguard against crop failure, and taking measures to counteract degradation of the natural resource base. Natural disasters such as drought and disease outbreaks, political instability and wars disrupt normal means of food supply to create emergencies, which may require immediate government intervention.

IARCs are well placed to address the twin issues of food security and poverty alleviation through their primary emphasis on productivity-oriented and natural resource management research. Technologies put into the hands of farmers by the IARCs in collaboration with National Agricultural Research and Extension Systems (NARES) include new improved varieties, quality seed, farm-level machinery and equipment, as well as knowledge and skills in natural resource management. Many of the new technologies often demand additional farmer education and extension effort to ensure effective use. Partnerships have therefore been formed with farmers in a participatory approach to research. These have targeted research more accurately to the needs of farming communities. Besides working with farmers, the CGIAR has entered into partnerships with Non-Government Organisations (NGOs), NARES, Advanced Research Institutes (ARIs) and the private sector in tackling the global problem of food security through joint efforts.

Natural Resource Management

The capacity of agriculture to continue providing food for rural and urban populations must be balanced with the capability of the land. Here, agriculture has an important role in protecting and improving natural resources (i.e., the land users' resource base) and the environment in such as way as to ensure the preservation of natural capital and to foster sustainable development.

Pressure on land leads to exploitation and degradation of natural resources. Land users frequently lack both the technology and the financial resources to apply sound appropriate land-management practices and to invest in effective resource maintenance and enhancement. (This is further exacerbated when farmers lack secure use or ownership rights of the land resources they use). As a result, agricultural activity, especially in marginal areas, frequently leads to the unsustainable over-exploitation of land resources. Stated simply, land users are often forced into this situation in order to ensure minimum daily needs and basic household livelihoods. Clearly, increasing population and concomitant consumption growth accentuates these pressures, particularly in fragile and marginal land areas. In instances in which no suitable alternatives are developed and applied, degradation of natural resources can quickly extend beyond recoverable thresholds.

Agricultural production frequently fails to match the needs and expectations of land users. In these cases, production and/or income alternatives have to be developed in order to safeguard the future development and well being of rural regions and their people. Solutions may also lie in non-conventional and/or non-agricultural use of land resources. The maintenance and, where possible, the enhancement of the natural resource base is one of the principal goals of research in the CGIAR System. Effective solutions to these and related problems will have to sensitive to the trade-offs between different goals and objectives. How

for example, does one balance the demands of household food security with those of good environmental management? Similarly, questions of scale and time are important, raising issues such as the varied impact of practices through space (such as up-stream and down-stream impacts in a river system) and likewise, the balance between short and long-term needs and effects.

In many parts of the developing world, resource-poor farmers are both the causes and victims of inappropriate land-use practices. This can lead to a vicious cycle of degradation and natural resource depletion. Effective research can help to break this sequence. In the final instance, research should lead to solutions that benefit both producers and the environment. It is clear than, that effective research across a wide range of different ecosystems requires an adequate understanding of their characteristics and multifunctional character. Knowledge of the socio-economic and biophysical processes which govern resource husbandry (i.e., depletion and enhancement of the natural and human resources) is critical for developing sustainable land-use practices which both improve the livelihood of the rural population and ensure appropriate use of natural resources.

Individual land use scenarios and the most applicable management practices are location-specific within a larger environment. International research institutions cannot be everywhere. They must work on a generic level, developing research mechanisms to permit the extrapolation and adaptation of technologies and methods to other regions. This means research scenarios have to be representative of other, larger areas with similar characteristics. The multi-scale characterisation of agro-eco-regions and their multifunctional particularities is therefore of great importance for appropriate natural resources management.

Effective agricultural research must be people-centred. If research in natural resource management is to contribute to development, the land users must play a central role. Instead, there is a tendency for researchers to perceive problems in their terms and to develop strategic solutions from their own point of view. This can often lead to an incongruence between real-world problems and research-based solutions. Instead, it should be recognised that, the conditions prevailing at the land-user level set the limits for, and the pace of the adoption of improved and more appropriate technologies. It is for this reason that land users are the focus for a substantial part of research throughout the CGIAR System. Indeed, recent experience shows that farmer participation leads to significant improvements in terms of both the suitability and effectiveness of research solutions, leading to benefits for both rural households and the natural resource base.

The challenge facing both the CGIAR System, and researchers in general, is to identify viable alternatives that deliver improvements in terms of production, economic and social benefits and land management so as to satisfy the competing demands of both rural livelihood improvement and sustainable natural resource use.

