Towards an Ecoregional Approach for Natural Resource Managament in the Red River Basin of Vietnam

Selected papers from a planning workshop held in the Ministry of Agriculture and Rural Development, Hanoi, Vietnam

Editors: N.N. Kinh, P.S. Teng, C.T. Hoanh and J.C. Castella

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Ministry of Agriculture and Rural Development
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The Agricultural Publishing House

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Preface

The ecoregional approach has been proposed by its advocates as a new approach to address natural resource management (NRM) issues within defined geographic areas, using the tools from many disciplines to diagnose problems and to introduce changes, to generate new knowledge, and to introduce solutions that are socially, ecologically and economically acceptable to the communities in the ecoregion. The Red River Basin as an ecoregion comprising the delta, sloping lands, uplands and highlands of northern Vietnam, is a suitable area to use this approach. In implementing the approach, it is generally recommended that a situation analysis first be conducted in which major stakeholders are assembled to review the status of the knowledge on NRM, to arrive at a common understanding of key NRM issues, and to participate in a research planning process using a common vision for NRM in the ecoregion.

The planning workshop from which papers were selected for this book, therefore represented a first step in the process of applying the ecoregional approach for NRM in the Red River Basin. To the extent feasible, resource persons and scientists from international organizations and advanced research organizations were invited to join participants from the key Vietnamese government and non-government organizations in developing this future research agenda. The workshop informed potential partners of the current and future scope of ecoregional approaches in the Red River Basin, of the nature, objectives and outputs expected from NRM research projects, and of the role of various institutions and projects in a coordinated program for NRM in the basin. While a summary of the presented papers was made available shortly after the workshop, it was felt that several papers contained information which were not generally accessible to many interested in natural resource issues in this northern part of Vietnam. It was for this purpose that the proposal for this book was made.

The papers have been divided into three sections: an introductory section, a section on current and proposed research, and a section on aspects of a future vision of NRM. The three papers in the introductory section provide a comprehensive introduction to the different ecoregional approaches, and also set the context for the Red River Basin as a pilot site within a new initiative called the Ecoregional Initiative for the Humid/Subhumid Tropics/Subtropics of Asia. The second section has twelve papers on different ongoing and new projects on NRM in the basin, and show the diversity of work on NRM which would be suitable for inclusion in a collaborative program. The third section contains two papers which explore some possible elements of an ecoregional approach to NRM.

This book and the workshop on which it is based, would not have been possible without the selfless assistance given by so many of our Vietnamese and international colleagues. We cannot list all of them here but would like to acknowledge specially the logistical support given by Ms. V. Lantican and Ms. N.T. Huyen. We would further like to acknowledge the assistance of G. Trebuil, O. Husson, P. Bergeret, R. Bourgeois, and F. Jesus in the scientific review of the papers, and to Ms. Gon van Laar for her invaluable help with technical editing. Many of our IRRI colleagues played important background roles to facilitate the valuable discussions during the workshop, especially. S.P. Kam and T.P. Tuong. Lastly, it is our sincere hope that this book will contain information that is useful in helping the scientists and policy makers in the Red River Basin to determine sound action for a sustainable future based on rational technologies for NRM.

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Section A

Background on ecoregional approaches

The ecoregional initiative and a rationale for ecoregional approaches to natural resource management

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Introduction

The Asian humid tropics is a region characterized by dynamic economic growth and social development, both of which are anticipated to continue into the next millennium. Countries in this region face common issues related to the ecological sustainability that is required to maintain economic development (Teng, Fischer & Hossain, 1995). These issues concern what alternative crops can be grown given water, labor and land constraints (diversification), how to increase the efficiency and productivity of current food crop production (intensification), and how to arrest the negative effects on the natural resource base due to agricultural practices (degradation and pollution). These issues further require a *systems approach* for their resolution due to their complexity and inter-relatedness. Research to generate options and strategies at an ecoregional level will require concepts and techniques that allow integration and interaction of different levels of biological, physical or social organization. Furthermore, work at high levels of integration (e.g. regional) will have to build on solid scientific foundations at low levels of integration (e.g. plant and crop), and vice versa (i.e. upscaling and downscaling).

The focus of the ecoregional approach is on conservation and management of natural resources to develop sustainable food production systems (Rabbinge, 1995). However, natural resource management (NRM) tends to be site-specific, and the opportunities for generalizing research results from one site to wider domains, and their spill-over effects, are often limited. Because of this, the conceptualization, conduct, and interpretation of natural resource management research is best done by considering socioeconomic factors in biophysically-defined *ecoregions.* Furthermore, the role of NARS is crucial in conducting NRM research and in implementing subsequent findings. In the Asian humid tropics, most NARS have the capacity for collaborative research with other NARS and with international centers, and NARS collectively outspent the CGIAR in this region. Advanced research organizations (AROs), specially those from European countries, have also been active in this region on NRM. There is an urgent case to implement fully an ecoregional approach to ensure that food security and natural resource conservation become mutually compatible regional goals.

Impact from NRM research has been more difficult to achieve in the humid tropics than the corresponding research on germplasm improvement. One reason is that NRM tends to be location-specific, on a small scale, and its application at one location is subject to strong external influences emanating from wider scales. Furthermore, most of the issues related to degradation of the natural resource base due to mis-management cannot be addressed on a small scale because phenomenon at the field/farm level are often symptoms of larger scale processes. In order to achieve any significant impact from natural resource management (NRM) research, it will therefore be necessary that strong links be forged between NRM at the field/farm level and NRM at the landscape level. These links include scientific, technical and institutional ones, but require organization into an ecological framework that would integrate socioeconomic with biophysical factors. Such a framework may be provided using a systems approach applied on a distinct geo-physical area, such as an ecoregion, which is a geographically-bound set of ecosystems and their human settlements and supporting infractructures. In this paper, ecoregional approaches are discussed with respect to a new initiative, called the Ecoregional Initiative - ECOR(I) – that has been proposed by the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR), to implement the approaches in humid, tropical Asia.

The Ecoregional Initiative for the Humid and Subhumid Tropics and SubTropics of Asia – ECOR(I)

The CGIAR/TAC approved in early 1995 a proposal to initiate this ecoregional project (IRRI, 1994; Teng, Hossain & Fischer, 1995) and requested IRRI to convene the ECOR(I) for the humid/subhumid tropics and subtropics of Asia, involving the following:

Convening center:IRRI

Participating countries: Vietnam, Thailand, Philippines, Indonesia, Malaysia, India, Bangladesh
Participating advanced organizations:
France -- CIRAD, ORSTOM
Netherlands -- Wageningen agricultural community (WAC)
International Consortium for Agricultural Systems Applications (ICASA)
Participating international organizations:IRRI, ICRISAT, CIMMYT, AVRDC, IBSRAM, CIAT, IIMI, ICRAF.

As convening center, IRRI has responsibility to be facilitator, catalyst and organizer of activities in the Initiative. Additionally, IRRI acts as a secretariat for the steering committee of the ECOR(I), called the Ecoregional Working Group (EWG). IRRI also participates in methodology development by brokering advanced technologies between AROs and participating NARS, and through research conducted in its Medium Term Plan in the pilot sites and the ecoregion as a whole. The EWG has selected two over-arching themes to characterize the work done under the ECOR(I) -- soil erosion, and diversification. The **Soil erosion** theme is led by IBSRAM, which together with PCARRD is also leading an Asian project of the same name for the CGIAR Systemwide Program on Soil, Water and Nutrient Management. IRRI is a research partner in this theme, particularly through its Upland Rice Ecosystems Program. Crop **diversification** was chosen as the second theme, with four sub-themes -- water, land degradation, technology options, and policy. It is anticipated that research synergy will be determined in planning workshops through (i) filling gaps in NRM research, (ii) rationalizing and harmonizing the current research agenda of different institutions, and (iii) minimizing overlaps in NRM research by delineating responsibilities for different research activities.

Rationale for the Ecoregional Initiative -- ECOR(I)

The justification for implementing ecoregional approaches via this initiative were established in the proposal submitted to TAC (IRRI, 1994), and further elaborated by Teng, Hossain and Fischer (1995), and are summarized below:

- The need to develop common vision among different partners for NRM in an ecoregion, such as in a basin
- The need to fill gaps in information required for NRM which are not currently generated by existing institutions or activities
- The need to rationalize any overlaps in the mandates and activities of commodity or topical institutions
- The need for partners in an ecoregion to develop an organized framework to conduct NRM research and to implement NRM knowledge at the regional level
- The need to ensure that a holistic systems approach is used in regional level NRM, to avoid potential conflicts in strategies between institutions,

disciplines and sub-regions which may lead to negative effects on natural resources in the ecoregion; and

- The need to develop a single, practical "model" for regional-level NRM.

In a world where resources are becoming increasing limited to support agricultural and rural development, synergies and catalysis of activities are much needed to ensure that farmers can quickly benefit from the results of research and concurrently, that new technologies do not degrade the natural environment.

Implementing the Ecoregional Initiative, 1997-1998

An annotated chronology of the ecoregional initiative is as follows:

- The CGIAR TAC approved in early 1995 an ecoregional initiative, (ECOR(I)), for the humid/subhumid tropics and subtropics of Asia, to be convened by IRRI.
- The ECOR(I) organized its first planning workshop in September 1995, at IRRI, Los Banos, Philippines (IRRI, 1996a);
    - This was attended by IARCs active in the region, NARS and AROs.
    - An Ecoregional Working Group (EWG) comprising representatives of the major stakeholders was formed to steer the ecoregional work in this area.
    - Two broad themes were identified for consideration by ECOR(I) partners -- knowledge base development at ecoregional level, and efficient NRM for production in diversifying systems.
- A NARS consultant worked at IRRI during 1996 to identify and develop a database on natural resources and institutions involved in NRM in the ecoregion.
- The ECOR(I) convened the first meeting of the Ecoregional working Group (EWG) in August 1996, in Kuala Lumpur, Malaysia.
    - Pilot study regions were identified and criteria developed for including future regions.
    - Four concept notes under the diversification theme -- respectively on lack of technology options, poor policies, water resource

depletion, and land degradation -- were identified for further development for possible funding (IRRI,1996b).

- Consultations with partners, to identify pilot regions to initiate activity, based on a high level of current relevant research and development work (September 1996 - February 1997)
- First ecoregional methodology development project, SYSNET, started in October 1996.
- Convening of the first planning workshop for an ecoregional pilot site, the Red River Basin in October 1997.
- Formalization of ECOR(I) into IRRI's Medium Term Plan for 1998-2000.
- Convening of sensitization workshops for scientists and administrators in Thailand (Chao Phraya pilot site – 1998; Ayerwaddy pilot site – 1998).
- Conduct of Scale Workshop in Ho Chi Minh City to improve researcher understanding of scale issues in ecoregional research, June 1998.
- Convening of first pilot site technical workshop, for the Red River Basin, in Hanoi, October 1998.

The above chronology is a brief summary of the highlights and does not reflect the many activities under each activity.

ECOR(I) activities

The ECOR(I)) has three major types of activities: ecoregion-wide activities, methodology development, and pilot regions.

1. Ecoregion-wide activities

These are guided by the EWG, which catalyzes, rationalizes and develops the comprehensive ecoregional program, and currently consists of the following:

- Thematic working groups to develop specific projects to generate outputs from ongoing activities by NARS, IARCS and AROs on water, land degradation, technology options and policy
- Databases or information on each region or domain (delta/watershed/toposequence) for sharing among partners, including results of diagnostic and characterization studies

- Assessments of food, feed and fiber demand by the ecoregion's growing population, and the relationship between this demand and the natural resource base
- Case studies within these domains to better define their key attributes (biophysical, socio-economic, institutional, policy) and to develop technologies for landscape level NRM
- Research on methodology for upscaling technologies in watersheds, and
- Training and supply of computer software to NARS teams for exploring land use options in different sectors of toposequences.

Partners for research on generic ecoregional issues are jointly identified through the EWG.

2. Methodology development

The SYSNET Project. Under the umbrella of the ECOR(I), a project involving NARS teams from India, Philippines, Vietnam and Malaysia was initiated in late 1996 with support from the ISNAR-managed Ecoregional Fund (Roetter & Teng, 1998). This project emphasizes the development of a specific set of methodologies to support ecoregional-level decision making. The two main activities are:

- Evaluation of generic crop models for estimation of potential yield of major agricultural crops at different scales; and
- Development of databases and their use with multiple goal optimization algorithms, to explore tradeoffs between apparently conflicting objectives in NRM.

The areas studied by SYSNET are The Kedah-Perlis coastal plain in Northern Peninsular Malaysia, The Mekong Delta (one province), in southern Vietnam, Haryana state in India, and Ilocos Norte province, in Luzon Island, The Philippines. It is anticipated that SYSNET will contribute databases to the other components of the ECOR(I), and will also identify research needs in NRM. The SYSNET project has a strong link to WAC and ICASA to tap into the latest computer software, models and algorithms for land use planning.

Other methodology development activities. In addition to the SYSNET project, a group of NARS is cooperating with IRRI to develop GIS-based techniques for better estimating rice supply and demand at a sub-national level. It is anticipated that this will lead in aggregate to an improved estimation of the food production capacity in the ecoregion. Additionally, a joint project between IBSRAM and IRRI is researching quantitative models for predicting nutrient flows in northeast Thailand.

3. Pilot studies in selected regions

In order to have a tangible demonstration of the potential benefits from adopting ecoregional approaches, the ecoregion's NARS in the EWG made a strong recommendation to focus efforts on several deltaic areas and their associated watersheds (IRRI, 1996a). They also urged that a process and the techniques to conduct inter-institutional, inter-disciplinary research on natural resource management be developed at these sites by building on current activities occurring along the transect from upland to lowland landscapes. The EWG further recommended that current mechanisms for research collaboration such as consortia and networks, either national or international, be tapped for inputs for ecoregional cooperation. It is therefore anticipated that most of the gap-filling research will be done by re-directing the agenda of the NARS institutions concerned, IARCs or AROs, although some new research, especially on the development of methods for "upscaling" knowledge, will have to be done. All stakeholders have committed themselves to sharing research outputs and data generated on the four sub-themes either by their own efforts or in this cooperative ecoregional mode, at the pilot regions. Databases from each theme will also be shared and updated each year for each region under study.

In each pilot region, a Regional Working Group (RWG) will be formed comprising representatives from all the key institutions involved in R & D activities. This RWG will inventory the ongoing work by various partners, conduct planning meetings to identify research needs and bottlenecks in implementing a regional level program for NRM, facilitate the creation of a common vision for NRM in the region, assist in the rationalization of any overlapping research agenda, identify technologies required for improved NRM, and assist in the development of proposals for research contributing to improved NRM in the region. Each year, a technical symposium will be held to enable synthesis and cross-subtheme interactions, from which it is anticipated that knowledge shared on each pilot region (watershed, delta) will be of general benefit and of specific use to each partner.

The following regions, with their associated watersheds/toposequences were selected for joint work based on the substantial volume of current research activities by the partners in this ecoregional initiative -- Red River Delta and associated uplands, Vietnam; Chao Phraya Delta, Thailand; Ilocos Norte region, Luzon, Philippines; and Mekong Delta, Vietnam. Additional study regions that require further consultation with NARS partners are those of South-east Kalimantan, Indonesia; Ayerwaddy Delta, Myanmar; and the Ganges/Brahmaputra Delta, India/Bangladesh.

Potential partners for each pilot region are listed below, but is not all inclusive until the working group for each study region has been convened:

Red River Basin: GRET (an NGO), CIRAD, ORSTOM, Vietnam Farming Systems Network members, IRRI, ICRAF, CIAT, CIMMYT

Chao Phraya Delta: ORSTOM, CIRAD, Kasetsart University, Thailand Department of Land Development, Thailand Department of Agriculture/ Rice Research Institute, IRRI, CIMMYT, IIMI, AVRDC

Ilocos Norte region: PhilRice, Mariano Marcos State University, UPLB, PCARRD, Ilocos Norte Provincial Government Planning Office, IRRI, AVRDC

Mekong Delta: CIRAD, ORSTOM, Can Tho University, Cuu Long Rice Research Institute, Water Resource Planning and Management Institute, IRRI, and CIMMYT.

Target outputs for each pilot region from the ecoregional research were identified by the EWG and include:

- Options for water management in each sector of the toposequence (i.e. deepwater/ tidal land, irrigated lowland, rainfed lowland, rainfed upland) and integration of these options for the entire toposequence
- Methodology for, and determination of crop options for different sectors of the toposequence.
- Improved coordination of collaboration mechanisms within the ecoregion with respect to NARS/IARC/ARO activities
- Land management strategies and practices developed to facilitate water catchment, water conservation and water utilization
- Quantification of the effects of diversification on the natural resource base
- Biodiversity-conserving crop diversification strategies developed for each toposequence sector (i.e. deepwater/ tidal land, irrigated lowland, rainfed lowland, rainfed upland), and their extrapolation potential determined

- Crop and nutrient management strategies and technologies developed for diversified cropping systems
- Pest management strategies developed for insects, diseases and weeds which recognize the spatial link between different crop-based ecosystems in an ecoregion
- Policy options developed for supporting crop diversification in a sustainable manner with minimal negative effects on the natural resource base
- Development of institutional frameworks for NRM at an ecoregional level

These targets are neither all-inclusive nor appropriate for all ecoregional pilot regions, and it is envisaged that a subset will be selected for each region and that other targets may be identified for specific regions.

Restating the characteristics of the ecoregional approach

The ecoregional approach is a relatively new research approach for tropical Asia, and has been proposed to focus on development of strategies and techniques for natural resource management at a regional level, in order to develop sustainable food production systems under pressures of increasing human populations and declining soil and water resources for agriculture. In implementing this approach, natural resource management research is to be done by considering socioeconomic factors in biophysically-defined *ecoregions* so that visible impact may be seen at different levels (farm to watershed) and from different perspectives (scientific and political). Increasingly, a partnership mode is recognized as being central to the ecoregional approach, in particular the integration of the individual research agendas of NARS institutes, international centers (IARCs), advanced research organizations (AROs), and non-government organizations (NGOs).

An ecoregional approach therefore fully leverages the comparative advantage of individual research and development organizations with those of policy and administrative institutions, into a comprehensive program to ensure that food security and conservation of the natural resource base become mutually compatible regional goals. In a world that is witnessing declining land and water resources to grow food, fiber and feed for its human inhabitants, ecoregional approaches take on urgency as the practical mode of implementing modern science and technology for sustainable development.

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An ecoregional approach for development-oriented research on agricultural systems

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Introduction

This paper is based on the recommendations made by a working group bringing together the French agricultural research institutions (CIRAD, INRA and ORSTOM)[1] and set up at the request of the Ministry of Higher Education and Research to draw up joint proposals in the field of ecoregional research. This concept is currently being developed by the Consultative Group on International Agricultural Research (CGIAR), where it has become an important component in the evolution of development-oriented research. French institutions are already involved in several ecoregional programmes and consider these initiatives as a step in the right direction, providing a means towards more effective development-oriented research. The proposals presented here aim to bring this concept another step forward by defining the principles of a 'second generation' of ecoregional projects that the French research community would like to put to its partners for discussion and implementation, for example in the case of the Red River Basin key site of the Ecoregional initiative for humid Asia, Ecor (I).

Development-oriented research and ecoregional approaches

Logically speaking, it should be possible to measure the effectiveness of development-oriented research, in the developing world especially, through its contributions to economic and social development in the countries

1 The members of this working group were for INRA: B. Vissac, C. Albaladejo and A. Sontot; for ORSTOM: G. Hainnaux, A. Lericollais and P. Gondard; and for CIRAD: F. Forest, D. Sautier, P. Lhoste and Hubert Manichon.

concerned. In practice, however, the development process is highly complex, reflecting the multiple interactions of human society with its environment, and such measurements are very difficult to make. Depending on the case, research may be alternately attacked or praised, without any objective proof of its responsibility in success or failure. Indeed, such subjective perceptions often influence the level of resources that communities are willing to invest in this area.

Despite such difficulty, agricultural research institutions are increasingly conscious of the role they must play in responding to social demand. Few are the scientists who now consider that their contribution can be limited to individual work on personally chosen topics. Recent years have seen a growing recognition of the need for collective, multi-disciplinary organization of research planning activities that need to be based on the analysis of needs and hence with clearly defined objectives.