Sustainable agricultural productivity is not only dependent on the direct management of the natural resources. It also requires appropriate enabling environments in terms of both general socio-economic conditions and a supportive policy matrix. Enabling environments include the incentives that encourage producers to invest in the strategies necessary for improved land use. Domestic policies for example, may provide direct support to initiatives that deliver positive benefits to the environment. Similarly, functioning local markets will allow producers to benefit from increased production surpluses resulting from new agricultural practices. Indeed, it is widely recognised that access to factor input (finance, equipment, natural resources) and factor output markets is a decisive factor shaping the viability of new innovations. Secure and reliable access to necessary land resources for example, coupled with suitable marketing and adequate rural infrastructure all encourage land users to invest and care for their land. In such enabling environments, improved

technologies developed through research will become more effective. When these conditions exist, research can help develop better production technologies and ways to optimise the management of natural resources for improved and more sustainable land productivity and environmental sustainability.

Sound agricultural practices not only involve better economic use of resources but also foster environmental protection. Downstream effects of, for example, increased water use, soil erosion, nutrient translocation and pesticide emissions are usually of national concern and of little interest to individual land users. Decreasing environmental hazards and building environmental resilience are overriding objectives at sub-regional (e.g., watershed), regional and national levels.

Socio-economic Conditions and Policy

The multifunctional character of agriculture and land refers to the full range of goods and services resulting from agricultural activity and related land-use. The meaningful deployment of the MFCAL Approach into the decision and policy-making processes is therefore contingent on both the development of effective valuation tools and the understanding of the factors that influence the generation of these goods and services in specific contexts. These may include international as well as national public goods and services. Carbon sequestration through improved crop and soil management practices, provides an example of an international public good whilst increasing employment opportunities and improved health are best viewed as national (or sub-national) public goods. Sustainable rural livelihoods and poverty reduction are common goals throughout the world. Clearly, the relative value and importance of these objectives varies through time and space, and even within countries themselves. Individual sectors within a single country for example, will benefit differently from improvements in rural livelihoods (and indeed, some sectors may decline as a result of these changes). Likewise, the value of these public goods may vary between urban and rural areas. Similarly, the relative importance attached to these goals in terms of overall policy priorities varies between developed and developing countries and between rural and largely rural societies. Research undertaken in the IARCs on issues including socio-economic conditions and processes and the policy-making process in general contribute to understanding the nature and significance of these differential valuations and can contribute to the eventual production of an improved and more effective mix of the goods and services that constitute the multifunctional character of agriculture and land. Several key issues for this type of research and its links with the multifunctional character are examined below.

Continuing this logic, it is clear that for most agricultural producers, the primary objective of agricultural activity is food production, for either domestic consumption or for sale in the marketplace. Socio-economic and policy research, guided by recognition of the multifunctional character of agriculture and land, examines how the mix of agricultural goods and services produced affect food security, the welfare of producers, sustainability of natural resources utilisation and the environment. Natural resources and environmental degradation have costs in terms of human health, pollution, and loss of natural habitats. The decisions producers make in choosing certain agricultural practices depend on the incentives and opportunities provided by markets and government policies. Socio-economic research sheds light through empirical studies on the effects of agricultural production systems on these negative externalities. Recently, bio-economic models have been used at community levels in assessing the complex interactions between population, agricultural practices, rural income, natural resources use, migration, and government policies. However, more work is needed particularly on assessing the impact of policies and consequent agricultural practices on the positive externalities of agriculture. Both macro- and micro-level studies are needed to answer questions at different levels of scale.

A range of methods are recognised for assessing the value of the goods and services that are produced by agriculture but not traded in the market.[72] Owing however, to the perceived limitations of these valuation methods and their limited application in developing countries, the contribution of agriculture on the non-income functions may be underestimated. This can lead to policy distortions. Likewise, the impact of agricultural technology on non-food benefits of agriculture is inadequately understood. The MFCAL Approach encourages the application of valuation methods to account for wide-ranging multiple functions of agriculture. Socio-economic and policy research of the CGIAR System contributes to understanding the impact of agricultural technology on these multiple functions.

A key function of agriculture refers to the contribution it makes towards poverty reduction. Similarly, the fight against poverty is the overriding goal of the CGIAR System. and is a cornerstone of the individual missions statements of all the constituent centres. The CGIAR centres aim to achieve this goal mainly through increased and sustained agricultural productivity, and an improved socio-economic and policy environment. In many ways, the Green Revolution attests to the record of the CGIAR in this regard.. But, in spite of this and similar successes, poverty remains prevalent throughout most rural areas in developing countries. Nonetheless, poverty is a complex problem and likewise, understanding of its causes and effects is evolving continually within development and research communities. There is little doubt however, that agriculture remains an important element in poverty reduction in rural areas throughout many parts of the world. Socio-economic research can lead to improved understanding of the role of agricultural research in poverty alleviation. The effects can be direct (in the case of improved nutrition and calorie intake) or indirect (through price effects and labour market) and are influenced by many factors. The first step in poverty alleviation is to understand the constraints and opportunities of the poor. Future socioeconomic research will deepen our understanding of the different dimensions of poverty and improve the efficacy of agricultural research in alleviating poverty.

Traditional agricultural research and extension approaches will not meet the needs of rural communities. Particularly in the less favoured environments, where agriculture is practised in difficult terrain, marginal soils and variable weather conditions, farmers have used indigenous knowledge and local skills over many centuries to develop ways to survive in these difficult environments. However, their production systems and the local institutional arrangements that govern the management of their natural resources are threatened by socio-economic changes. Development of sustainable production systems and rational use of natural resources and the environment therefore calls for a new research and extension approach with the participation of local communities. The MFCAL Approach illuminates many of the key issues that are important to both communities and the environment and provides a useful descriptive framework for their assessment.

Social scientists at the IARCs, in collaboration with biophysical scientists, are building new partnerships with producers, land users, NGOs, and NARES of the developing countries and advanced institutions. These partnerships will implement farmer participatory research involving producers as active partners rather than as mere recipients of information. This approach is expected to empower farmers with knowledge and skills that enable them to experiment with different options and choose those best for them. The CGIAR System's participatory research initiatives offer new opportunities for technology development and dissemination, helps to re-examine the roles of research, of extension and of producers, and

[72] There are 5 commonly recognised valuation techniques. These are: 1) direct use values (which include contingent valuation and hedonic pricing techniques) 2) indirect use values (which include techniques focusing on: foregone earnings; opportunity costs; preventative expenditure; replacement costs and; shadow inertia 3) option values 4) existence values and 5) bequest values. Of these 5 types of values, only direct and indirect use values are amenable to smooth monetisation. These methods are applied in the industrialised countries to many natural resources and agricultural situations, but less so in the developing countries. These valuation methods do not provide definitive measures. They all rely upon some degree of proxy measurement.

helps to assess the impact of technology on the multiple functions of agriculture. For example, participatory poverty assessment is a powerful tool giving deeper and comprehensive understanding of poverty. However, this new approach is still in its infancy and its impact has to be fully evaluated.

An important element of the socio-economic research carried out by the centres concerns the evaluation of the impact of technology on agricultural systems and rural livelihoods. In the past, this focused mainly on the economic impact. Evaluation of the impact of agricultural technology on the other functions of agriculture such as food security, poverty alleviation, environmental husbandry (e.g. desertification, carbon sequestration), sustainability of local communities, and an array of other functions is still to be investigated fully. In spite of methodological problems, the impact of technology on these other functions has to be evaluated if the MFCAL has to be fully understood. The CGIAR centres' policy research contributes to evaluating policy options with differing impacts on the different functions of agriculture.

Institutional Strengthening

Addressing the multifunctional character of agriculture requires a multi-partnership approach, which forges active relationships among national and international research centres and other players in the development process, including government departments, NGOs and the private sector. It is important that multiple actors work together and contribute their respective comparative advantages in knowledge, skills and experiences, since no single organisation can educate and empower farmers to make changes that can fulfil the multifunctional character of agriculture. Moreover, since the capacity of institutions varies from country to country, a complementary mix of institutions may seem a better way to effect change.

Intensive collaboration and networking with NARES is crucial to adapting the generic research outputs of IARCs to local conditions. Where NARES do not have the full capacity to do this, institutional capacity building is an important tool to encourage and enhance appropriate adaptive research. This applies particularly to the importance NARES attach to the role the land users themselves have in research.

IARCs endeavour to strengthen local capacity through training, technology transfer, information exchange and helping to influence policy reform. Many national programs in developing countries do not have the capacity to provide technologies suited to local needs due to a lack of trained persons, weak institutional arrangements and limited research and extension capabilities. There is a consequent need for assistance to be provided from outside. Over the past three decades IARCs have been found to be well suited to provide much of that assistance in the following ways:

- Collaborative research efforts between IARCs and NARS focused on problems that are best solved through joint research. International centres have scientific expertise, modern equipment and research methodology for tackling researchable issues in countries of their mandate regions. These countries provide testing ground for research outputs or technologies and through cooperative efforts gradually develop their own capabilities for independent research.
- Short-term professional training at country and regional levels for thousands of NARS staff. Sustainable agriculture approaches will not develop unless communities and institutions themselves develop through education and training.
- Longer-term degree training and research experience for more senior staff from national programs.

- Wide information dissemination through reports, and advisory services to farming communities, and to policy makers responsible for spreading knowledge and progress.
- Technical networks for exchanging insights and experience.
- Decentralised research and management through outreach programs that are focused on location-specific realities and needs.