The ecoregional approach is benefiting from these changes. It owes its development to the efforts now being made to improve the transparency and credibility of development-oriented research, its objectives, problems and organization. In particular, it has attracted the attention of funding agencies who view it as a tool for more effective analysis of the economic, social and environmental problems of developing countries.

For the CGIAR authorities, who have been developing this approach over a number of years, it provides a means to take into account, within the framework of the 'green revolution', of the difficulties encountered in regions with multiple constraints and, more recently, in regions with high development potential, and to give greater priority to environmental problems. To achieve this, *not only must the scope of research be extended beyond the biophysical aspects of production but, at the same time, problems must be analysed in terms of their technical and human dimensions* (CGIAR, 1992, 1994).

We must, therefore, define the geographical areas within which this multidisciplinary approach is to be applied. For organizational purposes, the CGIAR has suggested dividing the continents into 'ecoregions' (on the basis of agro-ecological zones defined by FAO). In certain regions, such as south and southeast Asia, consortia have been set up to carry out collaborative research programmes, bringing the concerned National Agricultural Research Systems (NARS) and their comparative advantages into closer and more equal relationships with the CGIAR centres and other Advanced Research

Organizations (AROs). As an example, Vietnam became recently a full member of the Upland Rice Research Consortium which is entering into its third phase. This institutional approach, providing a tool for renewed collaboration between North and South, will hopefully enhance the coordination and efficiency of development-oriented research projects. However, this approach also involves high 'transaction costs' which at a time when resources are scarce will only be acceptable if the hopes placed in this approach are fulfilled.

A necessary deepening of the ecoregional approach

The various ecoregional programmes already defined cover a wide range of topics; this is logical since the regions concerned are very different in nature. However, a large variety of scientific approaches are also used without any apparent justification for the differences observed. The programmes rarely stay within the limits of particular ecoregions, and indeed there often appears to be little true uniformity, in terms of agricultural and environmental problems, within a single ecoregion.

This problem must be studied more deeply. This need was recognized by the CGIAR authorities, who decided to set up a working group on this subject[2]. For the same reasons, the Dutch cooperation organized a symposium in December 1994 for the benefit of international centres.

The very objective of the ecoregional approach is to contribute to the sustainable development of a geographical region and this is also the necessary starting point for any evaluation of its scientific content. A positive contribution to development cannot be achieved simply by basing research projects in the region concerned. Nor is it sufficient merely to ensure that the issues being studied are related to the region's major development challenges, or to perfect the methods required to disseminate the results of this research. Indeed, experience shows that for innovations to be accepted, the new knowledge produced must be in harmony with the needs and strategies of the people for whom these innovations are destined and must take account the constraints to which they are subject. Furthermore, to ensure that the

2 This group was chaired by Cyrus N'Diritu (Kenya) and its members were: I. Abrol (India), H. Manichon (France), G.Norès (Argentina) and R. Van den Berg (Netherlands); the secretary was M. Collinson (CGIAR secretariat).

solutions to a problem do not, in turn, give rise to new problems when they are applied, their consequences, both direct and indirect, must be analysed in detail.

A given geographical region contains a large variety of situations, both among different categories of actors (farmers, traders, officials, etc.) but also within a single category. Consequently, it is quite unrealistic to imagine that a single solution can be imposed on the entire farming community (assuming that this is possible) to solve any given problem (increased agricultural production, improved product processing, or natural resource management). Though such a solution may be relevant for some, it would never be appropriate for all situations. This is particularly true where agricultural diversification and farm or regional specialization is occurring along the process of integration into market-driven economies such as in today's Vietnamese agriculture. On the contrary, a wide variety of alternative solutions must be provided, devised on the basis of a diagnosis bringing to light the problems affecting an entire region and the strategies of particular actors within it. They must be made available to all those concerned so that they can be used to establish new working methods and practices.

Whether it be to improve food security by increasing production, to reduce poverty by increasing income or to implement sustainable management of natural resources and environmental protection, the very roles of the diversity of stakeholders involved in production or management of resources are brought into question. For example, to improve the coordination mechanisms in key commodity chains being rapidly transformed following important socio-economic reforms like in Vietnam recently, the solutions provided will only be effective if they enable local actors to make positive changes in their activity. Local action is a prerequisite for overall development.

We must therefore acknowledge that no contribution can be made to the development of a geographical region without viewing the land, its people and their activities as a real object of research by itself. This is the message we propose to convey through the ecoregional approach. It involves the integrated study of a region, based on the current local situation, in order to identify the realistic margins for future progress and the means to achieve such progress. Of course, these ideas are not new. However, they are all too rarely applied in research programmes, even when conducted on a collaborative basis. The proposals presented below could, on this basis, contribute to the definition of a 'second generation' of ecoregional programmes and projects to complement and reinforce those which already exist.

Proposals for a second generation of ecoregional programmes

The proposals presented here have been drawn up largely on the basis of French experience. This experience is based on an understanding of the physical and human environments of developing countries, built up over time through a tradition of work in the field and long-standing relations with NARS partners. It covers all types of production in these environments: animals and plants, crops for local consumption and for export, food and non-food crops. Lastly, its results from the application, over many years, of a multidisciplinary and multi-scale systems approach with respect to the environment as it is actually perceived at different levels (cropping system at plot level, production system at the household-based unit and agrarian system from the village to the region and beyond). References to these topics can be found in the bibliography.

In the specific case of the Red River Basin, one must recall here the two very early and famous landmark publications, one by Pr. René Dumont's thesis in agronomy published in 1935 on 'Rice cultivation in the Tonkinese delta', followed the year after by Pr. Pierre Gourou's own master work in physical and human geography entitled 'Farmers of the Tonkinese delta'. Closer to the present, two volumes containing each a series of articles on recent changes in the agriculture of the Red River delta and based on the Red River Programme activities at the Vietnam Agricultural Science Institute (see the paper by B.H. Hien, this book), belong to this type of integrated studies on regional agricultural systems to guide development efforts. The very timely release this month of a joint special issue of 'Agricultures' and 'Agriculture et Développement' journals on the recent transformations in Vietnamese agriculture includes twelve articles on agro-economy and agronomy on the various aspects of changes in the agricultural production systems of the Red River Basin.

During the past years, several research methods and procedures have been designed and tested that could contribute significantly to a common 'basket of tools' to be made available to the various partners of the Ecor(I). As far as CIRAD is concerned, the following ones could be cited: agro-ecological zonations based on the integration of GIS and remote-sensed datasets, frequential climatic analyses, cropping systems typologies, on-farm crop diagnostic surveys and empirical modeling of yield build-up processes, household systems typologies based on farmers strategies, commodity chain and stakeholder analysis, multilevel analysis tool for agriculture (MATA model), multi-agents dynamic models and decision making helpers, patrimonial management of renewable natural resources (mediation, coordination, negotiation), etc.

We present below the role that ecoregional research may play in the identification of paths towards socially, economically and ecologically sustainable development in a given region (a more precise definition will be given later) and their practical implementation. The foundations of the ecoregional approach are first defined and certain implementation principles are examined, without seeking to cover every aspect of the question. The proposed approach is broad enough to be applicable either in the case of high productivity areas such as parts of the Red River Delta facing new kinds of natural resource management and socio-economic problems, or (at least until recently) more marginal areas of the hilly and mountainous zones of the Red River Basin displaying very constraining bio-physical and socio-economic conditions. It is also designed to be suitable for those situations characterized by rapid transformations of agricultural production processes.

Contents of the proposed ecoregional approach

A conventional approach would be to examine the following points in succession: (*i*) the identification of the major development challenges facing the region and their order of importance, (*ii*) their expression in terms of scientific questions and the search for answers which may have already been found, in the region or elsewhere, (*iii*) the definition and implementation of appropriate research methods and protocols to obtain solutions if none are available or applicable, (*iv*) the definition of methods for dissemination of results among the populations concerned and their implementation (*v*) the evaluation of results obtained.

Though this list contains many essential activities, it is not sufficient in itself to form the basis for the organization and long-term management of a research system capable of achieving the objectives presented above.

The first task is, of course, to identify regional challenges and real research needs; it deserves particularly careful attention. This identification of challenges clearly calls for expert opinion and an analysis of available data, often relatively abundant thanks to previous studies in the area. However, this exploratory phase alone is not sufficient to guarantee a relevant and useful research programme since, in this form, it is the scientists who impose their own vision upon the farmers and the economic and political decision-makers.

To ensure greater relevance and efficacy, the next task is to construct an overall diagnosis of the current dynamics of the region in collaboration with the various stakeholders concerned and through their direct involvement in the design of the research project and its institutional organization. This construction, not the product of scientists alone, thus results from consultation and negotiation between a social demand (which must be known) and a supply of research (to be constructed). This negotiation must be established from the outset. After constructing this regional diagnosis, additional research needs can be identified to fill existing knowledge gaps and appropriate research protocols combining surveys, testing and syntheses, can be devised.

However, as work progresses, it would be prejudicial to disconnect the knowledge creation phase from its utilization, allowing researchers to hand over the reins to others after achieving the desired results from their research protocols. On the contrary, there are several reasons why research work and practical implementation of new knowledge should take place side by side. Indeed, it may take a very long time to obtain answers to certain problems, whereas the knowledge already acquired in other areas can be transferred immediately. Research partners would not see any justification in delaying implementation until all results were available. Moreover, researchers would miss an opportunity to test their validity under real conditions. Indeed, it is often through the application of apparently well-proven 'solutions' that their shortcomings are brought to light and that new research needs are identified. The practical application of knowledge for innovation must therefore involve the scientists themselves, working in close collaboration with beneficiaries. Action-research interventions are required to achieve this end.

As it is not always possible to test the application of a research result, other strategies must also be available. The appropriate tool for progressive integration of acquired knowledge and simulation of its application is, of course, a model of the dynamics of the region based on the outputs generated during the phase of preliminary diagnosis. The construction of an overall representation of the structure and current dynamics of the region therefore lies at the heart of the proposed ecoregional approach. It forms the basis for the diagnosis and identification of research and development needs and can be used to simulate any changes that occur. Defined as the integrated study of bio-physical, socio-economic and policy factors of sustainable development in a given geographic area, the ecoregional approach thus corresponds to a long-term iterative process; its implementation is the progressive construction of a partnership project established between research scientists and key stakeholders operating within the geographical area concerned. Clearly, this breaks down the traditional boundaries between fundamental, strategic, applied and adaptive research categories, as it does between research and development; it is an integrated approach to development-oriented research.

Applying the approach

In this section, we propose to examine three questions successively: the type of geographical area within which the ecoregional approach can be applied, the components of the preliminary diagnosis and, lastly, the regional model and its application. Other important questions, such as the characteristics of thematic research procedures, the dissemination of research results and the assessment of their impact are not discussed here.

Choice of a suitable region

Practically, an 'ecoregion', as defined by the FAO classification of agro-ecological zones,i.e. a vast trans-national area whose boundaries correspond to climatic limits established on a somewhat arbitrary basis, would not be an appropriate choice. Indeed, though climatic and ecological factors are essential for assessing the potential performance of livestock and crops and for analysing the reasons behind current land use practices, they are not enough in themselves. The wide variety of agricultural situations co-existing within a single climatic zone demonstrates that climate is not the only factor to be taken into account, and that certain cultural, social, economic and political factors weigh heavily in the choice of production systems.

It is therefore more practical to delimit smaller areas within the ecoregions where all the factors affecting their dynamics can be examined simultaneously. The chosen study area is therefore a 'region', defined as an area within the ecoregion containing human societies whose activities result from (*i*) their own objectives and needs, (*ii*) the resources (natural resources in particular) that they can mobilize to this end, (*iii*) their mutual relations (exchange, competition, etc.) and (*iv*) the rules governing these relations.

Based on such a definition, a region comprises rural areas (in which economic activity consists predominantly of crop and livestock productions and forestry) and urban areas, displaying varying degrees of interactions.

It is also convenient, for an initial analysis at least, to use an administrative subdivision of a state. The situation in such areas is generally documented by thematic maps (soils, climate, roads, railways and energy networks) and by a variety of statistics concerning economic activities and population which, though they must be checked for accuracy, are precious sources of information. Moreover, centres of economic activity and consumption, political decision-making centres and potential research partners are clearly and immediately identifiable at such a scale.

The region may be chosen to include several different climatic (sub-)zones, such as in the case of the Red River Basin. This should not be seen as a complicating factor, but more logically as a necessity when the activities performed in these different zones are complementary and interacting, as is the case between the hilly and mountainous areas located around the Red River Basin and the delta itself with its major urban centers.

The collation of existing data and their synthesis by means of a geographic information system provides a spatial view of the region, of its internal variability, and of the relations between sub-groups defined within it. This synthesis document, enriched over time, can be used for example to select the places where particular research projects are needed and will provide the basis for delineating the domain of extrapolation of their results.

This analytical procedure must be repeated to study the relations and interactions between neighbouring regions (such as the Delta, the hilly 'zone moyenne' and the highlands of the Red River Basin for example), within one or more ecoregions, taking each region as a unit: an ecoregional structure may comprise several entities. It would run contrary to the very objectives of the approach to limit the study of regions to partial analyses through which no overall understanding of each region can be obtained and no valid comparisons made.

Components of the regional preliminary diagnosis

One commonly-used approach is based on the identification of hierarchical levels of organization (plot, farm, village, etc.) and the characterization of each of these levels. To examine the higher level of organization, a synthesis of data concerning the previous level is needed. This makes it very difficult to avoid potentially dangerous over-simplification when up-scaling. Particularly, we may lose sight of the diverse patterns of reasoning underlying the actions of stakeholders operating at each of these organizational levels or we may ignore the fact that some of these key actors are involved in several organizational levels simultaneously. To avoid such shortcomings, it is preferable to build up a picture of regional realities by combining several complementary, partially redundant 'points of view' in which the patterns of reasoning of the various actors can be included without necessarily associating them with a single level of organization.

Three points of view together form the foundation of a regional diagnosis:

- Commodity chains constitute the first point of view. They include all the functions (production, processing, marketing) and stakeholders involved in the chain leading from a biological raw material to one or more end-products used by human societies. These commodity chains may (or may not) provide appropriate responses to the quantitative and qualitative needs (food, energy, wealth, work, environment, etc.) of rural and urban populations in the region under study. Both local, domestic and export commodities are concerned, all playing a role - which must be assessed - in the economy of the region. By studying each stage (taking account of the production factors used and their use efficiency) in each major commodity chain, their critical segments, strong points as well as shortcomings can be identified.

- The land constitutes the second point of view. Zoning, based on the variability of the region's physical, economic and human characteristics, provides a basis for surveys concentrating mainly on the farm level[3]. The study of farms in a sample group of villages brings to light the range of production processes used to manage natural resources (by farmers, herders, foresters, communities) and the reasons, of whatever kind, behind the choice of such techniques

3 The term 'farm' is here used in its widest sense to mean a decision-making centre concerning the use of natural resources (and other resources) for production and for the needs of a family group. It includes entities with their own land and those without land; in each case, the multi-activity of each of the actors is taken into account.

(agronomic, economic, legal, cultural or social). The relations (competition or synergy) between the various stakeholders at the local level (the village territory), their mode of organization, the pressure they exert on land, must be studied in particular detail to gain an overall understanding of land use and of the results obtained. On this basis, diagnoses can be made concerning: (*i*) cropping and livestock production systems and the reasons for differences between their current performances and their potential output levels, (*ii*) the short- and long-term consequences of human activity on the environment, both in natural and cultivated areas and (*iii*) the assessment of the existing use of resources available in the environment.

- Policies must also be analysed. They concern: prices, credit, exchanges, land ownership and development, demography and immigration. This set of policies, like the operation of markets and the organization of agricultural extension, influences the behaviour of stakeholders, affecting their reactions to uncertainty, unexpected events and contributes to the creation of favorable (or not) conditions for the development of the local economic activity.

For each of these points of view, the analysis concentrates on the situation in the region at the present time. However, aspects of its past must also be known in order to obtain a clearer overall picture of the causal mechanisms that are at the origin of the current situation. In the case of the Red River Basin for example, recent changes in the land tenure systems and their impact on land utilization, demographic trends and inter-regional migrations, evolution of crop yields and farm prices, etc. could be important topics to be investigated.

The regional model and its utilization

The preliminary diagnoses drawn up for each component of the regional analysis give an initial list of questions concerning the region's development, thus providing guidelines for the creation of appropriate research and extension organization and plans. Here the approach is largely thematic in nature.

The integration of the findings from three points of view guarantees that the main stakeholders involved in the dynamics and development of the region, and their interactions, are taken into account in the regional diagnosis. This integration is achieved though the identification of key regional sub-systems and an analysis of their operation, the typological classification of stakeholders and the spatial representation of data synthesized in a geographic information system. This integration must concentrate on the levels where decisions are taken concerning production choices and natural resource management strategies. At this stage, an additional list of key questions to research can then be identified that will deal mainly with the relations between stakeholders and between the systems they manage.

Starting out from the overall diagnosis, a model of the region's current mode of operation is built up. It will then be used to simulate the changes that occur as a result of variations in major factors such as demography, main production and input prices, land tenure and credit policies, for example, or through the introduction of new technologies.

To make these simulations possible, the model must provide explicit information about the relationships among stakeholders, the activities they pursue and their determinants. It must indicate the linkages between the use of production factors and resources and the levels of production obtained, as well as between the types of land use and their economic or environmental consequences, between the behaviour of stakeholders and their economic, social and cultural environment. To achieve this, certain aspects must be taken into account which, though impossible to quantify, are nevertheless essential for the understanding of regional realities: if the regional model limits its scope to quantifiable data, the true complexity and diversity of the situation may well remain hidden.

Such a tool for monitoring the evolution of a regional agricultural system is enriched over time through the integration of ongoing research and development outputs and their impact on the farms. Beyond monitoring, simulations reveal the variability of economic and environmental results corresponding to different evolution scenarios. They thus bring to light key areas where, for example, new knowledge or new modes of social organization may become necessary in the future.

Conclusions

The organization of research efforts within a specified geographic area is not the only means to perform objective-oriented research. General thematic approaches are equally valid and their results are valuable for regional research. However, the particular advantage of regional research is its capacity to take into account simultaneously all the stakeholders (individuals, groups, firms and institutions) operating within an area and whose strategies interact to contribute to the development within the region. This development will not be real and sustainable unless there is a certain rationalization of activities, especially as regards the use of available resources within the area concerned. Of course, research alone does not hold the key to development. However, through an ecoregional approach, it is able to contribute to the definition of ways and means to achieve such rationalization. In the case of the Red river basin site, a key question to be addressed by future Ecor(I) activities will be: what types of coordination mechanisms should be put in place between the increasing number of stakeholders in the market driven regional agricultural economy to bend current practices toward a more productive and sustainable use of natural resources?

We must therefore understand the diversity which exists in the current use of natural resources, in the conditions for acceptance of technological progress and in the strategies used by the various actors to adapt to a constantly changing environment. To achieve this understanding, technical, social, economic and political aspects must be analysed together; the geographic area in question must therefore be viewed as an object of research in itself. Such is the concept presented in this communication. Very practically, Ecor(I) activities will need to be structured in a way that facilitates the comparative understanding of the functioning patterns and interactions among adjacent zones (delta, hilly, mountainous) in the basin.

Today, it is clearly necessary to deepen the ecoregional approach as it is applied in order to prepare for the future challenges analysed in the recent report entitled 'Sustainable Agriculture for a Food Secure World' directed by Gordon Conway. This report highlights the urgency of a new agricultural and ecological 'green revolution' to establish an agriculture which is both productive and in harmony with the natural environment. The regions subject to the greatest constraints are most directly concerned, such as the very densely populated Red River Delta or the fast degrading steeplands surrounding it. The ecoregional approach naturally has a major role to play on the path towards this 'doubly green revolution'.

The national and international research institutions of both industrialized and developing countries have achieved results in many areas, providing useful answers to the needs of developing countries. But these results have rarely been integrated into a sustainable development strategy on a regional level. This question, which cannot be answered without a major review of the organization and content of development-oriented research, is a major concern, and rightfully so, of most research institutions. The CGIAR, which first coined the term 'ecoregional', the universities and research centres in many countries including, in Europe, those of the Netherlands and France, along with regional organizations of the NARS, are all contributing to this debate. Faced with the urgency, complexity and diversity of the problems to be tackled, these various organizations must join forces to establish the principles and methods for more effective research and to enable development-oriented research to face up to future challenges with greater force and vigour.