The collaboration between IARCs and national programs have enabled more effective on-farm research, field demonstrations and training, which together could contribute to a better understanding of the multifunctional nature of agriculture and its impact on economic growth, food security and poverty alleviation in developing countries.

TECHNOLOGIES THAT ENHANCE THE SYNERGIES IN MFCAL

Available technologies

Over the past decades, research of the IARCs has contributed significantly to the development and improvement of methodologies and technologies that have helped to facilitate the improvement and increase of agricultural production.

More recently for example, issues relating to the environmentally appropriate utilisation of the land resources and the sustainability of land use systems attract more attention. This is of special relevance to marginal areas, where carrying capacities of the land are low and production risks for the land users are high. In these areas, the multifunctional character of agriculture and land is of especially high importance. The value of land should not only be measured in terms of its agricultural productivity and output: . the role it plays in maintaining the overall environmental stability of regions, and other possible economic potentials should also be considered.

The impact of new technologies and methodologies on land use practices has been considerable. Indeed, a short review of some of the results of the IARC activity demonstrates the depth of this impact, especially in the developing world.

Socioeconomics The socio-economic research of the CGIAR has contributed to the agricultural development of the developing countries is the following aspects: (i) developed, through diagnostic studies, better understanding of the conditions under which small poor farmers in the developing countries make decisions; (ii) assessed the acceptability of new technologies and their impact; (iii) supported researchers in developing appropriate technologies that target the needs of poor farmers, (iv) assessed the impact of government policies on technology adoption and food security. The contribution of the social sciences to the training of NARS' scientists over the last decades is also substantial. Nonetheless, it is clear that the multifunctional character of agriculture and land embraces issues far beyond that which has been covered by the social science research of the CGIAR Centres. These include for example, the determination of conditions under which different options that promote the production of different goods and services that agriculture produces are adopted; and the evaluation of the trade-offs that are inherent in choosing different options for agricultural land use, the assessment of poverty, and the evaluation of the non-market functions of agriculture. Social science research will help in understanding of the legal, cultural and economic interactions that may enhance synergies in MFCAL.

Agroforestry In many areas of the developing world, agroforestry systems have helped improve the protective cover of the soil against erosion; the trees and shrubs have supplied animal feed and fuel wood. Increased production of organic matter has improved soil quality and the introduction of agroforestry species has increased biodiversity on the farms.

Crop rotation and intercropping Improved crop rotation and intercropping systems have shown an important positive effect on soil fertility. This has contributed to a stabilisation and also increase of agricultural production. Organic matter build-up in the soils provides resilience against degradation.

Urban and peri-urban agriculture With increasing expansion or urban centres, urban and peri-urban agriculture will gain more and more importance and provide excellent opportunities for profitable agricultural production. A multitude of technologies are being applied in peri-urban and urban agriculture that enhance the synergies associated with the multifunctional character of agriculture and land. Intensive recycling of organic matter and the application of organic wastes contribute to the build-up of soil fertility. Excellent opportunities for income generation from agriculture also encourage the land users to invest in land to maintain its production potential and value.

As a result of increasing marketing opportunities for 'healthy products' in the urban centres, the use of 'ecological' methods of agriculture are being encouraged. This will show a positive environmental effect and enhance the awareness for environmental conservation of the environment.

Conservation-farming methodologies for sloping lands With increasing land scarcity, more sloping areas are being farmed in regions where no traditional steepland agriculture has been developed. These areas are under severe threat of degradation. 'Sloping agricultural land technologies' (SALT) provide options for the safe utilisation of these steep areas. Physical (e.g., terracing) and biological (e.g. hedgerows) stabilisation techniques create permanent fields for annual and perennial crops. Forest plantations provide fuel and timber and secondary forest products, such as fruits and wildlife. The principles of SALT technologies are universal but require very site-specific adaptations.

Required Areas of Technological Development and Innovation

Crop-livestock interactions Appropriate technologies are needed which enhance the integration of livestock with crop production. Especially for the arid and semiarid rangelands, livestock husbandry technologies need to be developed which are less detrimental to the environment. Solutions need be developed which mitigate the negative effects of livestock (over)grazing on vegetation and soil, and which restore or improve land productivity. Adjustment of the animal numbers to the carrying capacity and development of alternative feed resources are the most important needs. For rangeland already seriously degraded, it is often necessary to develop new and simple revegetation technologies which can be implemented by the land users without the need for costly government intervention.

Characterisation of land and land use Improved and user-friendly agroecological characterisation tools are required to identify and locate land-use 'hot spot' areas that are of concern for agricultural development. There is a need to identify potential land suitabilities and limitations for land-use and general levels of carrying capacities of different areas. The selection of 'representative' areas will enable technologies developed in certain areas to be transferred (extrapolated) to other areas with a minimum of modification. Areas and their limitations are not only characterised by their biophysical environment, but also by their socio-economic settings and societal context. In conjunction with geographical information systems (GIS), maps of technology development needs will need to be developed.

Information and communication The complexity of agricultural land use demands more comprehensive, accessible and user-friendly information and communication channels. Adoption of better technology at the farm level is often hindered by the failure of efficient communication between the different parties involved. The need for better integration and interdisciplinary action requires access to structured and useful information at various levels.

The information requirements of the land user, the policy maker and the researcher are different and so are their means to access this information. A comprehensive information platform and management system is required which permits information storage and flow in a transparent and consistent fashion.

In addition to modern digital databases accessible for example, through the Internet, traditional agricultural extension work will continue to provide an important link to ensure that the appropriate information reaches land users (although this type of activity may perhaps be increasingly augmented by new internet-based information technologies)..

MFCAL-RELATED RESEARCH ACTIVITIES AT IARCS

The following tables outlines a series of examples of research projects on five research themes that all refer directly to the multifunctional character of agriculture and land: 1) Broaden the genetic base of crops and secure agricultural biodiversity; 2) Characterising the environment to help identify priority areas; 3) Development of analysis and assessment tools for the evaluation of sustainability; 4) Development of technologies for appropriate management of crop and land resources and; 5) Integrating the socio-economic and biophysical contents of natural resources management.

Research Theme 1 Broaden the genetic base of crops and secure agricultural biodiversity

Examples of research projects	**Expected results and impacts**
The scientific basis of in situ conservation (IPGRI) A major *in situ* conservation project is being carried out in nine countries (Burkina Faso, Ethiopia, Hungary, Mexico, Morocco, Nepal, Peru, Turkey and Vietnam). It is designed to improve our understanding of the effects on the genetic diversity of local cultivar populations over time of farmer decision-making, agroecosystem dynamics, plant population structure and breeding systems.	Generate a matrix of environmental, socio-economic, ethnobotanic, agromorphological and genetic data that can be analysed to help determine key or limiting factors to changes in genetic diversity over time.
Multi-purpose sorghum (IPGRI) Activities in Sub-Saharan Africa have involved the promotion of the conservation and sustainable use of many multi-purpose crops. Sorghum, for example, is one of the most popular cereals in the savannah zone of West and Central Africa. While improved cultivars of this crop are available, research has shown that many African farmers conserve the taller local landraces because they grow sorghum not only for the grain, but also for the stalk, which is used for many purposes, including building shelters, making fences, weaving mats, etc.	Better farmer adoption of improved crop varieties
Under-utilised plant species (IPGRI) Throughout the Asia and Pacific region, collaboration with local and regional partners is promoted in activities on under-utilised crops and tropical fruit, particularly species that are important for food, nutrition, fodder, oil and other industrial uses. These are generally crops in which national programs may not have enough expertise to achieve comprehensive conservation and effective use. The genetic diversity is assessed and complementary conservation methods are developed. Typical crops include buckwheat, sesame, safflower, rambutan, litchi, mangosteen and durian. Many of these genetic resources are important as food staples (e.g., buckwheat), sources of income (e.g., sesame for oil production), nutritional components (e.g., tropical fruits) and medicinal crops (e.g., safflower). The extent of genetic diversity and genetic erosion in several tropical fruits is investigated, including wild species, which are valuable for multi-purposes.	Meeting the need of local communities for food, nutrition, fodder, timber and fuel, and contribute also to environmental conservation
Enhancing the utilisation of coconut (IPGRI) Several projects are	Derive greater value and enhance the