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Exploring land use options under multiple goals in support of natural resource management at a sub-national level

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Introduction

Vast areas of the humid tropics of Asia are undergoing accelerated land use changes, mainly driven by market forces, increases in population, and rapid economic growth. As a consequence, agricultural systems are in transformation, being challenged by the requirements of increased productivity, more diversified products and environmental protection to meet the multiple societal claims on natural resources including land (Pingali et al., 1997). At the same time, there is also a pull of human resources from agriculture to other sectors. Both 'Pushing and Pulling factors' lead to accelerated migration of people from rural to urban areas and to increasingly disintegrated forms of land use.

One response to the challenge of producing more on less land, with less water and less labour, while maintaining the quality of the natural resource base, is to increase resource use efficiency in an unprecedented way (Greenland, 1997; IRRI, 1997). Apart from increased efforts in conventional research (plant breeding, soil and water management and genetic engineering) focusing on improved resource use efficiency at field and farm level, the agricultural research agenda has to be widened and address environmental and economic issues at higher (regional) levels of integration. Analysis of sustainable options of land use and resource management at regional levels is required in order to support appropriate policy change by offering feasible options, instead of restricting research efforts to curing the possible consequences of inadequate agricultural and environmental policies. Moreover, regional level studies help in identifying crucial research gaps, and thus, in setting research priorities at lower (farm, field, plant) levels of integration.

Commonly, where agricultural land is scarce and production does not keep up with population growth, research and development (R&D) measures, such as irrigation and improved fertilizer management, are initiated, and geared towards higher yields per unit area. Unfortunately, in many such cases success is limited, partly because the required external inputs are either not available or too expensive. As a consequence there is often no alternative to meet the increasing demand for agricultural products except either to over exploit the natural resource base, or to remove some of the constraints, e.g. by subsidizing prices of inputs or produce (Dasgupta & Mäler, 1994). The latter measures, however, often discourage farmers from adopting resource use efficient technologies. Thus, both lack of required external inputs and inadequate price policy can lead to undesired environmental effects, undermining the sustainability of agricultural production systems. This underscores the need to take technical, socio-economic as well as ecological dimensions into account when identifying pathways for sustainable agricultural development for any given region (Dent, 1997; Beek et al., 1997).

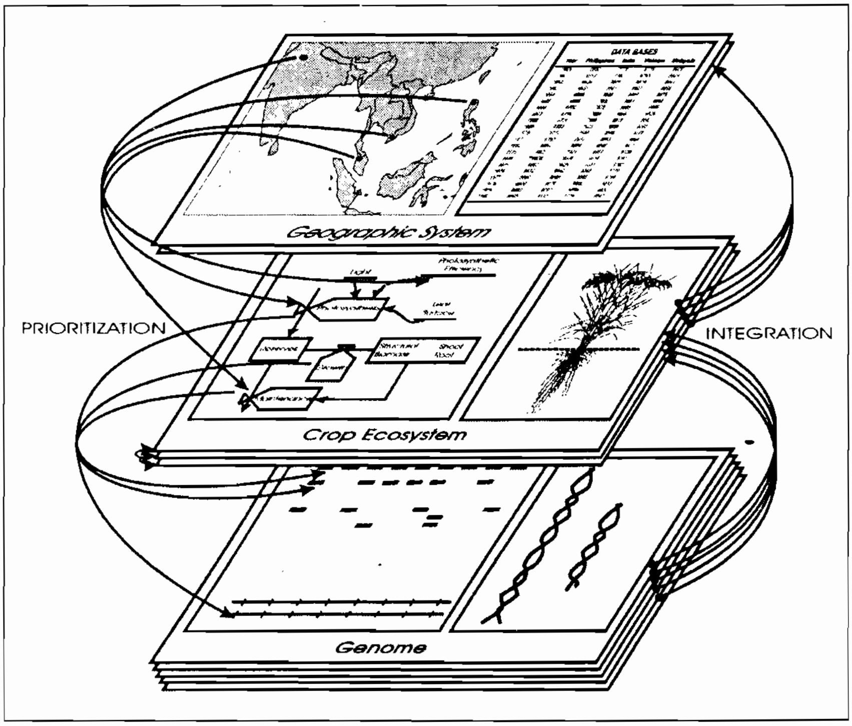


Figure 1. Systems approaches to link agricultural research activities at different scales (adapted from IRRI, 1994).

SysNet project

Overview and characterization of study regions

To ensure that the fruits of research efforts at field and farm level, such as integrated nutrient and pest management have a higher impact, decisions on (agricultural) land use and natural resource management at regional level should be based on sound scientific knowledge. Such knowledge needs to be synthesized and made accessible in the form of decision-making support systems, taking into account the different current and alternative scenarios of the future functions of the rural environment.

Understanding and information gained from analysing various scenarios of land use change and its impacts on the natural resource base should become an integral part of (integrated) economic and environmental, regional development plans. Developing a systems methodology for that purpose is the motivation for this new project on regional land use planning in support of natural resource management in tropical Asia.

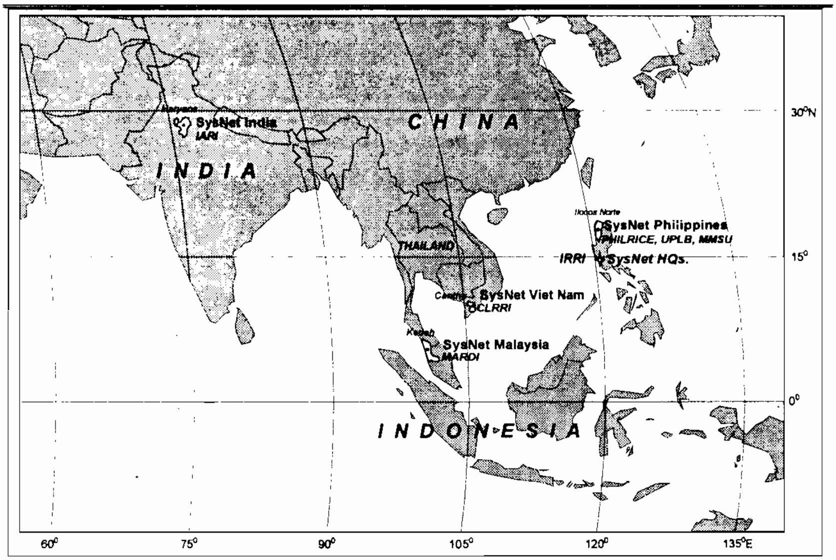


Figure 2. SysNet project (1996-99): Partners and study regions

Under the umbrella of the Ecoregional Initiative for the humid and sub-humid tropics and sub-tropics of Asia (ECOR(I)) (Teng et al., 1995), the project 'A Systems Research Network for Ecoregional Land Use Planning in

Tropical Asia' (SysNet), was launched in late 1996, involving NARS teams from India, Philippines, Vietnam and Malaysia, and coordinated by the International Rice Research Institute (IRRI). The purpose of the project is, to develop methods of systems analysis for improving the scientific basis for land use planning (at sub-national level) in various eco-regions of Asia. Four study regions (Haryana, India; Kedah-Perlis, Malaysia, Ilocos Norte Province, Philippines and Can Tho Province, Vietnam) were identified.

Characterization of study regions

Haryana State in northern India, with a total area of 4.39 x 10^6 ha, experienced the full success of the green revolution with increases in the area under high yielding crop varieties from 0.9 to 2.7 x 10^6 ha and in food production from 2,600,000 to 10,500,000 tons (Agarwal & Roest, 1996). In recent years, this prosperous state, which has the second highest per capita income in India, is increasingly facing serious resource degradation problems which have partly resulted from intensified agricultural production systems. In the central and south-western region, canal irrigation in areas with brackish groundwater, and without drainage outlets has led to rising water tables, water logging and flooding, and secondary salinization. The water table is further declining in the semi-arid to arid eastern region, and in other areas with fresh groundwater.

The *Kedah-Perlis Region* in northern Malaysia is one of the most important agricultural areas in the country and is the major 'rice bowl', contributing 40% of national production. With a total land resource of 1.01 x10^6 ha, a population of 1.73 x10^6 and a labour force of 0.62 x10^6 it is one of the poorest regions in Malaysia (at 60% of national per capita income); moreover, large disparities in income exist within the region. Currently, about 52% of the total land resource is agricultural land. However, rapid transformation to manufacturing and tourism (currently 35% GDP; 47% employment) is taking place. Labour shortages and rising costs of production are seen as the most serious constraints to agriculture. Modernization of the agricultural sector, aiming at both more diversified production (high value crops) and intensification, is the declared goal. At the same time it is expected that the region maintains its level of contribution to rice production in support of the national target of 65% self-sufficiency.

Ilocos Norte Province in northwestern Luzon, Philippines, with a total land resource of nearly 0.34 x10^6 ha, is a region with large forest resources (46% of total area) and a relatively low population density. About 25% of the total area is classified as cropland. Based on 1994 data, there are 5.68 persons per ha cropland. Agriculture in the province basically consists of rice-based production systems with 33,000 ha planted to rice with irrigation and 24,600 ha rainfed. During the wet season, various crops such as corn, sugarcane, and vegetables are planted in the uplands. During the dry season, diversified cropping is practiced in the lowlands where tobacco, garlic, onion, corn, sweet pepper, and tomatoes, all under irrigation, are cultivated. As a result of excessive use of inputs (namely nitrogen fertilizer) on these dry season crops, leaching of nitrate has led to high nitrate concentrations in the groundwater. Agro-processing, ceramics and handicrafts are the major industrial activities in the Province. Major environmental problems are soil erosion on sloping land and groundwater pollution in the lowlands.

Can Tho Province, with a total area of 296,812 ha, is located in the central part of the Mekong Delta, Vietnam, 170 km southwest of Ho Chi Minh City. Total population of Can Tho in 1994 was 1.82 million. The Province is located in the monsoon climatic zone with a high temperature throughout the year. It has a very flat topography with fertile soils, and abundant fresh water sources. In 1994, about 83% of the total area was under arable farming, with the various rice cropping systems (69%) as the predominant land use type. The major physical constraints to economic development in Can Tho Province are:

- Annually, 200,000 ha is flooded from 0.3 to 1.5 m for 2-3 months;

- Part of the Long My district (about 7,000 ha) is intruded by brackish water for 3-4 months; and

- A large area of the Long My and Phung Hiep districts is affected by acid water from the acid sulphate soils at the beginning of each rainy season.

The aim for each case study was to explore technically feasible development pathways for the agricultural sector in a region, while giving full weight to the different socio-economic, biological and physical boundary conditions as well as to the different goals of the community. Such analysis should reveal to what extent the various goals can be met, given the major constraints, and provide estimates of the trade-offs between costs and benefits incurred in order to attain the various goals.

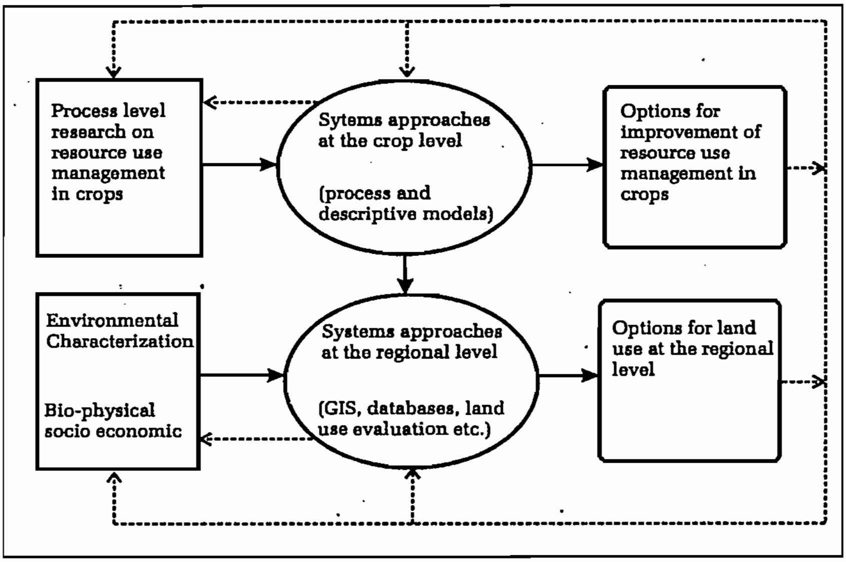


Figure 3. Structure of ecoregional research in support of natural resource management and land use planning.

Origin, key accomplishments and future thrusts

Origin

During the last phase of the project 'Systems Analysis and Simulation for Rice Production'

(SARP) (Aggarwal et al., 1996) it was found that there is an urgent need in south and southeast Asia to apply systems approaches at regional scale levels. This is in order to analyse conflicts arising from required production increases and natural resource management for larger areas and in different socio-economic environments (Figure 3). A conceptual framework for such analyses was elaborated, among others, by FAO (1995) following recommendations made by the Commission on Sustainable Development, Chapter 10, Agenda 21 (Kwakernaak, 1995; Johnson, 1993).

Figure 3 illustrates two aspects. Firstly, methodologies and tools need to be developed for scaling up and integrating knowledge on production ecology and natural resource management generated at plant and field level. Secondly, research priorities at lower levels of integration may be guided by results obtained for the regional level.

Three major project outputs have been defined for SysNet:

1. (intermediate output) Crop models identified/developed and evaluated for yield estimation at different scales.

2. Options for agricultural land use explored at four representative domains in tropical Asia.

3. Teams of trained scientists who can apply systems analysis techniques at the regional level to identify development potential and opportunities.

SysNet key accomplishments by output

Output 1:

- Development of a preliminary Asian version (6.0.1) of the generic crop growth simulation model WOFOST for estimating potential, water- and nutrient-limited yields for a range of tropical crops.

- Evaluation of preliminary version WOFOST 6.0.1 for various rice cultivars (potential production situation) and comparison with other models (e.g. ORYZA1 and ORYZA_W).

- Incorporation of additional input data and modification of subroutines of the generic crop growth simulation model according to requirements by the various SysNet partners (WOFOST version 7.0).

Output 2:

- Stakeholder awareness: consultative workshops were held with stakeholders in Ilocos Norte and Can Tho on the nature of the case studies and the type of quantitative information required for carrying out the case studies; key institutions in the region were consulted by SysNet teams in Malaysia and India.

- Development of databases for case study regions (pilot studies): two zones in Haryana; Kedah-Perlis; Batac municipality, Ilocos Norte; and five subregions in Cantho Province.

- Agreement by all teams on a common approach for exploring land use options at regional level. Linear programming models were developed and applied to the four study regions during a IRRI SysNet workshop held on 23 Sep to 3 Oct 1997.

Output 3:

-Additional scientists were recruited to fill gaps in the composition of four multi-disciplinary NARS research teams that had been formed according to the decisions made at the 'Systems Approaches Planning Meeting' held at IRRI in December 1996.

- Four SysNet Training Courses on Regional Systems Analysis Methodology and Tools (Simulation models, GIS, Linear Programming) were held at

- IARI, New Dehli, India, March 10-17, 1997

- PhilRice, Muñoz, Nueva Ecija, Philippines, April 28 to May 1, 1997

- CLRRI, O Mon, Vietnam, June 9-14, 1997 and

- MARDI, Serdang, Selangor, Malaysia, August 25-29, 1997

- A workshop on linear programming models with participation of all teams was held at IRRI, 23 Sep to 3 Oct 1997.

-Various training manuals on Regional Systems Analysis Tools were produced: WOFOST 6.0.1 documentation and exercises; Linear Programming (theory), Linear Programming exercises with Excel and, on Multiple Goal Linear Programming theory and exercises using OMP software package were developed.

Future thrusts

Output 1: Crop model calibration and evaluation for other crops than rice; documentation of generic crop model and of evaluation results; further development and evaluation of the module for assessing attainable yields under given N, P, K nutrient supply; development of interpolation, combination and aggregation algorithms of the various data needed for assessing regional production potentials within a GIS framework.

Output 2: LP models developed during IRRI workshop (23 Sep – 3 Oct 1997) will be further elaborated. Results of four case studies to be presented at the International Workshop on Methodology at Can Tho, Vietnam (June 1998) with feedback from stakeholders (participants include stakeholders from more than 12 provinces of the Mekong Delta, Sysnet teams from the four countries and IRRI, and SysNet International Steering Committee).

Output 3: In-country training on LP modelling and on GIS techniques all SysNet teams; Individual training abroad on region-specific topics (e.g. on 'environmental modelling'): four in-country workshops on model development are scheduled for the first half of 1998.

Systems methodology on ecoregional land use planning in support of natural resource management

General methodology and concepts of explorative land use systems analysis at regional level

Why a systems analysis approach?

Systems approaches may have different objectives, e.g. conceptualization, explanation, prediction, exploration or planning (Rabbinge, 1995). Early examples of applying systems analysis and simulation to agricultural problems include dynamic crop growth simulation models, which integrate the physical, chemical and physiological processes that determine crop growth to explain crop performance and production. More recently, models have been used to explore land use options for agricultural development and to support natural resource management at a regional level. Such models do not explain but formalize the analysis of land use systems to confront various objectives (goals) and constraints in a quantitative manner. Models based on the concepts of systems analysis have the common feature of bridging various hierarchical levels of understanding and, therefore, integrate knowledge from different disciplines (Rabbinge et al., 1994; Bouma et al., 1995).

In prognostic studies in general, as well as in studies on the future of the land, different types of studies (Figure 4) and techniques can be distinguished (Haggett, 1983; Van Ittersum et al., in press), depending on the purpose. If the purpose of the study is to forecast daily weather, for instance, the techniques and models applied in the analysis will be quite different from those applied in analysing the consequences of alternative scenarios on population and economic growth and associated estimates on carbon dioxide emissions, atmospheric concentrations and climatic change. For short-term weather forecasts, physical models simulating atmospheric dynamics are applied, fed with measured data from various layers and locations of the atmosphere system to predict the weather of the next 1-7 days. The accuracy of the forecasts decreases rapidly beyond the time horizon of 7 days due to the short-time scale for processes involved and the error propagation of inaccurate data from day zero onwards. For short-term forecasts of daily weather, the detail (what, when, where) is important. Such detail cannot be aimed at in medium- or long-range forecasts which rely heavily on statistical analysis based on seasonal or pluri-annual cyclical tendencies, with often limited value for forecasting (Lamb, 1995).

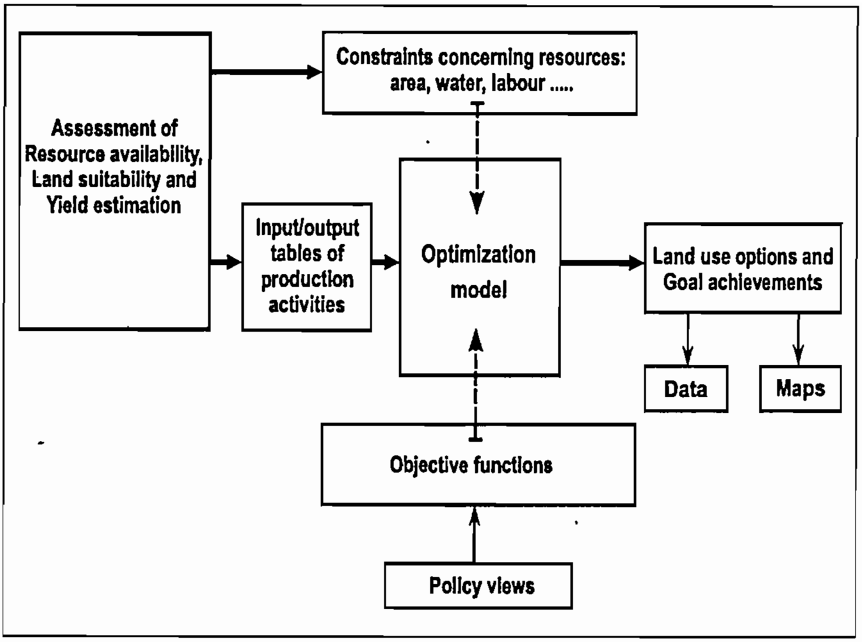


Figure 4. Types of prognostic studie.

For the much more complex systems describing climate change, a number of techniques are combined, such as trend projection for population growth, scenarios on carbon dioxide emissions, and coupled ocean-atmosphere general circulation models for estimating the effects on changes in temperature, solar radiation and rainfall. Many of the processes involved in climatic change are not well understood and many of the required data for gaining a better understanding are lacking; therefore, explorations (what-if) are conducted to learn about the possible range of quantified consequences of various alternative scenarios on a given process or phenomenon.