implemented which seek to develop conservation and use strategies for important industrial cash crops, which are important to smallholder farmers throughout the tropical world. These include bamboo and rattan, cacao, coffee, bananas and coconut. The species involved contribute not only to the alleviation of poverty, but also to protection of the environment, often being grown in small plots in marginal areas such as hillsides and coastal zones and in conjunction with other crops. Most of these species have multiple uses, which helps to conserve diversity of landraces prized for different qualities. Coconut, for example, is used not only as food, but also as a source of oil, building material, basketry, fibre, beverage, soap, dyes and medicine. However, with increasing socio-economic and environmental pressures on small scale traditional farming systems, the competitiveness of coconut with other commodities is rapidly being lost at the farm level.	genetic bases for multiple uses of coconut. Socio-economic and participatory research tools will be identified to develop appropriate strategies for coconut germplasm conservation and use by farmers.
Agrobiodiversity (CIAT) Narrow genetic base, due to domestication events and intensive breeding, is a major problem in most crops. The identification, characterisation and use of new sources of genetic variability for economic traits like yield and quality are key steps towards broadening the genetic bases of crops. Wild species and other alien sources constitute a rich reservoir of variability whose exploration has only now become possible. Transfer of agronomic traits such as disease and insect resistances from *Phaseolus* species like tepary and runner beans has been achieved through interspecific hybridization with common bean commercial varieties aided by embryo rescue - *in vitro* culture techniques.	Increased yield potential by means of genetic transformation using viral-derived cloned genes.
Seed Security ICARDA) As a key element of both food security and genetic conservation in risk-prone areas, seed security is an important research agenda at ICARDA. With support from USDA, information has been collected from Ethiopia, Yemen, Sudan and Eritrea from which strategies have been developed for areas prone to natural disasters, particularly that of drought. Participation in the global dialogue on seed security for food security is also important.	Wider use and application of published results and guidelines in many countries prone to natural disasters and seed insecurity.
Seed systems and biodiversity (ICRISAT) A main constraint to the adoption of improved varieties of crops of the SAT farmers is the limited private-sector interest in commercial seed production for these crops, because they have low market value and trade volume. As a result seed distribution tends to be carried out on an ad hoc and sporadic basis. Hence, the objective is to identify more sustainable mechanisms for seed supply of new varieties, through work with seed companies, NGOs and NARS. The analysis of varietal diversity impacts will offer a preliminary assessment of gains to efforts to maintain such biodiversity, and help understand what motivates farmers to adopt, or not to adopt new varieties. Other activities help NARS to collect, conserve and document land races and evaluate them for their value.	Alternative seed supply strategies and recommendations for improvement of existing ones. Effective understanding and utilisation of landraces and improved varieties

Research Theme 2 Characterising environments to help identify priority areas

Examples of research projects	Expected results and inputs
Land Use (CIAT) A new database has been developed for Central America with environmental and socio-economic indicators. This database holds information that can be input into six categories of land-use models. Analyses of environmental patterns and processes were completed in the Colombian savannahs benchmark site. Biomass analysis of gallery forests for the Yucao watershed allows calculating regional-level changes in carbon stocks under different scenarios of future land use. The natural dynamics and current uses of gallery forests were assessed. Possible threats from land-use intensification were identified. Land use analysis in Puerto Lopez municipality will aid future planning of land-use changes.	Several indicators of poverty were derived from unit-level census data, at household and village scales, and presented graphically. These scales allow for a comparison and a contrast of the level of poverty spatially among villages. Improved geographic poverty targeting aids decision-makers in prioritising projects and assigning funds appropriately in Honduras.
Development of a methodology to identify suitable water-harvesting sites (ICARDA) A methodology is being developed to identify suitable water-harvesting sites using remotely sensed (RS) data and geographic information systems (GIS). The project is being implemented in a typical dryland steppe region of Syria. Satellite image scenes are being used together with layers of information on topography, soils and rainfall in a GIS map to produce a classification of the various conditions associated with water harvesting. A set of expert criteria was developed and will be applied to produce a suitability classification for water-harvesting technologies.	The methodology will save substantial amount of effort required for conventional terrestrial methods of suitability assessment and for planning large-scale water-harvesting projects in other dry areas
Multiscale land use systems analysis (ICRISAT) To incorporate existing variability in agroecological and socio-economic conditions in evaluating options for agricultural development in West Africa, an interactive approach to land use planning dubbed "Multiscale Land Use Systems Analysis (MLUSA)" is applied. The approach covers scales of household, village and district, and provides a framework to integrate past research results. The components and functioning of land use systems are analysed in six steps to provide land use options at different levels of aggregation that are relevant to both farmers and policy makers. The steps are *(i)* goal setting, *(ii)* multiscale characterisation, *(iii)* selected research, *(iv)* scenario analysis, *(v)* evaluation of technologies and interventions, and *(vi)* monitoring of progress. The method is applied in collaboration with NARS, NGOs and village farmers in two semi-arid key-sites each in Burkina Faso, Mali and Niger	Guidelines to farmers and policy makers for manage resources to satisfy changing human needs while conserving or improving the natural resource base and environment. Multiscale methodologies that facilitate collaboration with the various stakeholders at each level of scale

Research Theme 3 Development of analysis and assessment tools for the evaluation of sustainability

Examples of research Projects	Expected results and impacts
Modern concepts, methodologies, and diagnostic tools (IBSRAM) Primarily through consultation workshops and validation projects, the development and evaluation of sustainable land management (SLM) concepts and tools have been initiated. These are the Framework for the Evaluation of Sustainable Land Management (FESLM), the soil, water and nutrient management (SWNM), and the resource management domains (RMDs) concepts. The	The concepts provide a logical and practical method for assessing the sustainability of land utilisation types. They are useful to land-use managers and planners, extension workers, scientists, and even bankers and insurers.

application of these concepts necessitates the use of related approaches such as participatory technology development and transfer and the consortium approach to natural resources management.	

Research Theme 4 Development of technologies for appropriate management of crop and land resources

Examples of research projects	**Expected results and impacts**
Integrated Nutrient Management (CIAT) Research on the use of organic materials for integrated nutrient management has revealed that green manures are inefficient as providers of N for crops compared with split doses of N-fertiliser. Most green materials tested, although containing high amounts of nutrients, decompose too rapidly, losing substantial amounts of N to the atmosphere via volatilisation and/or to ground waters via leaching. The results suggest that the favoured green manuring practices operating in for example, Central America, may in fact result in environmental pollution and contribute substantially to green house gas emissions. This work suggests that there is a role for selecting germplasm with anti-quality factors that can help slow decomposition thereby providing a better synchrony between crop demand and supply from on-farm organic materials. In addition, *in vitro* digestibility tests can be used to select for rapidly or slowly decomposing plant material in the soil.	To identify suitable plant components for animal feed, nutrient cycling and soil quality improvement.
Beans in Africa (CIAT) An Atlas for Common Bean Production in Africa was published. Better access to data on 57 variables for 96 bean production areas, including both agroecological and socio-economic dimensions, is expected to improve research efficiency, targeting of information and germplasm, policy formulation and seed relief efforts. An example of the application of this database was the prediction, by modelling, of new areas in which bean root rot is expected to become a serious problem in the near future. Incidence and severity of root rots, already estimated to cause 221,000 tons per year loss in production in Africa, are associated with high intensity of bean production and with less productive soils. The bean breeding activities resulted in the release of new and valuable genetic variability for Eastern Africa, Central America and the Andean Zone. Particularly in Africa, several promising lines with multiple disease resistance are now available. National program scientists in these regions will adapt this germplasm for use in systems where beans are important	NARES in susceptible areas evaluated a first regional root rot nursery and were encouraged to develop or verify other components of integrated management that are proving useful in Rwanda and Uganda, particularly soil fertility. Strong adoption of new varieties is evident in many areas, and particularly in Congo and Rwanda. In Tanzania, an easy-to-cook line may save as much as 10 percent of fuel wood.
Appropriate technologies and practices (IBSRAM) In different networks throughout the world, soil and crop management technologies developed by different research institutions have been tested and evaluated under the conditions prevailing in the different countries. This approach provides the adaptation of these technologies, giving better chances of adoption. For instance, the broad bed-and-furrow systems from ICRISAT, land development techniques from IITA/ICRAF, and tillage tools from ILCA were tested and adapted in Africa. The tied furrow-ridge system on Vertisols was tested in Zimbabwe while the use of poultry manure was evaluated on the upland soils of Ghana. In the Pacific and in Asia, soil-conservation technologies on sloping and steeplands were tested. These included variations of hedgerow cropping, grass strips, hillside ditches, agroforestry, and grid planting for fallow improvement. Soil loss was reduced greatly when barriers (hedgerows, grass strips, and hillside ditches) were	Based on visual assessments, farmers recognise the yield advantages with the tied furrow system and they are likely to adopt the system, provided the necessary machinery is available. In the case of upland soils in Ghana, IBSRAM has promoted the use of organic farming methods in combination with the use of inorganic fertilisers. These technologies gave improved agronomic and economic performance.

established across the slope. In Southeast Asia, liming, use of organic amendments, and appropriate sources of phosphorus were tested to overcome phosphorus limitations on acid infertile soils.	In Southeast Asia, a better understanding is now available of the impact of, and interactions between, applications of organic materials and inorganic phosphate on the efficiency of P utilisation.
Integration of farmers' knowledge into crop breeding (ICARDA) The principles of decentralised breeding and farmer participation have been combined to merge scientists' and farmers' knowledge bases. Decentralised selection by scientists fits crops to the physical environment, while farmers' choice is largely governed by their diverse, and often changing, requirements, such as agronomic practices and farming systems in their environments.	Farmer-participatory breeding programs have shown that the adoption rate of varieties and lines selected developed jointly is significantly higher than with conventional breeding programs.
Watershed development (ICRISAT) Despite huge investments in watershed development, particularly in Asia, most rain-fed agriculture programs are trial and error-based as few take a scientific approach. This situation is perpetuated by a lack of knowledge about the impact of empirical approach, since these projects are often not rigorously assessed for impact component. The current watershed research therefore aims to scientifically identify and evaluate options for recharging groundwater in watersheds and to assess their impact on Length of growing season through joint learning with NARS and NGOs in India, Vietnam, Thailand, and Ethiopia.	Options for farmers for more efficient management of key natural assets (land and water) for sustainable rural development in watersheds in the semiarid tropics.
Diversification of cropping systems through a broader choice of crop and livestock options (ICRISAT) Farmers in the semiarid tropics often have too few cropping options to break out of the cycle of poverty. Higher-value crops might enable significant impacts on poverty alleviation, and increase environmental sustainability as well. Legumes, for example, can add protein to the diet, and cash to the family income stream; meanwhile, they also complement cereals in the production cycle, and improve the soil. Tree crops adapted to the semiarid tropics can perform multiple functions (e.g. soil improvement, land stabilisation, cash generation). More nutritious crop residues can increase livestock production, and consequently cash income, and provide soil-building manure supplies as well. Activities include to develop options for increasing the diversity and productivity of farming systems, and identify numerous and enhanced crop and livestock choices and exploit positive interactions between them	Benefits of diversified systems demonstrated and documented, and more productive crop/livestock strategies validated for the semiarid tropics.