Hence, depending on the complexity of the system and/or the uncertainties in the various data required, and the required detail in the results, different techniques, such as scenario analysis, simulation, sensitivity analysis, projections or expert judgment may be distinguished.

Exploring land use options

Land use planning is a process aimed at finding the best use of land in view of the objectives expressed by the community of land users, associated environmental and societal aspirations and constraints, and at determining appropriate measures to implement required changes in land use (GTZ, 1995). Explorative studies are an important component in this process and a widely accepted approach is to make use of multiple goal linear programming techniques for integrating biophysical and socio-economic information (FAO, 1995).

The general approach for exploring land use options under multiple goals in support of land use planning at a regional level has been described in detail by De Wit et al. (1988), Van Keulen (1990, 1993), Rabbinge & Van Latesteijn (1992) and Rabbinge (1995) with multiple goal linear programming (MGLP) models as the centre-piece (Figure 5). These models allow biophysical and technical possibilities and constraints to be confronted with the largely socio-economic, value-driven objectives of stakeholders (Figure 6). Illustrative examples of applications of this systems approach with particular

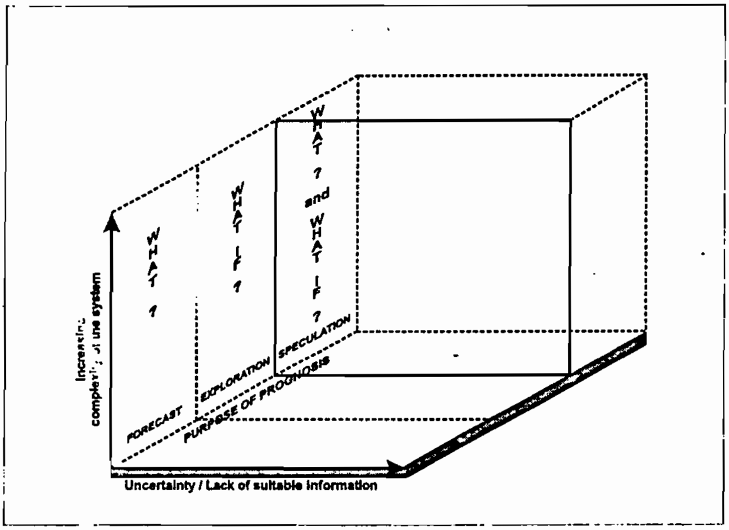


Figure 5. General methodology for explorative land use studies.

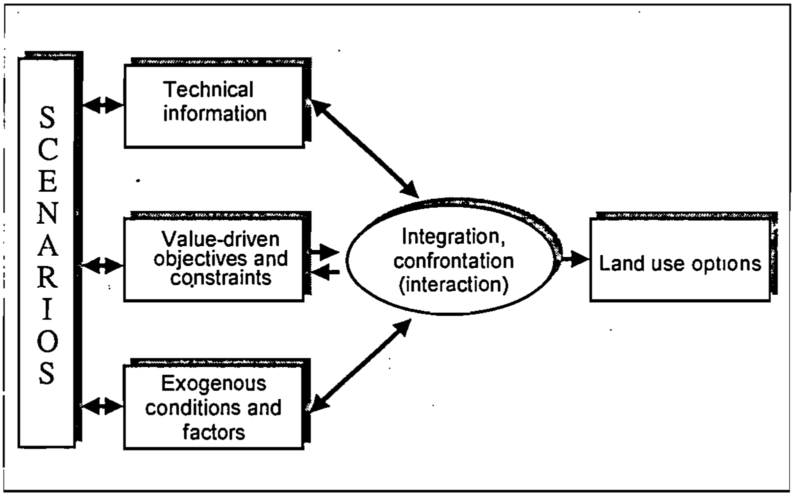


Figure 6. Concepts under-lying the Interactive Multiple Goal Linear Programming technique.

emphasis on natural resource management at a regional level have been given, among others, by Hoanh et al. (1997), Jansen et al. (1997) and Van Ittersum & Rabbinge (1997).

The general building blocks include: (*i*) quantitative land evaluation, providing an assessment of the suitability of land for the various use forms and estimates of potential and attainable yields or production for land units that are relatively homogeneous in terms of climate, soils and hydrological conditions; (*ii*) quantification on input-output relations for all relevant (current and possible future) production activities (incl. physical and monetary in- and output) for each land unit; (*iii*) application of an integrative tool, IMGLP, a linear programming (optimization) technique with several objective functions. When running an MGLP model for one policy scenario (comprising a set of goals expressed as objectives and translated into objective functions), one objective is optimized (maximize total gross revenue from agricultural activities), while the other objectives represent constraints (e.g. required rice production) to optimize that goal (Table 1).

Upper and lower bounds can be put on these 'goal constraints'. For each policy view scenario, the consequent land use allocation (land use option) can be generated. Each option thus represents the consequences on land use of optimizing and defining bounds for a given combination of objectives considered relevant to regional development. Objectives (maximize, minimize goals x, y, z etc.) are referred to as the technical term for expressing goals for a given region (e.g. increase in total annual rice production).

In principle, a large number of goal variables may be defined for optimization or the setting of minimum requirements; in practice, only few of these variables are optimized (maximized or minimized), the remainder serve to ascertain that predefined upper or lower limits are taken into account. The conceptual framework underlying IMGLP is illustrated in Figure 6.

A set of concepts in production ecology has been developed over the past 25 years (Rabbinge, 1986). Those applied for analysis of agricultural input-output combinations may be characterized as follows (Van Ittersum & Rabbinge, 1997, p. 198):

Production level:Level of primary output per unit area.

Production activity:Cultivation of a crop or crop rotation in a particular physical environment completely specified by its inputs and outputs.

Production technique:Complete set of agronomic inputs.

Production orientation:Value-driven aims and restrictions of the production activity that direct the output and input levels.

Table 1 Simplified example of a setting for a regional MGLP model run.

	Variable	Objective	'Goal restriction' (constraint)
I. Goal to be optimize	Total gross revenue from agricultural ctivities	Maximize attainable total gross revenue	
II. Goal restrictions (constraints)			
Constraint 1	I migration		<=50000 persons
Constraint 2	Rice production in a normal year		>42000 ton
Constraint 3	Employment		>336000man-years

In an MGLP mode applied for exploring sustainable land use options at the regional level, the *technical information* that quantifies input-output relations for current and alternative production activities, is integrated with a set of *objectives* for a given region and the various *constraints*, taking into account *exogenous* boundary *conditions*. Decision-makers and various interest groups are confronted with the consequences of multiple, conflicting goals. If there is, for instance, no feasible solution for optimizing land use under the specified targets, the modelling becomes interactive: value-driven objectives need to be reformulated in consultation with stakeholders, or additional production activities need to be considered, or the assumptions made on socio-economic boundary conditions need to be adjusted. This may finally lead to a modified (policy) scenario, which consists of a specific set of objectives, exogenous conditions and technical information. A land use option represents the consequences of optimizing land use allocation for a given regional scenario.

Among the various tools for multiple criteria analysis, the IMGLP technique has the advantage that no *a priori* specified goals are required, a progressive definition of preferences is possible and that the trade-offs among the various goals can be assessed (Table 2).

Methodology and tools applied in SysNet

The underlying theme of the SysNet Project is land use planning in support of regional agricultural development based on the criteria for sustainable development: economically viable, environmentally sound and socially acceptable. Within this framework, the obvious goals in rural environments for increasing food production, increasing net income for farmers and non-farmers in the community, and the various region-specific needs of improving/maintaining the quality of the natural resource base are conflicting under the given constraints, at least in the short- to medium-term.

An integrated approach to land use planning entails the participation and comprehensive cooperation of partners and stakeholders (institutions and groups) at national, provincial and local levels in decision-making concerning land resources planning and management.

The methodology to be developed in SysNet has to cover various aspects. At the core is the challenge to develop a general framework for identifying production activities that fulfil pre-determined criteria for sustainable agricultural development in a given region. The scientific-technical aspect comprises the quantification of input – output relations of the various production activities that are relevant to a given set of objectives representing a possible pathway for sustainable land use. These data are fed into an optimization model to generate optimum land use allocation for a given set of multiple goals. The tools that will be developed and applied to four regional case studies include simulation models, Technical Coefficient Generators, GIS techniques, and Multiple Goal Linear Programming models. The number and type of scenarios to be analysed as well as their results need to be discussed in close collaboration with the various stakeholders of the region in order to have any impact. This requires involvement of stakeholders from the early stages of the project and frequent interactions.

Table 2. Overview of tools for multiple criteria analysis.

Tool	Pareto optimal solutions	priori specified goal		Distance function	Trade-offs	Progressive definition of preferences
		Absolute	Relative			
LGP	X	X				
WGP	X		X			
CP	X		X	X		
MOP	X				X	
IMGLP	X			X	X	X

LGP: Lexicographic Goal Programming
MOP: Multi-Objective Programming
WGP : Weighed Goal Programming
IMGLP: Interactive Multiple Goal Linear Programming
CP: Compromise Programming

In SysNet, the methodology for explorative land use studies is developed for the sub-national level. The regions are states or provinces and the policy views and derived objectives vary among the four study regions (Table 3). For instance, maximizing agricultural employment is not a relevant objective for Kedah-Perlis region, or, minimizing soil loss is an important objective for Ilocos Norte, while it is not considered relevant for Haryana and Can Tho.

Spatial modelling (GIS technique) is essential for generating input to the MGLP model as well as for presenting the spatial pattern of the resulting land use allocation (Figure 7). Input-output relations from plot and farm levels need to be aggregated to biophysically and/or socio-economically defined land units. GIS techniques are also required to integrate the various data types and generate new data

Table 3. Objectives as identified for the four SysNet study regions

OBJECTIVES	HARYANA (INDIA)	KEDAH (MALAYSIA)	ILOCOS (PHILIPPINES)	CAN THO (VIETNAM)	RRB
Maximize Income	x	x	x	x	?
Maximize Food Production	x	x	x	x	?
Maximize Non-Food Agricultural Production	x	x	-	x	?
Maximize Labour Productivity	x	x	x	x	?
Maximize Land Productivity	x	x	x	x	?
Maximize Input Use Efficiency (Fertilizer, Pesticide)	x	x	x	x	?
Maximize Water Use Efficiency	x	x	x	x	?
Maximize Employment in Agriculture	x	-	x	x	?
Maximize Equity					
a) income	?	-	(x)	x	?
b) food production per capita	(x)		x	-	?
Minimize Pesticide Use	x	x	x	x	?
Minimize N Loss	x	x	x	x	?
Minimize Soil Loss	-	(x)	x	-	?
Minimize Water Use	x	x	x	x	?
Minimize Agricultural Employment	-	x	-	-	?
Minimize Fertilizer Use	-	x	-	-	?

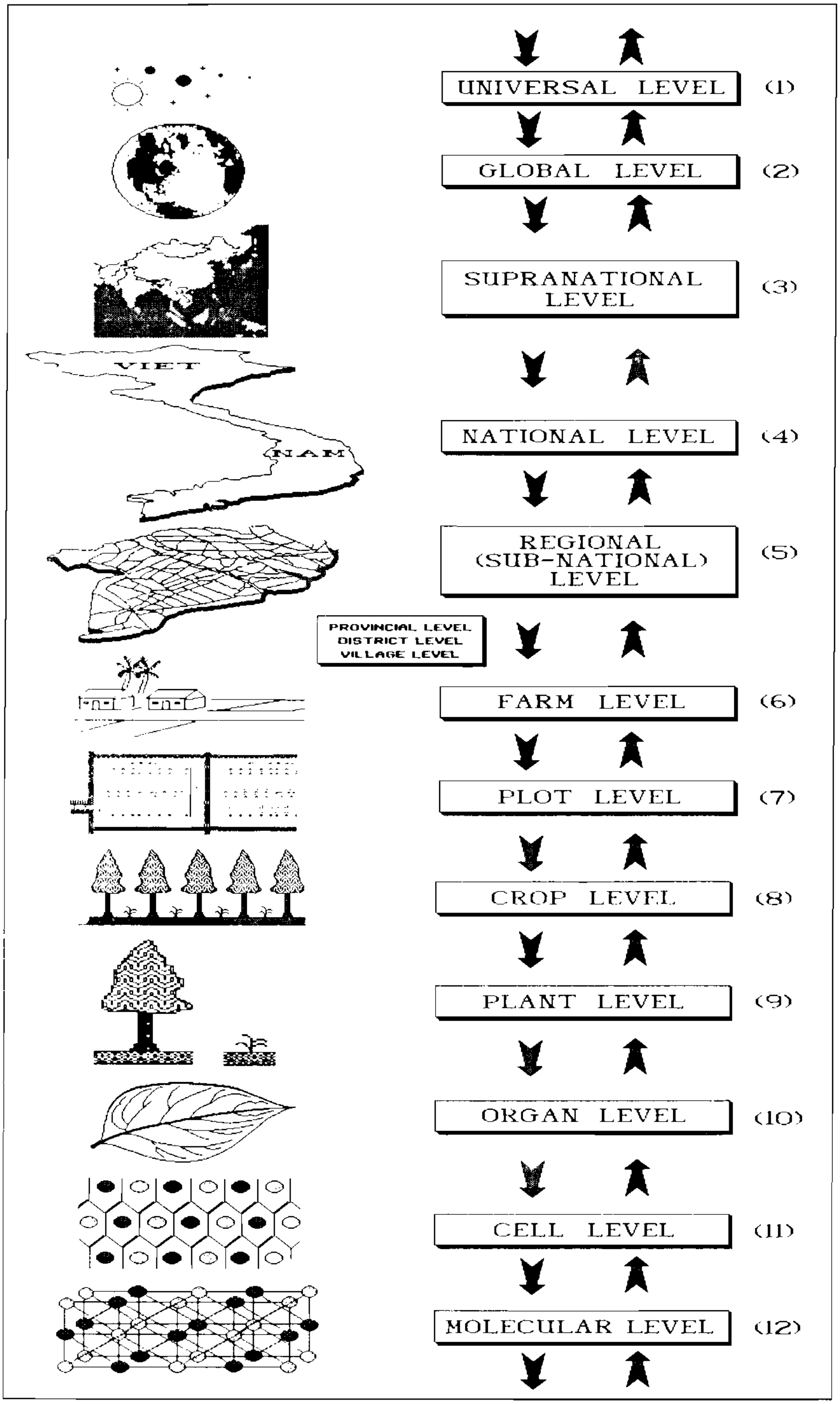
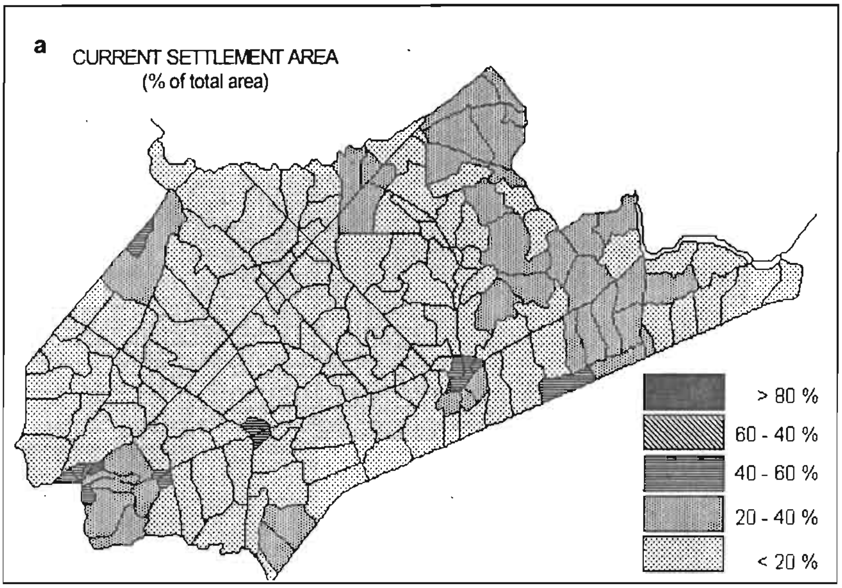


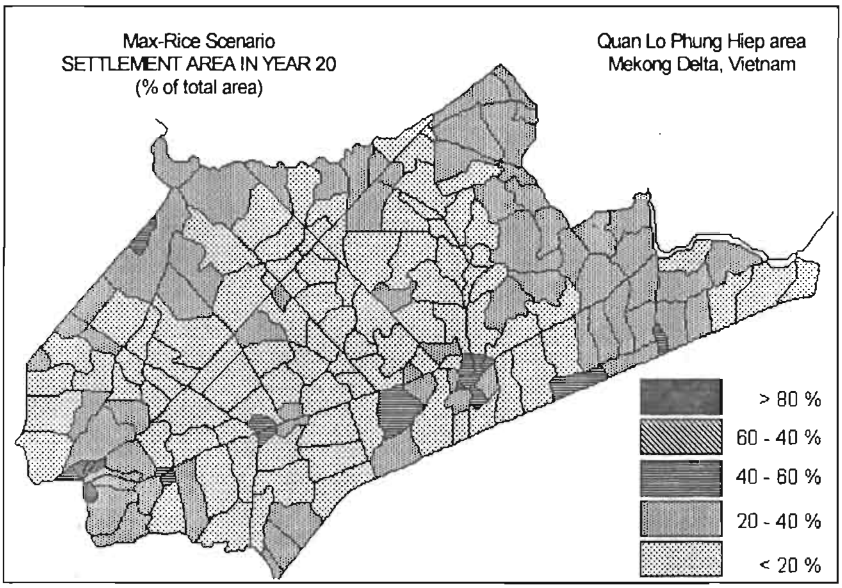
Figure 7. Levels in spatial modelling (Source: Hoanh, 1996).

surfaces (such as estimated annual soil loss ha^{-1}). Information and knowledge from different levels are integrated in crop growth models for simulating potential and attainable yields. The generic simulation model WOFOST (Hijmans et al., 1994), being evaluated for that purpose, distinguishes potential, water and nutrient-limited production situations. Potential production is solely defined by the crop characteristics related to physiology and phenology of the plant, solar radiation and temperature at optimum supply of all inputs. When water supply is limiting and the availability of macro-nutrients is sub-optimum, the situations are called water and nutrient-limited production. The attainable production level is defined by the limiting factors water, nitrogen and phosphorus. The difference between attainable and actual yields is caused by growth-reducing factors such as pests, pollutants and calamities (e.g. typhoons).

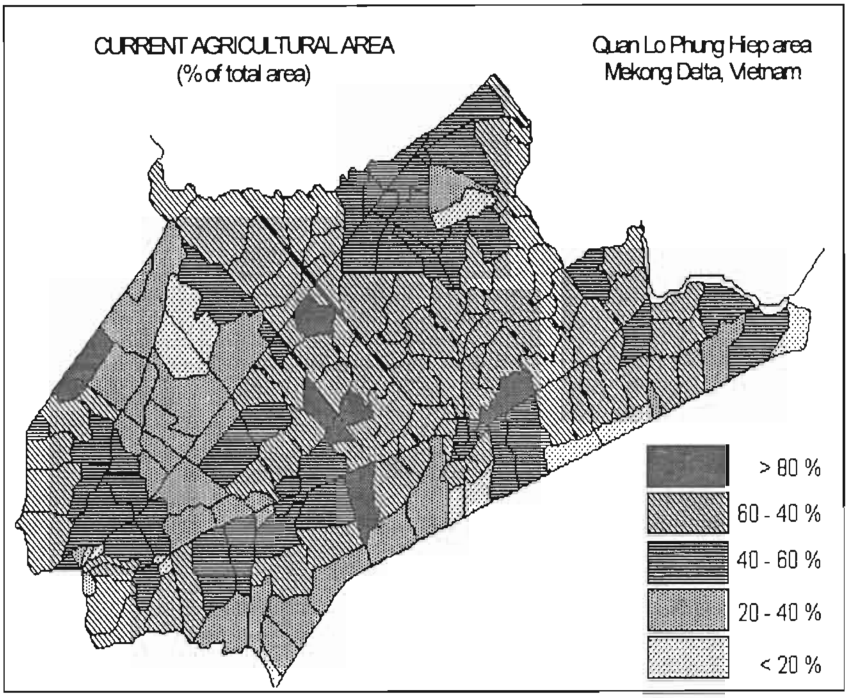
Potential yields can be raised by new cultivars, while the gap between potential and attainable yields can be narrowed by (more efficient) use of water and nutrients. The gap between attainable and actual yields can be narrowed by yield-protecting measures, which are often exchangeable (such as labour, mechanization and pesticides). Though formal simulation models are being developed for various annual crops (cultivars) for most perennials, simpler yield models and expert judgment will be used for estimating potential and attainable yields.

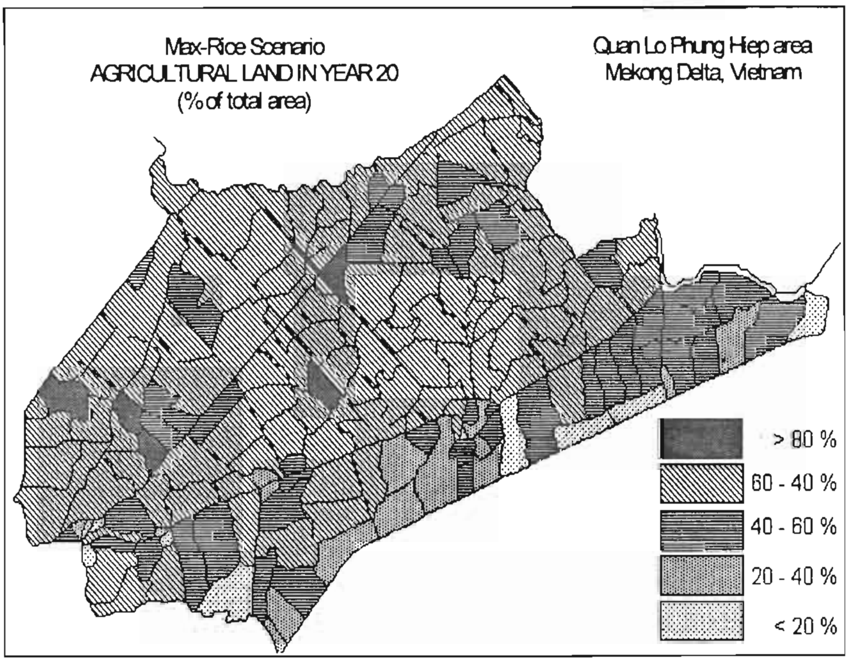
A simple example of an output is illustrated by four maps (Figure 8, a-d), showing current and future (20 years from now) percentage of agricultural and built-up (settlement) area per land mapping unit for the Quan Lo Phung Hiep area (Mekong Delta, Vietnam) under a given set of multiple and, partly, conflicting goals.





Figures 8. Land allocation from multiple goal exercise: Maximum Rice Production Scenario (time horizon: 20 years): (a) current agricultural area, (b) agricultural land in year 20, (c) current settlement area (d) settlement area in year 20.


CURRENT AGRICULTURAL AREA
(% of total area)
Quan Lo Phung Hiep area
Mekong Delta, Vietnam
> 80 %
60 - 40 %
40 - 60 %
20 - 40 %
< 20 %


Max-Rice Scenario
AGRICULTURAL LAND IN YEAR 20
(% of total area)
Quan Lo Phung Hiep area
Mekong Delta, Vietnam
> 80 %
60 - 40 %
40 - 60 %
20 - 40 %
< 20 %

The output illustrates changes (%) in agricultural and settlement are per land mapping unit – units homogeneous in soil and hydrological conditions - for the maximum rice production scenario. Increase in rice production is emphasized, while the three other goals ('land use strategies') taken into account represent goal restrictions, like increased income from rice production, crop diversification and minimizing effects of acid water (Hoanh, 1996, p. 96). For year 20 as for all other years in the time series, target values were defined for the various goals relevant to the region. While the change in agricultural area mainly depends on how well biophysical conditions can be improved by water management, the change in settlement area also depends on natural population growth rate and migration – the latter triggered by changes in income.

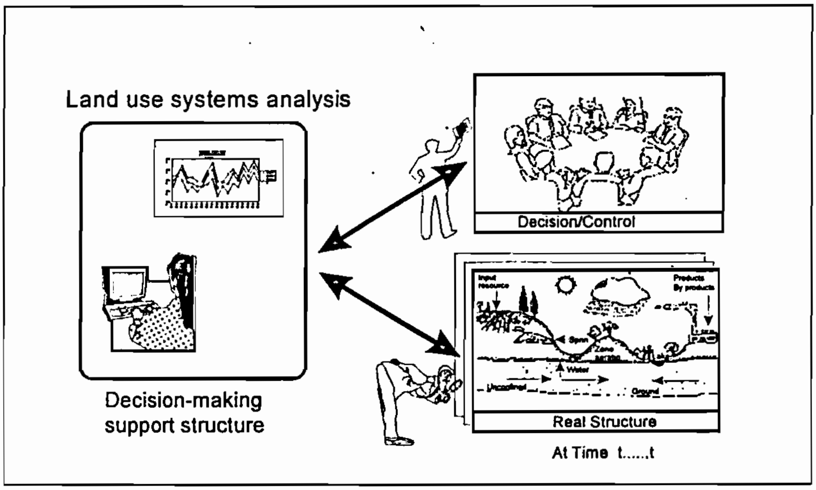


Figure 9. Schematic diagram of 'Real', 'Control' and 'Decision-Support' structures in agro-ecosystems.

The final aim of the SysNet Project is to come up with decision – making support structures for sustainable land use in the four study regions. Through land use systems analysis as described in the previous sections, an attempt is made to link the wealth of information generated on natural resource management at the plot level ('by the magnifying glass') with the information needs of decision makers dealing with land use planning (Figure 9).

Application of the methodology to the Red River Basin (RRB)

Specific features of the RRB: an overview

The Red River Basin (RRB) is the largest and most important basin in the north part of Vietnam (Figure 10) with a total area of 169,000 km^2 of which 86,000 km^2 is located in Vietnamese territory. The mountainous, midland and delta areas in the Vietnamese portion of the basin cover 60,000 km^2, 9,000 km^2 and 17,000 km^2, respectively. The RRB may be divided into 4 agro-ecological zones: the North East (3.4 x10^6 ha), the North-Vietnam Hoang Lien Son (3.3 x10^6 ha), the North West (3.6 x10^6 ha) and the Red River Delta (1.2 x10^{6}ha) (NIAPP, 1995).

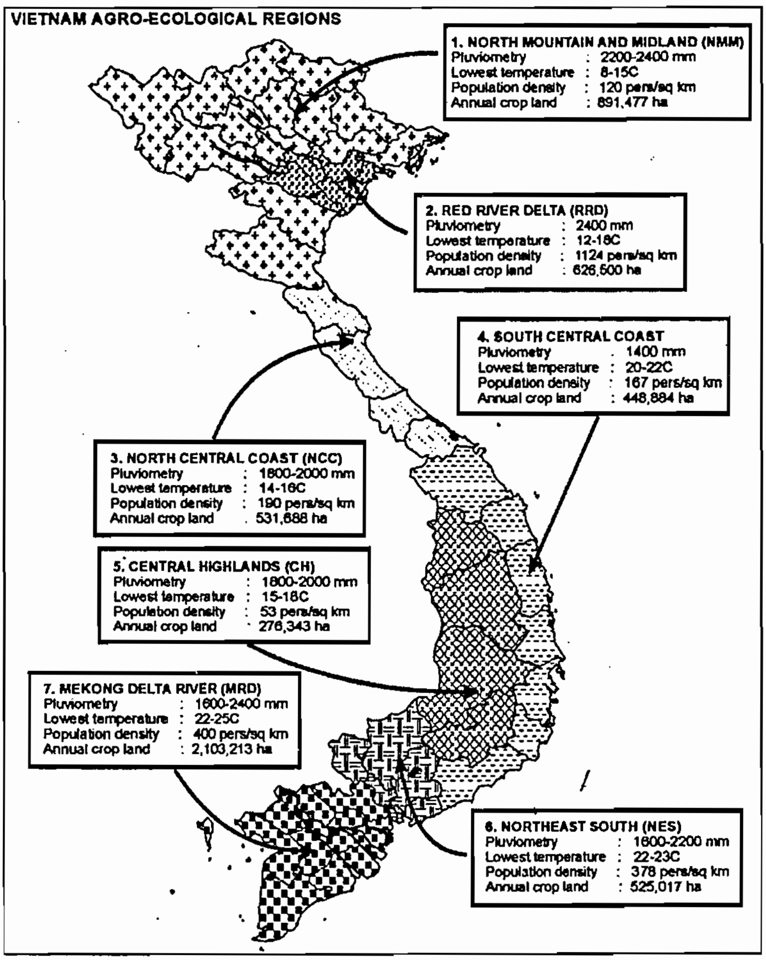


Figure 10. Vietnam: Broad agro-ecological zones.

River flows appear to be sufficient to meet foreseeable demands for irrigation and water supply in all seasons. Abundant hydro-electric resources are available in the basin, with a potential of 100 billion kwh per year. All river banks have been diked, some for centuries. Flooding in the delta is generally caused either by a breaching of dikes or diversion into designed flood detention areas to protect key economic zones (World Bank et al., 1996).

The total agricultural land in the basin is 1.8 million ha, of which 1.5 million ha is annual crops, mainly two or three crops of paddy, or one paddy with one or two subsidiary crops. About 1,6 million ha is covered by tropical forest.

In 1995, the total population in the basin was 24.5 million, of which 21 million were rural and 3.5 million were urban. Annual population growth rate is 2.2%. There are 27 ethnic minorities living in the highlands and midlands while the 'Kinh (Vietnamese)' are of majority in the Delta. About 17 million people is living in the Delta, where agriculture is intensively developed with approximately 1.0 million ha, including 0.7 million supported by extensive irrigation infrastructure. Average agricultural land per capita is 0.07 ha, and average holding per household is only 0.3 ha.

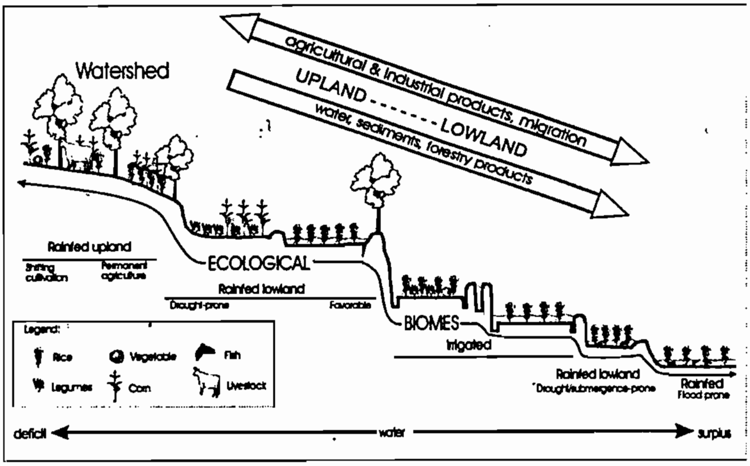
Average GDP per capita in 1993 was estimated at 148 US$ in the Delta, and much lower in the midlands and highlands. The Vietnam Living Standards Survey in 1992-1993 reports that 60% of the rural population lives in poverty conditions.

Adaptation of SysNet methodology to the RRB: a conceptual model for land use planning

<u>The issues in land use</u>

The most important issue in the RRB is the severe imbalances which can occur in the social economy of the people. Water is not the issue, land is not the issue, the issue is too many people in agriculture (Red River Delta Master Plan, Binnie & Partners, 1995).

The long-term outlook for the RRB is an economic structure similar to that of developed nations, with about 5% of population in agriculture and 80% urban. Moving from the current 15% urban to the future 80% urban will lead to several problems in urbanization, such as urban employment, income disparities, environmental pollution, etc.



LAND USE CHANGES DRIVEN BY MARKET FORCES

Figure 11. Land use changes and relevant processes to be considered for the Red River Basin.

Interactions between the uplands, midlands and lowlands (Figure 11) become more and more significant in the RRB. Beside the physical flows (of water, sediments, forest products, agricultural products, industrial products, migration, etc.), the intellectual flows (culture, lifestyle, etc.) between these zones, in particular from the lowlands to the uplands will become more and more significant under the expected economic development.

<u>The objectives</u>

Many objectives in the list of objectives of the four SysNet case studies (Table 3) can be adopted for the RRB. Taking into account the major issues of the RRB, in particular 'too many people in agriculture', the most important objectives of land use planning in the RRB could be to maximize income, to maximize income equity, and to maximize employment in agriculture for current situations.

However, in the long term, the ultimate objective may be to minimize agricultural employment in support of urbanization and industrialization. Moreover, taking into account the low agricultural productivity in the RRB compared with other regions, such as the Mekong Delta, objectives relating to environmental impacts, such as minimized N loss and minimized soil loss, are important for sustainable development in the area.

<u>Land use and production systems</u>

In general, land use in Vietnam is classified into agricultural land, forest land, rural residential areas, urban land, land for specialized use and unused land. While agricultural land decreased year by year due to the expansion of residential and urban land, about 6 million ha in the RRB are bare hills or mountains.

Production systems in the RRB comprise agricultural cropping systems, aquaculture activities and forestry. Annual crops are important in all the three zones, highlands, midlands and lowlands, while perennial crops are dominant in the first two zones. Selection of relevant production systems for current situation and promising production systems for the future, and setting input/output table for each production system is a great challenge in developing a conceptual model for land use planning, since the economic situation is changing rapidly in the whole basin.

Constraints to agricultural land use

People in the RRB have found several alternatives to overcome the salient natural resource constraints. Application of fertilizer, flood control and irrigation have been practiced for a long time, and many natural resource management projects have been implemented successfully, such as the flood control systems.

Socio-economic constraints are becoming more and more important to agriculture and rural development during the reform process towards a free market system. Main constraints are improper land management system (small land area per household and tiny plots), lack of capital and weak marketing system. With increased production in recent years, the latter constraint is likely the most important. To improve the marketing system, confidence between farmers and trade companies would have to be created. Under stable market conditions, the input/output ratio for production was predicted more accurately and uncertainties was anticipated to diminish with optimized land use.

Policy view scenarios

Although food crops are still important in the RRB, the targets or orientation of agriculture in the RRB has shifted from self-sufficiency in food production to export. Scenarios for agricultural land use in the RRB could be (*i*) food security oriented scenario; (*ii*) diversification for internal market; and (*iii*) diversification for export. These scenarios can also be considered as different phases in rural development.

Conclusions

The purpose of SysNet is to improve the scientific basis for land use planning at sub-national level. The general methodology for explorative land use analysis is characterized by the Interactive Multiple Goal Linear Programming Technique (IMGLP) for integrating quantitative information on land suitability, input-output relationships for relevant production activities with socio-economic constraints and objective functions for different sets of goals (scenarios). Specific methodology will be developed for each of the four case studies, taking into account the natural and socio-economic conditions at the site. As such, the methodology can be adapted for application to natural resource management problems, as identified for the Red River Basin. Such application will be a test on applicability of the SysNet methodology to another region with specific conditions, and is likely to contribute to a better understanding of natural resource management in this region.

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Section B

On-going and proposed NRM research in the Red River Basin

Eco-agricultural research and development activities of the Vietnam Agricultural Science Institute in the Red River Delta

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Introduction

The Red River Delta (RRD) plays an important role in the economic, social, political and cultural development of Vietnam. It is also the craddle of Vietnamese traditional culture. Although many years have passed with various historical events, the area has not only developed but also successfully retained its specific traditions and culture. The government of Vietnam has, particularly during the last 10 years, spent much effort on all aspects of the development of this important area of the country.

The Vietnam Agricultural Science Institute (VASI) was founded in 1952, and has since been the leading institution in the training and research on agricultural and rural development. It has greatly contributed to the agricultural and rural development in the whole country, especially in the Red River Delta. The institute's activities concerning the Delta's eco-agricultural development and research have been carried out during different periods of the country's economic development:

- The land reform period, 1953- 1954;

- The Cooperative construction period, 1960- 1963;

- At the time of the adoption of order No. 100 of the government, granting certificates of land use to the farmers; and

- After the adoption of resolution No. 10 of the government on granting certificates for long- term use of land to farmers, 1993.

In this paper, the research and development activities of VASI on eco-agriculture in the Red River Delta during the last 10 years will be described.

Research and development activities and outputs

In terms of rice production, the RRD ranks second in the whole country and first in the North. The area comprises the provinces/cities of Ha Noi, Hai Phong, Thai Binh, Nam Dinh, Ha Nam, Ninh Binh, Ha Tay, Hai Duong, Hung Yen and parts of Vinh Phuc, Phu Tho, Bac Ninh, Bac Giang, and Quang Ninh, with a total area of 16,644 km^2 and a total population of about 17 million, of which 73% are rural.

Aiming at sustainable development, VASI's activities are concentrated on two aspects: ecosystem sustainability and socio- economic sustainability.

Research for development of cropping systems, animal raising and agro- products processing

In 1988, VASI carried out comprehensive research and analyses in order to identify the principal factors affecting agricultural and rural development in the RRD. Based on the results, the Ministry of Agriculture and Food Industry (now changed to Ministry of Agriculture and Rural Development) gave instructions to develop a plan for the area's development. Focussing on eight selected cooperatives representing different agro - ecosystems in the area, the Institute identified the main factors affecting agricultural production in the RRD to be:

- Organic matter availability (i.e. number of pigs per hectare of crops). This factor indicates the intensity level of the agricultural production;

- The area of winter cropping per total farm area, and the labour force per ha. This indicates the level of agricultural diversification; and

- The amount of agricultural labour force and commodity agricultural products. This indicates the commodity character of agricultural products.

The agro-ecosystems in the RRD are not uniform. Four different agro-ecosystems may be observed:

- Intensive cropping systems in fertile land with fresh alluvium (comprising 24 districts);

- Semi-hilly less fertile areas and degraded soils on old alluvium (11 districts);

- Low lying areas subject to flooding (22 districts); and

- Saline areas (14 districts).

On the basis of the research results, VASI has participated in developing a programme for sustainable agricultural development in the RRD aimed at increasing the area for agricultural production to meet the demands of a constantly growing population. In 1988, the goal was set for rice production increase. Adaptation of new high yielding - varieties, resistant/tolerant to adverse conditions can be a low- input option for meeting this goal. Diversification of cropping patterns by planting winter crops can also contribute to increasing total agricultural production. Further, if properly managed, the winter crops can also help raise rice production. There are two main groups of winter crops:

- Early winter crops, such as corn or soybean (planted in October). These crops can be planted after early maturing summer -autumn rice.

- Late winter crops, e.g. vegetables, potato (planted in November). These can be grown in the land previously planted to late maturing rice.

Thus, winter crops are of great importance to both the domestic and the export markets.

In 1991- 1995, VASI coordinated a national research project concerning cropping systems in the RRD. Its activities focussed mainly on assessing, and identifying solutions for increasing the economic outputs of different ecosystems, such as:

- Deep water systems of low lying fields;

- High-and medium-elevation fields;

- Cropping systems on river levees and river banks between dikes; and

- Cropping systems on saline and acid sulfate soils.

Generally, the cropping patterns do not vary much between these four ecosystems. Most of the irrigated land area are planted with one or two rice crops and some other crop, e.g. short - duration industrial plants, while less rice is grown in the rainfed areas. The most popular crop rotations are:

- One rice crop. The land is left fallowed after harvest;

- Two rice crops: winter- spring and summer- autumn;

- Two rice crops and one non-rice crop: winter-spring and summer-autumn rice + a winter non-rice crop;

- One rice crop and one non- rice crop: summer- autumn rice + a spring non- rice crop;

- One rice crop and two non- rice crops: a spring non- rice crop + summer- autumn rice + a winter non- rice crop; and

- Three non-rice crops.

The economic outputs of these patterns vary between ecosystems and sub- regions.. However, the following remarks can be made for the whole Delta:

- The total value of agricultural production and the gross output are proportional to the number of crops per year.

- Monocropping of rice gives lower economic output compared to multi-cropping rotations, and the highest value is given by the last crop rotation mentioned above.

Rice yields are also variable between different sub- regions. According to the General Statistical Office (1996) the highest provincial average of rice yield was obtained in Thai Binh with 4.97 t ha^{-1}, and the lowest, in Ninh Binh with 3.65 t ha^{-1} (26.4% lower).

Differences in rice yields are also observed between different fields within a sub-region depending on land fertility, and between farming households. This indicates that rice yields can be further increased.