Research Theme 5 Integrating the socio-economic and biophysical contents of natural resources management

Examples of research projects	**Expected results and impacts**
The Soil, Water and Nutrient Management (SWNM) Initiative (IBSRAM) The SWNM initiative calls for a new scientific and development approach to land management, with a view to reversing the spiral of unsustainability. It advocates a much closer association of farmers and technical advisers with research workers to adjust the scientific principles of sustainable land and water management into practical farmer realities. It expresses concern at the low rates of adoption of improved management practices, which, it was concluded, arose largely from policy constraints or a lack of adequate adaptive research	The SWNM initiative advocates the formation of consortia on key research themes and the need to harmonise the present and future activities of the many organisations involved.
Resource Management Domains (RMD) Concept (IBSRAM) The concept of RMDs implies human interventions in the management of natural resources, particularly rural landscapes. The integration of biophysical and socio-economic domains is recognised in the development of the principles and procedures for the Framework to Evaluate Sustainable Land Management (FESLM) and it is being applied increasingly in ecoregional approaches. Thus, the RMD concept aims to improve the integration and interpretation of biophysical and socio-economic data and assist decision-makers in resource inventory and management, research priority setting, and technology transfer	The best results have been obtained where farmers have been involved as partners through all stages of technology generation, and where knowledge and research capacities of farmers are joined with those of scientific institutions. Thus, training in participatory technology development, in improved communication skills, and in participatory monitoring and evaluation has been a major impact of the network.
Impact of land tenure and other factors on mountain terraces in Yemen (ICARDA) The terraces in the highlands of Yemen represent over 25 % of the county's arable land and provide employment and livelihood for a large part of the rural population. The dramatic social and economic changes in the country over the past 30 years have led to a migration of the rural people to urban areas. Reliance on the land for food supply has declined. These factors led to the abandonment and degradation of the terrace agriculture. Under the prevailing economic situation, restoration of the degraded terraces may not be economically feasible. The study aimed at identifying key constraints to terrace rehabilitation and enabling factors. Land tenure was identified as a key factor determining the state of the terraces. Traditional, but no formal land registration exists in the country. Owned terraces were in better shape than sharecropped terraces. Terraces with perennial cash crops, such as coffee or *qat* were better maintained than terraces with seasonal rain-fed crops. Although there exist customary rules regulating the maintenance of terraces, these rules are not enforced	The study showed that government support is needed for local institutions to strengthen land registration and increase agricultural credit that is targeted to land improvement. The study also suggests that better prices for the produce will result in investment in the land and introduction of better agricultural technologies.
User-driven rangeland rehabilitation (ICARDA) In Turkey, a project for range rehabilitation involving researchers, extensionists and local communities is being implemented. The project involves systematic biophysical and socio-economic surveys of the community grazing and farming systems. In the villages, the villagers set up steering committees. A first aim is to stimulate	Already after one growing season, the effects of range protection and reseeding of grasses on the rangelands could be clearly seen. The farmers also realised that feed legumes planted on cropland

discussion and create increased awareness among the villagers of the rangeland degradation problems. Rehabilitation measures are being developed jointly with the researchers and extensionists.	increase feed availability significantly.
Combating desertification (ICRISAT) The strategy of Desert Margins Program (DMP) is to 1) review and analyse the extent and nature of land degradation and its socio-economic and biophysical causes; 2) identify and test available solutions together with farmers, NGOs, and NARS; 3) develop improved solutions through participatory research; 4) assess the likely impact of solutions in solving degradation problems and designing monitoring systems for measuring impact; 5) collaborate with researchers, farmers, communities, NGOs, policy makers, and donors in implementing and monitoring the findings and recommendations of DMP in Botswana, Burkina Faso, Kenya, Mali, Namibia, Niger, Senegal, South Africa and Zimbabwe.	An integrated national, sub-regional, and international action program for developing sustainable natural-resource management options to combat desertification