One possibility for increasing total agricultural production is to introduce more winter crops (at present, only about 23-26% of the cultivated area). However, various problems must be solved to expand the winter crop area, such as water management, farming investments, and product processing and marketing.

Thus, VASI also participated in identifying and developing appropriate cropping patterns for the RRD, aiming not only at food security but also at increasing the production of fruits and industrial plants (Table 1). VASI also proposed alternatives for increasing land use efficiency as the cultivated land area is shrinking due to urbanization, industrialization and increased development of the transport system.

Research on varietal improvement and development of agricultural techniques

One of the important strategies for rapidly increasing agricultural productivity is to develop intensive agriculture for growing crops as well for animal raising. This strategy involves the activities described below.

Table 1. Proposed cropping patterns and their constraints.

Field type	Current cropping patterns	Proposed cropping patterns	Constraints	Solutions
Low elevation	- One rice crop - Two rice crops (unstable)	Deep parts: fish raising + fruit crops - Higher parts: Rice + fruit crops - Depressions: Rice + fish	- Capital limits - Technical limits - Unconsolidated land - Insecurity on food production	- Loan and credit from Agricultural Development Bank -Loan to poor farmers -Agricultural extension Appropriate land management and Agricultural policies
Medium	Two rice crops	Developing winter crops	- Drought in the winter - Capital and technical limits	Improvement of the water Management systems - Credit to poor farmers - Agricultural extension
Higher	One rice + one non-rice crop	- Another rice or non- rice crop	- Lack of irrigation system - Technical and capital limits	- Developing water manage- ment systems - Credit & loan to poor farmers - Agricultural extension
River's levees	- Non- rice or indus-trial crops - Only non-rice crops	- Further cropping intensifying - Monoculture of specific crops	- Old customs - Technical and capital limits - Lack of appropriate varieties	- Agricultural extension - Credit
Saline	- One rice and one non- rice crop - One rice crop	- Another rice crop	- Lack of fresh water - Saline water during spring	Development of water management systems

Source: Nguyen Duy Tinh and Nguyen Thi Hong Loan. pers. Comm.

Development of high- yielding varieties appropriate for each agro-ecoregion

VASI has spent efforts on developing high- yielding and good quality varieties, resistant to abiotic and biotic stresses. During 1991- 1995, many new varieties developed by the institute were approved by the Ministry of Agriculture and Rural Development for large- scale application in the RRD, such as for:

- Rice: VX- 83, V- 18, CRO- 1, 79- 1, NR- 11, X20, X21;
- Soybean: M- 103, DT- 80, AK- 05, VX- 92;
- Groundnut:V- 79, 4329;
- Potato: KT 2;
- Cassava: KM 60;
- Mung bean:004;
- Stevia:St 88.

Besides, 21 other varieties of rice, groundnut, soybean, cassava and mung bean have been approved for specific areas. Research for application of hybrid vigour in rice and animals has also been undertaken.

Each year, the institute has also introduced about 1,500 -2,000 accessions of various crops and micro- organisms for use in crop varietal improvement and for production of microbial products.

In recent years, research on new technologies has resulted in significant achievements in biological control of rats to reduce damages for various crops. Research on relationships between crops and pests and weeds as well as on the dynamics of the ecosystem is important not only for pest control by varietal improvement, but also for finding out the ways to reduce the damages, e.g. by improving the environmental conditions and changing the cropping patterns.

Development of winter crops is the main alternative for increasing the total cropped area. However, since 1990, the winter crop growing area has been stagnated. Further, there is a slight reduction in the areas of some winter crops (Table 2). Nevertheless, the productivity of some crops, such as rice and corn has increased due to intensification.

Research on improvement of water management system in the RRD

For the whole Delta, a good water management system has been developed since 1955. The irrigated areas unceasingly increased year by year, especially in the period of economic renovation. In 1995, a total of 1.29 million hectares of land were irrigated, including 0.63 million hectares of winter- spring rice, 0.66 million hectares of summer- autumn rice and 0.2

million hectares of other crops. However, the irrigation rate is still low (0.8 l s^{-1} ha^{-1}), while the requirement is much higher (1.2 l s^{-1} ha^{-1}). In addition, many canal systems are not sufficient to meet the irrigation demands, and in fact only 250.000 ha are properly irrigated.

Thus, the following activities must be done in order to meet the irrigation demand when the irrigated area increases from 180,000 to 200,000 ha in the coming years:

- Improving the existing irrigation systems; and

- Since the adoption of Resolution No. 10 by the Government, the cooperative systems have largely changed, hence the water management system must be changed accordingly.

VASI also carries out research on water management systems in different ecosystems in the RRD, and the following findings can be reported:

- In urban areas, there are various factors causing higher floods, such as the high rate of population growth, construction and industrialization, which limit the areas of water reservoirs and stuck the water draining systems.

In deepwater areas, flood is also an important factor affecting the crop yields. Moreover, in the low lying areas there is no area suitable for winter crops and hence agricultural production depends mainly on rice cropping. Improving or developing water management system for this area requires high investments, which obviously cannot be met by local budget.

Table 2. Area, yield and production of main food crops and short- duration industrial crops in the Red River Delta

Crops		Year					
		1990	1991	1992	1993	1994	1995
I.	Food crops						
	- Area (1000 ha)	1246.9	1262.7	1235.9	1233.3	1209.1	1209.6
	- Production (equals 1000 t rice)	4100.7	3456.7	4693.1	5388.1	4619.1	5073.3
1.	Rice						
	- Area (1000 ha)	1057.5	1013.8	1024.7	1033.5	1026.8	1042.1
	- Yields (100 kg ha^{-1})	34.2	29.3	40.0	46.8	40.1	44.4
	- Production (1000 t)	3618.1	3038.3	4101.6	4843.3	4121.4	4623.1
a	Winter- Spring rice						
	- Area (1000 ha)	513.1	494.7	503.0	505.1	509.8	511.9
	- Yields (100 kgha^{-1})	35.9	17.8	40.5	47.2	49.7	47.1
	- Production (1000 t)	1844.5	884.8	2039.0	2387.2	2533.4	2410.9
b	Summer- Autumn rice						
	- Area (1000 ha)	544.6	519.0	521.6	528.3	517.0	530.2
	- Yields (100 kg ha^{-1})	32.5	40.0	39.5	46.4	30.7	41.7
	- Production (1000 t)	1773.6	2145.2	2062.7	2456.1	1588.0	2212.2
2	Corn						
	- Area (1000 ha)	96.3	57.7	73.4	74.6	75.4	75.3
	- Yields (100 kg ha^{-1})	21.3	17.8	22.6	25.6	26.5	27.1
	- Production (1000 t)	148.1	113.2	166.3	191.4	200.1	203.6
II	Short- duration industrial crops						
	- Total area (1000 ha)	60.4	65.5	48.4	55.8	65.8	58.7
3	Groundnut						
	- Area (1000 ha)	21.1	19.1	17.5	17.5	20.7	17.7
	- Yields (100 kg ha^{-1})	10.4	10.3	9.0	12.5	10.5	13.0
	- Production (1000 t)	22.0	19.8	15.8	22.2	21.9	23.2
4	Soybean						
	- Area (1000 ha)	16.1	14.8	11.8	19.8	30.1	25.7
	- Yields (100 kg ha^{-1})	9.4	9.7	10.9	10.7	10.3	11.4
	- Production (1000 t)	15.1	14.4	13.0	21.4	31.0	29.4

Source: General Statistical Office, 1997.

Research on soil chemistry

Almost the whole Delta is formed by the Red River's alluvium. The area is not uniform in terms of soil characteristics, fertility and elevation. This diversity in turn causes a large level of diversity of the cropping patterns in the Delta. Many crops, starchy and non- starchy food, fruit and industrial, are popularly grown in the area.

The institute's activities concerning the Delta's soil chemistry and its effective exploitation have been focussed on the following topics:

- To develop and to release varieties appropriate for each kind of soil conditions in different sub- areas as well as to establish plant management procedures for each of these varieties and for each soil type.

- To study the chemical characteristics of the different soil types (pH, clay and organic matter level etc.) in high, medium and deep (low lying) fields, in order to propose appropriate cropping systems and plant management procedures for each of these field types.

There is a large area of saline, acid sulphate or degraded soil in the depressions in the Delta. New high- yielding varieties are difficult to adapt to these soils. VASI, in cooperation with the Institute of Soil and Fertilizer has carried out studies on increasing agricultural production in these areas.

Together with the total agricultural production increment , most of the land has been degraded due to over- exploitation or over- utilization of nitrogen fertilizers. VASI, collaboratively with the Institute of Soil and Fertilizer, has carried out a joint project with IRRI (named Mega project) for dealing with this problem.

Fertilizer inputs for rice crop vary very much. In Thai Binh, the total amount could be 1.5 higher than in Hai Duong and Hung Yen. The production of winter- spring rice requires high inputs and in some provinces production costs can exceed market prices. This is a constraint for encouraging farmers to increase total agricultural production.

Research on farming household economy and the cooperative system

The RRD is a key- site among the seven ecosystems covered by a project concerning household economy and cooperative system research under the national programme for comprehensive socio- economic development in the rural areas in Vietnam. This project focuses on the following two main aspects:

- Household economy in different areas in Vietnam; and

- The current status of the cooperatives in different regions.

The research outputs are being used to forecast the trends in the household economy and cooperative development in the coming years.

Household economy in the RRD

Farming households are now mainly responsible for agricultural production in Vietnam. Household economic development implies increasing the amount of commodity production households.

According to Dao The Tuan (1997), the number of self- sufficient households remains very high at present, in the whole country. In the RRD, it accounts for 60%, while the number of the commodity producing households accounts for only about 25%. The main reason is lack of capital (Table 3) and low input efficiency.

At present, the agricultural banks can only provide loans to commodity producing households. The self- sufficient ones, due to high risk, are not targeted by these banks. Thus, an alternative is to reduce the interest rate for poor farmers, and this can be done through developing a non- commercial banking system for agricultural development. Recently, a joint programme between Vietnam and France coordinated by VASI has gained significant achievements on this issue.

Table 3. Household types according to their production goals.
(From a surveys covering 15 cooperatives in different locations in the Red River Delta).

Location		Year	Self- sufficient households*						
			1	2	3	4	5	6	G
1	Hung Thai, Hung Yen	88- 89	0	7	30	0	0	1125	0.10
2	Me so, Hung yen	88- 89	0	0	33	48	11	1771	0.15
3	Quat Dong, ha Tay	88- 89	0	62	0	38	0	967	0.18
4	Dai Tu, Ha Noi	88- 89	0	50	28	22	0	1149	0.14
5	Thai Tan, Hai Duong	88- 89	0	39	0	39	21	1018	0.12
6	Cong Hoa, Hai Duong	89- 90	0	0	28	32	35	1352	0.13
7	Quoc Tuan, ha Duong	89- 90	0	58	26	5	10	1740	0.11
8	Thanh Binh, Hai uong	90- 91	0	13	54	25	8	1345	0.13
9	Song Ho, Bac Ninh	91- 92	0	1	52	0	46	1026	0.15
10	Thai Tan, Hai Duong	93- 94	0	0	48	10	42	1479	0.10
11	Yen My, Ha Noi	93- 94	0	50	26	0	24	1916	0.12
12	Yen So, Ha Noi	93- 94	0	64	30	0	4	2180	0.16
13	Hoang Liet, Ha Noi	93- 94	0	52	10	26	11	2268	0.18
14	Quoc Tuan, Ha Duong	94- 95	0	0	69	0	30	2454	0.15
15	Me So, Hung Yen	94- 95	0	0	37	32	29	3760	0.12

*1: Starving　4: Self- sufficient and commodity producing
2: Cannot reproduce　5: Commodity producing
3: Can reproduce　6: Income, 1000 d/person　G: Gini Coefficient
Source: Dao The Tuan, 1997.

The consolidation of cultivated land in order to form large plots is currently difficult in Vietnam since households that are not directly involved in agricultural activities still keep the land provided to them. Thus, in parallel with increasing agricultural production by intensive cultivation, developing industries in rural areas is also an alternative for reducing agricultural labour needs and for increasing commodity production in these areas. Another issue is to find reliable markets and to develop good transport systems in rural areas. All this, however, requires a proper agricultural system.

The application of advanced techniques also varies between households, but does not lead to high crop yield, as rich farmers often use more organic matter, while the poor rely more on chemical fertilizers (Table 4). The former often rear animals for the market to increase the household income, while the latter cannot. Rich farmers, hence, spend much more on inputs for animal raising than the poor ones.

Table 4. Rice yield and main affected factors of different household types

Location, year		Household type		
		Poor	Average	Rich
Thai Tan and Quoc Tuan (1991-1992)	Rice yield (t ha^{-1})	4.10	3.95	4.22
	Organic matter (t ha^{-1})	6.1	6.5	9.2
	N (kg ha^{-1})	79.0	72.0	75.0
	Plant density (hills m^{-2})	22	17	18
	Elements determining the yield (ranked according to their importance)	P Organic matter N	N P Organic matter	Organic matter P N
Cong Hoa	Rice yield (t ha^{-1})	4.64	5.07	4.63
	Organic matter (t ha^{-1})	4.8	7.3	6.20
	N (kg ha^{-1})	9.0	90.0	101.00
	P (kg ha^{-1})	31.0	14.0	21.00
	Labour (hours ha^{-1})	2678	2390	1380
	Elements determining the yield (ranked according to their importance)	Organic matter Labour	N P Labour	N Labour

Source: Dao The Tuan, 1997.

Production organization in rural areas

Since the adoption of Resolution No. 10 of the Government, households have been considered the basic agricultural producing units in Vietnam. However, for further development in agriculture, households need much more support to overcome the various problems they are now facing. The research results show that there are three types of agricultural cooperatives in the RRD:

- The old cooperatives that now do not have capital for their operation and account for 42- 70% of the total number of cooperatives in the Delta.

- The reformed cooperatives that now have limited capital for their operation, mainly to provide material inputs and services for their farmers. They account for about 20% of the total number.

- The cooperatives that have been reformed in order to support their farmers in terms of capital, job generation, etc. They represent about 9- 18% of the total number.

In brief, the most important problem for the cooperatives in the RRD is the lack of capital for ensuring their operation.

Conclusions

During the last 10 years, VASI's research and development activities in the RRD have focused on those aspects dealing with the ecosystem and its socio - economic sustainability. Though not completed, the results so far have significantly contributed to agricultural development in different ecosystems in the Delta.

In the coming years, the strategic goal is sustainable eco- agricultural development in the RRD through new cropping patterns to make land cultivation more profitable. On the basis of expertise and research results, reliable alternatives to diversify cropping patterns, to intensify rice cropping and to develop winter crops and animal raising have become available. Also, fruit trees and industrial crops can largely contribute to the socio- economic development of the RRD. The role of forestry is also important in the Delta, since protection of land from erosion, and crops from natural disasters has become more and more important. In the long- term, the cooperatives will play an important role in agricultural and rural development as they can provide various services, such as loans, marketing, product processing, and job generation. Thus, the reform of the cooperative system is necessary and must be done in various ways in accordance with specific conditions at each location.

In order to contribute solutions for the above problems, VASI continues to make efforts in research and development projects in the RRD, such as local projects of the Ministry of Agriculture and Rural Development, national projects of the Ministry of Science, Technology and Environment, and international collaboration projects with IRRI, CIRAD, ORSTOM.

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Implementing the ecoregional approach in the Red River Basin uplands (Vietnam) Mountain Agricultural Systems (SAM) Project*

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Introduction: Problem setting

From development issues to scientific challenges

The main driving forces of the rapid and profound land use changes which have been occurring in Vietnam since the late 1980s are privatization of the economy, land redistribution and political reforms. Technical, economic and social transformations affect land use dynamics, agricultural production and natural resources management. Fragile upland ecosystems are endangered by the regression of forested areas and the development of non sustainable agricultural practices. On the other hand, sloping land redistribution increases farmers' differentiation and creates social tensions between people relying on the same natural resource base. Unfortunately, these land use transformations are often happening without any knowledge or prediction about their medium and long- term ecological, agronomic and social impact.

Many authors have described the general features of the northern Vietnam uplands and have emphasized the difficulties of breaking the vicious circle of increasing population pressure, environmental stress, impoverishment and marginality (Dao The Anh & Jesus, 1995; Eeuwes, 1995; Kerkvliet & Porter, 1995; Le Trong Cuc & Tran Duc Vien, 1995; Rambo et al., 1995; Rossi, 1995; Bal et al., 1997; FARM, 1997). A recent

* SAM is the French acronym for 'Systemes Agraires de Montagne'

contribution of Donovan et al. (1997) to the understanding of development trends in the northern Vietnam highlands classified problems of the highland regions into seven categories, namely:

- Physical constraints (e.g. broken terrain and steep slopes, low accessibility, poor acid soils, heavy rainfall, uneven rainfall distribution in time and space, etc.);

- Environmental constraints (e.g. deforestation, erosion, flooding, etc.);

- Infrastructural constraints (e.g. poorly developed systems of communication and transportation);

- Economic constraints (e.g. subsistence oriented agriculture, poor access to market);

- Population pressure (e.g. rapid growth rate, migrations, high level of unemployment);

- Cultural constraints (e.g. low level of education, different dialects, conflicting relations between ethnic groups); and

- Intellectual constraints (e.g. inadequate scientific knowledge of the highlands, belief in a single uniform development plan for the uplands).

This latter problem is identified as a major one constraining the development of a common vision for natural resource management (NRM). Attempts to apply a single uniform model, originally designed for the rather homogeneous lowlands, have proven to be disastrous most of the time in the highly diverse socio- economic systems of the uplands.

Methodological and conceptual problems are superimposed on the first six development issues (see above) when addressing specific upland environments. Research programmes are confronted by three major obstacles that make traditional approaches irrelevant.

Firstly, the extreme diversity, both ecological and social, is a major constraint to the generalization of local studies to higher integration levels. The main development trends are expressed in many different ways at farm or village level depending on local circumstances. This high diversity creates a very complex picture where nothing exists like a typical district, village or even household. The high heterogeneity raises major methodological problems for sampling procedures, data collection, and extrapolation of locally obtained results. Under these circumstances 'no single development plan can be broadly applicable, and no single model will prove to be successful everywhere' (Rambo, 1997).

Secondly, the very rapid pace of change in the region, especially since privatization of the economy, land redistribution, and political reforms of the late 1980s profoundly modified the relationships of people with their environment and also the interactions between stakeholders; regarding with such rapid changes, research results may be obsolete and/or useless before they can be released if methodologies cannot adapt continuously to this very dynamic environment. Keeping pace with the rapid agro- ecological and socio- economic changes is thus a major challenge for research programmes in order to maintain their relevance to development issues.

Thirdly, external driving forces play a major role in the transformation of mountainous areas of the Red River Basin. Studies focusing on development trends in the uplands cannot ignore external influences such as national policies, attraction of Chinese or western markets, etc., without the danger of becoming irrelevant. Locally rooted research needs to integrate broader perspectives when weighting relative advantages and constraints of proposed technological or institutional changes, as trade- offs often appear between different space- time scales. As a consequence, despite the will expressed by each NRM project in the Red River Basin (RRB) uplands to go towards an understanding of agricultural and forestry dynamics at regional level, research works often fail to go beyond local scales. This situation is mainly due to methodological problems (to cope with the high diversity and rapid pace of change) and to the lack of relevant institutional frameworks to develop such integrative activities. The challenge of research on NRM in the northern Vietnam mountains is to develop such methods and to facilitate the process of collective learning and to support mechanisms of negotiation among local people, so that they find their own way towards sustainable development.

The need for paradigm shifts

Heterogeneity as a source of information

Cartesian scientists reduce reality to its elementary parts to which the assumption of homogeneity (*ceteris paribus*) can be applied, as uniform environments are easier to deal with. But they need then to reconstruct the whole picture to find applications for their results. As the picture is becoming rapidly complex, the easy solution to extend the domain of application of their research is to make their environment become more uniform, which has proven to give disastrous consequences (Giampietro, 1997). For these scientists, the factors that cause undesired variation are regarded as disturbances that adversely affect the analysis of field experiments.

However, some authors re- interpret variation, giving it a totally new meaning and explicitly positive connotation (De Steenhuijsen Piters, 1995). Bio- and socio- diversity are now rehabilitated by the scientific community as they have proven very valuable to adapt to an uncertain and rapidly changing environment (Altieri, 1993). However, efforts to identify and define the factors that cause variation remain fragmented. Because of the focus on experimental research and of the inherent multidimensionality of the problem which, therefore, means that many disciplines are involved, an integrated approach for its analysis is lacking. Priority should be given to the development of such an approach, and variation should be treated as an object of research instead of as a statistical residue, in order to determine its objective importance and to derive essential information from it (De Steenhuijsen Piters, 1995).

Systems approaches provide key methods, concepts and tools to *reconstruct the picture*, to deal with hierarchies and systems characterized by a high level of diversity. They can help take advantage of the high spatial heterogeneity of northern mountain environments.

Creating a bridge between 'hard science' and 'soft systems'

The issue of sustainability concerns the evolution of ecosystems in interaction with societies that rely on them for their development. When dealing with long term evolution, one implicitly enlarges the space- time scale to encompass larger areas, with various sectors of activity and groups within society, future generations, and other societies and ecosystems distant in space but interacting through trade and communications (Giampietro & Pastore, 1997). As the aggregation level at which environmental problems occur moves upward, systems of regulation have to be created at the appropriate level that are compatible with lower and higher levels. For example, increased use of limited natural resources pushes social interdependence up to the ecoregional level, which leads to conflicts and to the need for negotiation about shared resources at this level. The scientific challenge becomes then to integrate multiple perspectives to accommodate conflicting interests and to reach agreement with regard to the use of natural sources at complementary levels: from the field to the ecoregion[1]. Beyond

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1 An **ecoregion** is defined by the convergence of constraints and objectives of people living in a given geographic area and managing its natural resources: 'an area containing human societies, whose activities result from (*i*) their own objectives and needs, (*ii*) the resources (especially natural resources) that they can mobilize to this end, (*iii*) their mutual relations (exchange, competition, etc.), and (*iv*) the rules governing these relations' (Manichon, 1998).

the question of how people interact with their environment, the question of how they interact together about their environment is thus becoming increasingly important.

Unfortunately, so-called 'hard sciences' or natural sciences cannot answer the latter question (Röling, 1994) despite the major breakthroughs in agricultural development that they have allowed in the past. Hard sciences are based on the assumption that systems, defined unambiguously by their boundaries, operate on the basis of natural laws (Rabbinge et al., 1994). Under this paradigm, the role of researchers is to discover the truth and to unravel nature's secrets. Simulation models explore the future states of the system under different human objectives (De Wit et al., 1988; Rabbinge & Van Latesteijn, 1992; Van Keulen, 1993). People are supposed to maximize utility functions and researchers indicate the best technical means to achieve their goal. This type of reasoning has worked well from a productivity-driven perspective, under linear knowledge transfer from researchers to extensionists and down to the end- users. However, it shows its limits when upscaled to the ecoregional level for NRM. Hard sciences can show that an ecosystem is endangered but cannot impose 'ready- to- use' solutions or policies on stakeholders. People have to interact at the relevant aggregation level to find their way towards more sustainable management of natural resources.

The type of research needed to facilitate negotiations among stakeholders relies on a different paradigm than the one of hard sciences. Soft systems (Checkland, 1981; Röling, 1994) are based on the assumption that people construct their own realities through learning in social processes. Knowledge produced by human actors transforms the perceptions, and thereafter the actions, of other people in the society. Sustainability is thus closely linked to the perceptions that people have of their environment, and whether they can create platforms of interaction among them for concerted decision making about their environment (Dent et al., 1994; Darré, 1996; Röling, 1996). The role of research is then to make the problems become visible, and to provide information that facilitates the emergence of platforms of negotiation at the relevant aggregation level (e.g. problems diagnosed at farm level that must be solved at watershed level).

The two approaches presented here are not mutually exclusive, they are complementary (Figure 1).

Natural sciences paradigm	⇔	Social sciences paradigm
Epistemology		
Positivism (reality exists independenly of the observer)	⇔	Constructivism (reality is constructed by the observer)
Hard platform (De Wit, Rabbinge, Van Keulen, etc.)	⇔	Soft platform (Checkland, Darré, Röling, etc.)
Tools and simulation models		
Explorative models (technical / repeatable systems)	⇔	Heuristic models (agro- eco- socio / unique models)
Evolution from crop models to prototyping for vanguard farms	⇔	Evolution from farmer's decision making supports to virtual laboratories for socio- economic experiments
Main characteristics		
Generic models → universal	⇔	Negotiation support systems → Location specific
Long life span	⇔	Evolving: obsolete as soon as presented to stakeholders for validation
Linear knowledge transfer from scientists to extentionists to farmers	⇔	Iterative, interactive process facilitation of community learning
Scientist driven innovations	⇔	Stakeholders' interactions
Scientific rigor	⇔	Relevance for development

Figure 1. Complementarity of natural and social sciences paradigms for sustainable NRM.

Sustainability is an emerging property of this coupled system (Röling, 1994). Natural and social scientists should thus work together to develop new methods to make things visible from the complex ecoregional picture (Rabbinge, 1995; Dent, 1996; Manichon, 1998). However, the picture cannot be simplified by removing the actors. It would lead to scenarios delivered to decision makers without the keys to implement them. Social and cultural dimensions of sustainability are determinants not only of decision- making, the last step of the collective learning process, but also of the first stage of problem formulation (i.e. description of the system, spatial and temporal boundaries, actors perceptions of the problem, etc.). The different stakeholders, including scientists, should work out in an interactive fashion a common vision on NRM at the ecoregional level that would lead to new indicators, shared monitoring procedures, information systems, and concrete alternatives for action.

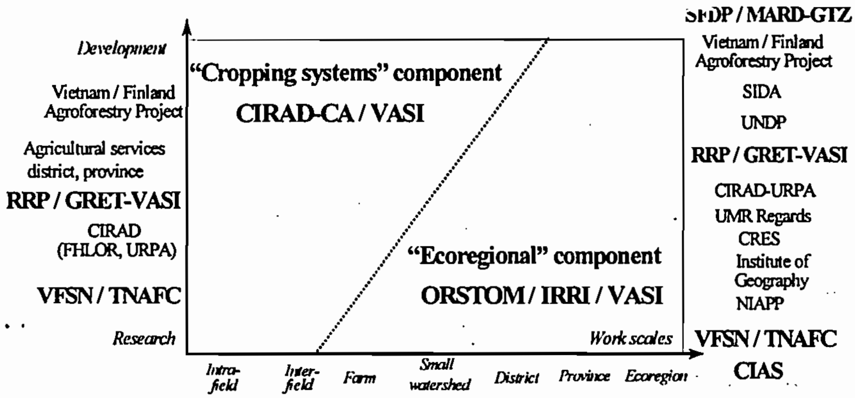

Figure 2. SAM Project's institutional framework: a continuum across scales and across research and development activities through partnership mechanisms. For acronyms see Appendix.

The SAM Project approach and methodology

The Mountain Agricultural Systems (SAM) project was designed as a response to the above presented challenge: implementing the EcoR- I (Ecoregional initiative for the humid and subhumid tropics and subtropics of Asia) approach in the highlands of the Red River Basin (RRB). As shown in Figure 2, it associates the Vietnam Agricultural Science Institute (VASI), CIRAD- CA (Annual Crops Department of the Centre for International Cooperation in Agronomic Research for Development, Montpellier, France), ORSTOM (Institut Français de Recherche Scientifique en Coopération pour le Développement, France) and IRRI (International Rice Research Institute, Philippines). It is conducted in close collaboration with several Vietnamese Institutions (Thai Nguyen Agroforestry College, FIPI, NIAPP, NCST Institutes, Vietnam Farming Systems Network, district and provincial agricultural services), and with European (e.g. GRET, GFA/GTZ) and international organizations (e.g. CIAT, ICRAF).

The SAM project combines case studies in a limited number of sites with the development of a knowledge base on NRM in the RRB uplands. The case studies:

- Confront local realities with constraints of field work, and thus become real partners in the discussions with other groups involved in communication platforms on NRM;

- Provide gap-filling research with disciplines, approaches, and sites complementary to existing activities; and

- Help to develop methodological tools adapted to local NRM and socio-economic development issues.

These interdisciplinary studies, when implemented on the different R&D sites, provide *empirical data* for feeding the knowledge base. The comprehensive and up- to- date information is essential for the database to go beyond a descriptive inventory of statistical data.

Interdisciplinary case studies to root global understanding in the local realities

In each site, a comprehensive study on land use changes (from field and farm to regional level) is proposed, with more applied research on developing sustainable cropping systems in sloping lands and extension activities on agroforestry participatory development and community learning.

Objectives

Objectives of the case studies are:

- *Characterization* and representation of the intra- and inter- field variability up to the watershed scale, and of cropping systems and farming systems diversity: Accounting and monitoring natural resources as well as flows of goods, people and information; and identifying and ranking limiting factors on sustainable production increase;

- *Understanding* processes of agricultural production, intensification, diversification, farming systems differentiation, migration, land degradation, deforestation, resource base depletion, agricultural policies implementation and commodity chains evolution;

- *Adaptation of research methods* to a high biophysical heterogeneity (taking advantages of this diversity) and to an extremely dynamic technical and economic environment in rapid evolution;

- *Designing, testing and extension of organizational and technological innovations* to enhance the overall system productivity while sustaining the resource base and socio- economic development; and

- Training of partners in the systems approach, in on- farm research, and provision of *Collective learning* towards more sustainable NRM.

Site selection

The following criteria guided the site selection procedure:

- A condition for platform formation is that *stakeholders recognize a common problem*. Their consciousness of the problem is a guarantee for their further commitment and active participation in the project activities. Researchers' contributions are to make the different aspects of that problem visible, at different scales and from different points of view. Thus the sites should be selected from a problem- oriented perspective.

- The dynamic nature of the study also affects site selection. *Diachronic* analysis at each site will be combined with *synchronic analysis* of different sites situated at the successive stages of an evolutionary path. Diachronic analysis requires that enough historical data or knowledge sources are available at the selected site. Synchronic analysis requires that sites be selected according to assumptions on their stage in an evolutionary process (e.g. integration to market, monetization, infrastructure, rural exodus).

- On each site, research activities should be combined with development programmes. A *continuum from basic research to extension activities* will benefit all partners. Research provides development agencies with an understanding of the major factors at work, and also provides guidelines to facilitate the process of social learning. On the other hand, development activities provide researchers with lasting support from local authorities and stakeholders.

- Combination of SAM sites with other project sites should *cover the overall regional diversity*.

As a consequence, two contrasted agro- climatic zones of the RRB uplands have been selected within the SAM project: (*i*) northern provinces of Thai Nguyen, Bac Kan and Cao Bang and (*ii*) north-. western provinces of Son La and Lai Chau. Within each zone, sites are selected along a transect from the remote highlands to the Delta rice bowl in order to investigate the interactions between the uplands and the lowlands.

Methods

Systems analysis is the general methodological framework of the project and therefore of the case studies. Systems boundaries are agreed upon by the different partners at the successive hierarchical levels. Studies on the interactions between sub- systems allow emergent properties of the whole system to be represent and to modelled at the relevant level.

Agronomic surveys are conducted at different scales :

- At farm and regional levels they include regional agro- ecological zonation, historical profile of the recent agro- ecological and socio-economic transformations, and functional and dynamic typology of farming systems (Trébuil & Dufumier, 1993; Trébuil et al., 1996). An understanding of farmers' current practices and indigenous knowledge serves as a basis (*i*) to identify research topics suited to local circumstances and constraints hindering farmers' adoption of innovations; (*ii*) to assess the impact of innovation dissemination on the well being of people; and (*iii*) to predict the effects of agricultural practices on the environment;
- At field level, investigations consist of detailed surveys of major crops (to assess yield variability and rank limiting factors).

On- farm experiments support the design and testing of technical innovations, while ensuring farmers' participation and therefore further acceptability of research results.

Spatial applications are developed using aerial photographs, remote sensing imageries and GIS technologies as the spatial dimension of above-mentioned agronomic studies are of great importance in such a diverse environment. They aim at studying the functional relationships among spatial units at different hierarchical levels (e.g. uplands- lowlands interactions at the toposequence level, plots scattering within a farm as a risk management strategy, etc.). Figure 3 shows the type of relationships that are studied at the different scales. At the field level, geostatistical analysis of observations and measurements of agronomic data and mapping of heterogeneity aim at identifying main factors of heterogeneity. This allows to control them and use this information for further research. Other disciplinary approaches will be added when necessary from partner institutions or through networking mechanisms.

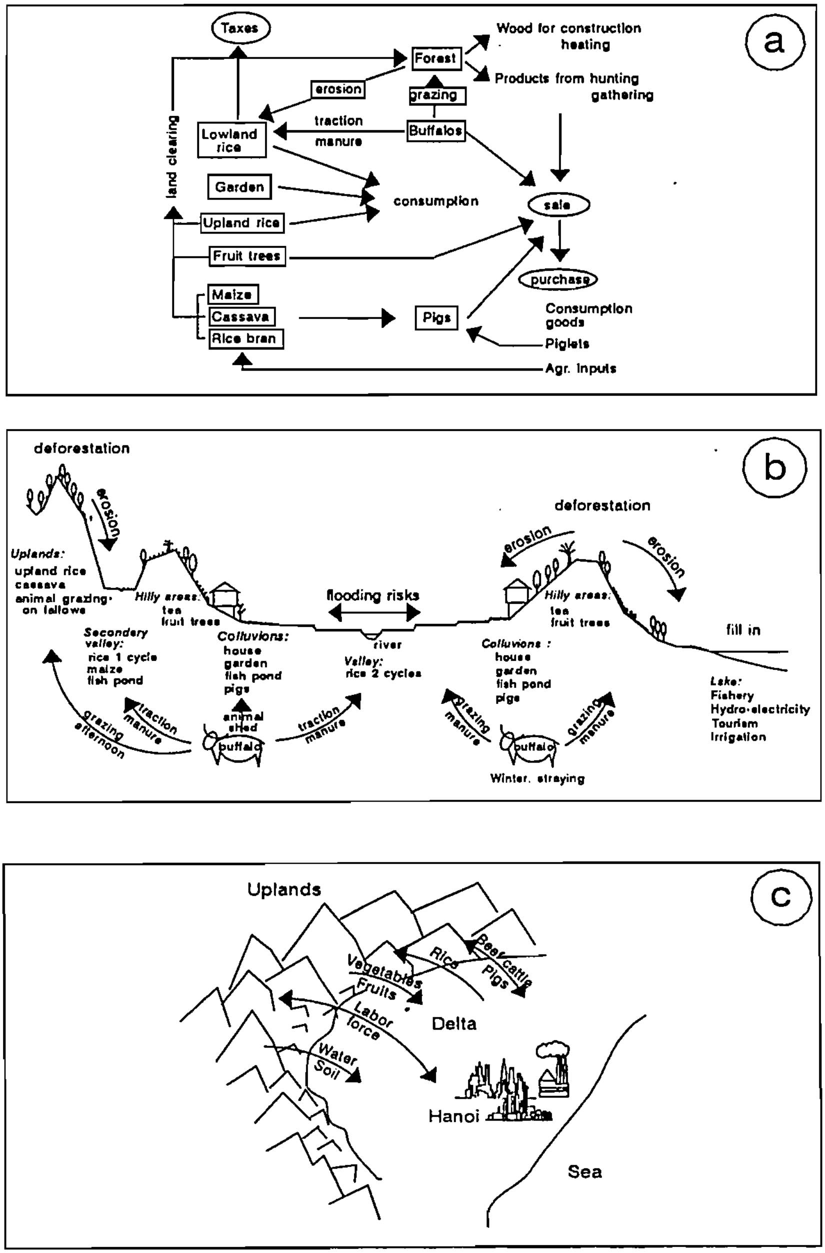

Figure 3. Functional relationships between uplands and lowlands, agriculture and animal husbandry, agricultural and non agricultural activities at (a) farm, (b) watershed (adapted from Dao The Anh & Jésus, 1993) and (c) basin level.

Coordination mechanisms

Integration of scales and multiple perspectives requires to be really practiced interdisciplinarity. The multi-agent simulation model will force dialogue among scientists, help them find a common language and *look for compromises between scientific interest and relevance for development.* NRM learning platforms will be set up at the different R&D sites. Cooperation between the partners makes it possible to create a continuum across the scales and between activities (Figure 2).

Comparison of the two agro-climatic zones selected by the SAM project together with other provinces of the RRB 'covered' by other R&D programmes allows research results to be upscaled up to the basin level.

Towards a shared knowledge base on NRM in the RRB uplands

Objectives

The knowledge base is a tool for *integration* to higher aggregation levels of local and often fragmentary knowledge acquired by the R&D programmes. It aims (*i*) at reconstructing the complete complex picture, through the representation of quantitative and qualitative, synchronic and diachronic information, (*ii*) at understanding processes and dynamics, and (*iii*) at making visible, emergent properties of the systems when upscaled to the ecoregional level.

The knowledge base provides a *communication platform* between scientific disciplines, between researchers, extensionists and other stakeholders in NRM. It is a framework for collective learning on NRM at regional level. It also supports the development of collective agencies that will conduct actual NRM at the relevant level of aggregation.

Content

The type of information to be incorporated in the database ranges from geographic and non-geographic data, pictures, sketch maps, graphic, to textual information and field reports. A first step in constructing the database is to compile existing information on the mountain areas of the RRB. Many reports that already exist about these regions are difficult to access. They are often not properly inventoried or spread over different libraries, and it is very difficult to learn about their existence (Rambo et al., 1997). The problem is also that only very few copies are published and some reports are edited in a format and quality that confine them to the status of gray literature irrespective of their content. A *comprehensive bibliographic* compilation will make this information available in a computerized database.

Statistical data from different sources will be compiled and cross checked. A critical assessment of data reliability will be performed through comparison with empirical data obtained from the case studies.

Structure

The computerized database structure will evolve together with the understanding of the system it is supposed to represent. A rigid database structure fixed at the early stage of a research programme, when the accumulated knowledge on the reality to be represented is at its lowest level, is often a constraint to further integration and handling of information as the project evolves. The *dynamic structure* of the database is provided by object-oriented programming methods (Gayte et al., 1997). Objects representing any type of data can be added or removed at any time and the nature of linkages between objects can be changed, without affecting the overall database structure.

The database integrates different perspectives of the same reality. Its content as well as its structure should thus be *negotiated* regularly by the different partners. The indicators integrated in the database should be meaningful for everyone without reducing the complexity to the lowest common denominator. It should also handle fragmentary information, with missing data, collected under non standardized procedures. Integration of data from different sources requires that keys for transfer and validation of information between different frames of reference be developed.

Database structure is compatible with the development of *multi-agent simulation models* that study the emergence of higher level organization from the behaviour of individuals. The main objective of these models is to force interactions, coordination between scientists of different disciplines towards a common vision (Figure 4). This tool is then used as a catalyst of NRM negotiation platforms among regional stakeholders (Figure 5). It stresses more concerted, and therefore more sustainable, natural resource management.

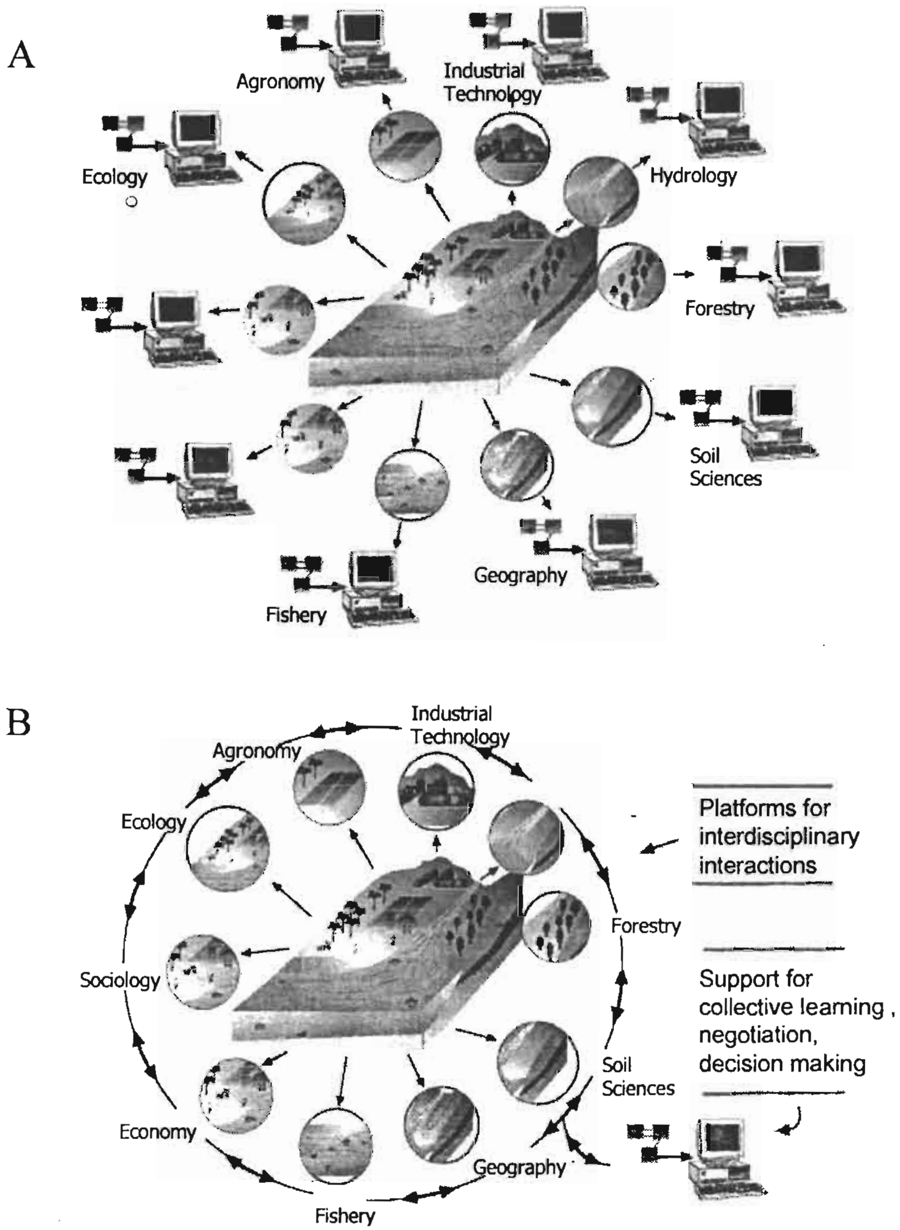

Figure 4. From discipline oriented to integrative simulation models (adapted from Pavé, 1997).

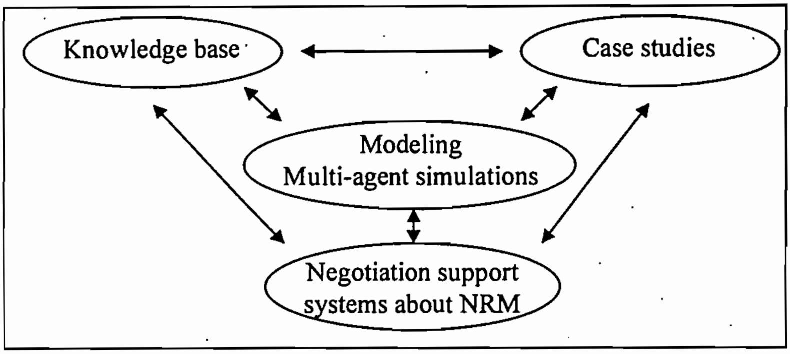

Figure 5. Methodological framework of the SAM Project

Coordination mechanisms

The practical implementation of the knowledge base rely very much on *partnership mechanisms*. SAM Project can not develop R&D activities everywhere in the RRB uplands to cover such a large range of diversity. In order to multiply the research and information management capacity, networking is emphasized between the different R&D programmes involved in NRM in the RRB uplands. However, each research or development programme should keep its own *identity, visibility*, and know-how to be a good component of such a platform. The objective is not to merge existing projects in a mega-NRM-project at each location. Such a proposal would create an unmanageable structure with a decreasing commitment of individuals as its size increases. Instead, the goal is a soft platform (Röling, 1994) at the relevant hierarchical level that allow people to confront their views on NRM and enrich the common picture.

Special attention has to be paid to the mutual benefit of partners joining the knowledge base venture. This activity designed for the common good should also match individual interests. The knowledge base provides partners with the necessary information, concepts and methodological tools to put their own R&D activity into a larger perspective, to assess the domain of extrapolation of their results or investigate other locations where they could be applied. They feed the knowledge base with their own experience and skills and in the process interact with others. Their vision of the system thus evolves as it is questioned by others. Database feeding process works on the information sharing mode much more than on data transfer procedures from individual databases to the collective database. Technical meetings and workshops are organized regularly to share experience and allow tools and concepts to evolve according to new goals and/or to better respond to rapid changes in the RRB.

However, beyond the written research proposal, potential partners should see their interest in joining the project. That is the reason why in a first phase the database relies essentially on SAM project case studies to provide the necessary empirical knowledge. Then the project will be in a favorable position to *demonstrate the usefulness* of the approach and develop more intensive partnerships.

Conclusions

Particular situation of the northern Vietnam mountains pushes towards innovative research and methodologies as the traditional ones show their limits. Difficulties to apply academic, basic research results in the real world does not question the quality of research work neither its usefulness but its compartmentalized mechanisms of problem formulation that often miss some aspects of the problem and responses or solutions that are already brought by local people. This breaks down the traditional boundaries between fundamental, research and adaptive research, as it does between research and development. (Rambo et al., 1997; Manichon, 1998). Ecoregional research cannot rely completely anymore on the paradigm of universality and on the *ceteris paribus* assumption that allow basic research results to be scientifically recognized and published in refereed journals.

The challenge of EcoR-I is thus to produce results that are both scientifically sound and relevant for development. This leads to a rethink of research approaches and mechanisms much more than just changing research topics.

It is much more difficult to work on complex dynamic systems than on homogeneous static parts of it. Reconstructing the picture in its whole complexity requires both high level of disciplinary knowledge and mechanism for knowledge integration. Also, as scientific fields, concepts and tools are becoming more complex no one can handle alone all of them anymore.

It is unfortunately often much more difficult to work together than to work alone. It requires subjecting ones' own knowledge, skills and experience to the test of others, to take a new look at one's own activities, and to test the limits of one's competence. Working in an interdisciplinary mode also requires a common language. Disciplinary fields have evolved independently and now have some difficulties communicating with each other. This miscommunication problem is especially true between the natural and social sciences that are founded on two different paradigms. It is time to join efforts to develop a common vision of the same complex reality and to facilitate collective learning towards more sustainable NRM. This is what the EcoR-I is about.

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Appendix: List of acronyms

CIAT	Centro Internacional de Agricultura Tropical, Colombia.
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France.
CIRAD-CA	Annual Crop Department of CIRAD
CIRAD-FHLOR	Fruits, Horticulture and Vegetable Department of CIRAD
CIRAD-URPA	Research Unit on Agricultural Policies and Prospective of CIRAD
CRES	Center for Natural Resources and Environment
EcoR-I	Ecoregional initiative for the humid and subhumid tropics and subtropics of Asia
FIPI	Forest Inventory and Projection Institute, Vietnam
GFA-GTZ	Gesellschaft für Agrarprojekte-Deutsche Gesellschaft für Technische Zusammenarbeit
GIS	Geographic Information Systems
GRET	Groupe de Recherche et d'Echanges Technologiques, France
ICRAF	International Center For Research in Agroforestry
IRRI	International Rice Research Institute, Philippines
MARD	Ministry of Agriculture and Rural Development, Vietnam
NCST	National Center for natural Sciences and Technologies
NIAPP	National Institute for Agricultural Planning and Projection
NRM	Natural Resources Management
ORSTOM	L'Institut Français de Recherche Scientifique pour le Développement en Coopération, France.
R&D	Research and Development
RRB	Red River Basin
RRP	Red River Programme (VASI - GRET)
SAM	French acronym for Mountain Agricultural Systems project
SFDP	Social Forestry Development Programme (MARD / GFA-GTZ)
SIDA	Sweden International development Agency
TNAFC	Thai Nguyen Agroforestry College, Vietnam
UMR Regards	Unité Mixte de Recherche CNRS-ORSTOM Regards, France
UNDP	United Nation Development Programme
VASI	Vietnam Agricultural Sciences Institute, Vietnam.
VFSN	Vietnam Farming Systems Network, Vietnam

CIAT Projects on Natural Resources Management in Asia with special reference to the Red River Basin of Vietnam

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Introduction

The Centro Internacional de Agricultura Tropical (CIAT), located in Colombia, South America, has within the CGIAR System a world mandate for research and development on beans (*Phaseolus vulgaris*), cassava (*Manihot esculenta* Crantz), and tropical forages, as well as a regional mandate for rice (*Oryza sativa*) in Latin America. In 1992, CIAT also accepted regional responsibility for research on the management of natural resources in Latin America, especially in the tropical lowlands and the hillsides. In early 1997, however, CIAT was restructured with all activities organized within 16 projects, which replaced the previous commodity and natural resource management (NRM) programs. One of the 16 projects is entitled 'Sustainable Systems for Small-holders'; it has as its main purpose the development of sustainable combinations of crop and livestock technologies in smallholder farming systems of Latin America, Asia and Africa, where beans, cassava, forages and rice are system components.

Forage research in Asia

In 1992, the CIAT Tropical Forages programme together with the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia set up a Southeast Asian Forages and Pastures R & D Network, coordinated by a CIAT pasture agronomist stationed at IRRI in the Philippines. This Regional Forage Seeds (FSP) project, funded by AUSAID in Australia, introduced, multiplied and evaluated a large number of grass and legume forage species from CIAT's germplasm collection in Colombia.

In 1995 this project evolved into the Forages for Smallholders (FSP) project, also funded by AUSAID, which continues to coordinate regional forage research and development, but now concentrates its efforts mainly in Vietnam, Laos, the Philippines and Indonesia.

The Forages for Smallholders Project (FSP)

Previous on-station evaluations of forage germplasm had identified some species with wide adaptation to different environments, such as *Brachiaria decumbens* cv. Basilisk, *Brachiaria brizantha* cv. Marandu and CIAT 26110, *Brachiaria humidicola* cv. Tully and CIAT 6133, *Panicum maximum* T-58, *Centrosema pubescens* and *Stylosanthes guianensis* CIAT 184. However, adaptation under experiment station conditions did not necessarily mean adaptation under on-farm conditions, and did not always result in acceptance and adoption by farmers. Thus, the new FSP used a different approach and emphasized the farmer participatory evaluation of forages and technology development to ensure the relevance of research and increase the chance of adoption (Horne & Stür, 1997).

The overall objectives of the FSP are to increase the availability of adapted forages and the capacity to deliver them to different farming systems, in particular, upland farming systems in Indonesia, Lao PDR, Philippines and Vietnam; and to develop close linkages in forage development activities between these countries and Malaysia, Thailand and tropical areas of P.R. China. To achieve these objectives, the FSP:

- Conducts regional evaluations of forage species (environmental adaptation);

- Supports farmer participatory evaluation of forages (develop forage technologies with farmers);

- Develops supply systems for successful technologies;

- Trains local partners in farmer participatory research (FPR) and forage technology; and

- Promotes the sharing of information through networks, meetings and newsletters.

While tropical forages are mainly considered to be feed for grazing animals, especially cattle and water-buffaloes, under the smallholder conditions in Asia forages are often used for many other purposes, such as the cut-and-carry forages for feeding penned cattle or goats, green manures for soil improvement, soil cover in plantation crops such as rubber, oilpalm and coffee, contour barriers for erosion control, and the shading out of weeds such as *Imperata cylindrica.* In partnership with farmers, many forage species are now being evaluated for their adaptation to specific environments, cropping systems and uses.

Participatory diagnoses in various locations indicate that in Asia most farmers have only enough land for raising a few head of cattle, buffaloes or goats. Cattle and buffaloes are mainly used for land preparation and transport, for accumulation of capital and for production of manure, while goats are used for production of meat and milk. For most farmers, the overriding problem is the supply of sufficient animal feed during the dry season. They are therefore particularly interested in evaluating the productivity of grass and legume species under both wet and dry season conditions.

In some cases the integration of crops and forage species can increase the productivity and sustainability of the whole system. Thus, in Laos a system is being tested to undersow rainfed rice with *Stylosanthes guianensis* at the time of last weeding in order to provide a dry season forage fallow. The forage can be grazed by cattle during the dry season or cut periodically to feed penned animals; it can also be cut and mulched to improve soil fertility and suppress weeds. Similarly, in East Kalimantan of Indonesia, maize was undersown when two weeks old with *Centrosema pubescens* and *Stylosanthes guianensis*. This resulted in less weed growth and higher maize yields, even without fertilizer application (Horne, 1997).

Arachis pintoi is increasingly being used as soil cover under fruit trees to control weeds and erosion, while several grass species are being evaluated in Thailand as erosion control contour barriers in cassava fields as an alternative to vetiver grass (*Vetiveria zizanioides*).

FSP in Vietnam

In Vietnam, the FSP is coordinated by the National Institute of Animal Husbandry in Hanoi. Regional forage evaluations have been conducted at upland sites in Hue, Lam Dong, Dac Lac, Gia Lai, Lao Cai, Yen Bai, Ha Giang, Tuyen Quang and Phu To provinces. Farmer evaluations of forages commenced at three broad locations, in Dac Lac in the south, in Hue in Central Vietnam, and in several mountainous provinces in north Vietnam.

Constraints identified by farmers at FSP sites in Vietnam include general feed shortage (quantity and quality), dry season feed shortage (mainly quality), weed invasion (e.g. *Imperata, Cromolaena*), and soil erosion. Farmers are evaluating the following forage technologies to address these constraints:

- Intensively managed plots (grasses);
- Tree legumes in fence lines;
- Contour hedgerows (grasses, herbaceous and tree legumes); and
- Grasses and legumes for grazing (monoculture or in association).

M'Drak, Dac Lac On-farm evaluation of forages commenced with 30 farmers in Chu' Caroa commune, M'Drak, Dac Lac province, in May 1997. The area is dominated by *Imperata* grass land. The main interest of the farmers was in grasses and legumes for reclamation of *Imperata* areas and for providing dry-season supplementation for grazing cattle. The most promising species so far have been *Stylosanthes guianensis* CIAT 184 and *Brachiaria decumbens* cv Basilisk. In response to a growing demand from farmers for help with reclamation of *Imperata* areas, the future focus of the project will be both on the Chu'Caroa commune and an area of *Imperata* to the southwest of M'Drak. In addition to supervising this work, Tay Nguyen University in Buon Ma Thuot also has been conducting an evaluation of forage tree species with potential for dry season feeding.

Xuan Loc, Hue On-farm evaluations of forage and tree legume technologies commenced with eight farmers at Xuan Loc, near Hue. The main concern of the farmers was to find forages for year-round feeding, as their traditional grazing resources have disappeared as a result of expanded cropping and forestry activities. The most promising species so far have been *Panicum maximum* T-58, *Stylosanthes guianensis* CIAT 184 and several lines of *Brachiaria brizantha.* With staff of the University of Hue, the FSP will expand the number of farmers evaluating forage technologies at Xuan Loc and commence on-farm work with farmers at Hong Ha commune in nearby A Luoi district.

Vietnam-Swedish project sites in the Red River Basin In collaboration with the Vietnam-Swedish Mountain Region Development Project, on-farm evaluations of forage technologies commenced with 50 farmers in five northern provinces (Lao Cai, Yen Bai, Ha Giang, Tuyen Quang and Phu To).

The most promising species so far have been *Panicum maximum* T-58, *Brachiaria decumbens* cv Basilisk, *Stylosanthes guianensis* CIAT 184 and *Brachiaria brizantha* cv Marandu. The most common concern of farmers was to find green feed for fish and to supplement pigs. The future focus of the project in the area will be on farmers in Ha Giang and Tuyen Quang, with expansion next year into areas where World Vision is working with the Hmong ethnic minority, who raise cattle in remote highland areas.

These activities are also supported through training of partners, farm field days, demonstrations and farmer training activities on forage agronomy and multiplication.

To coordinate the various activities, one CIAT forage agronomist is stationed at IRRI in the Philippines and a CSIRO forage agronomist is stationed in Vientiane, Laos. The project is funded until December 1999.

Cassava research in Asia

In 1983, CIAT established a Regional Cassava Office in Asia, located in Bangkok, Thailand, when the CIAT cassava breeder was transferred from CIAT headquarters in Colombia to Asia. In 1986, a CIAT agronomist was also transferred to the office in Bangkok to set up a regional network of cassava agronomists in Asia.

During the past 15 years the CIAT cassava breeder has actively collaborated with cassava breeders of national programs in those countries in Asia where cassava is an important crop. Up till 1997, nearly half a million sexual seeds of cassava have been transferred from Latin America, the center of origin of this crop, to Asia. Breeders of national programs have used this seed to broaden the genetic base of the crop, and to develop new varieties with higher yield potential and starch contents. So far, about 30 new cassava varieties have been released in various countries of southeast Asia, and these are now grown in over 600,000 ha. In Vietnam, which started its collaboration with CIAT only in 1987, five new varieties have been officially released. These varieties can produce yields that are about 20-50% higher than those of the traditional local varieties, and they have higher starch contents.

Since 1987, the CIAT agronomist at the Regional Office in Bangkok has conducted agronomy research in collaboration with national program scientists, with emphasis on soil fertility maintenance and erosion control.

Numerous long-term fertilizer trials have shown that in Asia cassava responds mainly to the application of N and K, while a significant response to P was observed in only two of eight locations. It was also shown that soil erosion can be markedly reduced by various soil/crop management practices, such as reduced tillage, contour ridging, fertilizer application, mulching, intercropping, and the planting of contour hedgerows of grasses or legumes. However, few of these practices are adopted by farmers, as most require some additional input of capital or labor, while they seldom provide clear short-term benefits to the farmers (Howeler, 1998a).

Nippon Foundation Project

In 1994 the Nippon Foundation in Tokyo, Japan, agreed to fund a 5-year project with the specific aim of enhancing the adoption of more sustainable production practices in cassava-based cropping systems in Asia, through the development of a farmer participatory research methodology. To achieve this, the projects has the following three components:

1. Strategic and applied research to develop new options for soil fertility maintenance and erosion control, conducted in collaboration with national research institutes and universities.

2. Adaptive Farmer Participatory Research (FPR) to test and select the most promising options in collaboration with research and extension organizations as well as cassava farmers.

3. Training of researchers and extensionists in FPR methodologies.

The FPR component of the project is presently being conducted in 2-3 pilot sites each in Thailand, Vietnam, China and Indonesia. These pilot sites were selected through Rapid Rural Appraisals (RRA) in those areas where cassava is an important crop, where it is grown on hillsides, and where erosion is perceived to be a major problem. The main characteristics of the selected pilot sites are shown in Table 1.

Table 1. Characteristics of selected pilot sites for the Farmer Participatory Research project on Improving the Sustainability of Cassava-Based Cropping Systems in Asia

Country	Thailand		Vietnam		China		Indonesia	
Province	Nakorn. Rat	Sra Kaew	Thai Nguyen	Vinh Phu	Hinan	Hainan	E-Java	E-Java
District	Soeng Saang	Wang Nam	Pho Yen	Thanh Hoa	Baisha	Qiongzhong	Malang	Blitar
Subdistrict		Yen					Dampit	Wates
Latitude	14^0 20'N	13^0 40'N	21^0 20'N	21^0 30'N	19^0 20'N	19^0 5'N	8^0 19'S	8^0 13'S
Altitude (masl)	~300	~400	~40	~80	100-200	~300	400-500	300-400
Rainfall (mm yr^{-1})	948	1404	2007	~1800	~1700	>2400	~1800	~1500
Rainy season (>60 mm)	Apr-Oct	Apr-Nov	Apr-Oct	Apr-Nov	May-Oct	May-Oct	Oct-June	Oct-June
Mean temperature (^{0}C)	26-28	26-28	16-29	15-28			25-27	25-27
Landscape	rolling	hilly	hilly	hilly	hilly	hilly-mount.	mountain.	mountain.
Soils	loamy	clayey	sandy loam	clay loam	sandy cl.l.	clayey	clay loam	clay loam
	Paleustults	Haplustults	Ultisols	Ultisols	Hapludults	Paleustults	Mollisols	Alfiosls

Table 1 – Continuous

Main crops	cassava rice fruit trees sugarcane maize	maize soybean cassava sugarcane rice	rice sweet pot. maize cassava	rice cassava tea	rubber sugarcane rice cassava	rubber rice cassava bamboo	cassava maize rice	maize cassava rice
Cropping system[1)]	C monocrop	C monocrop	C monocrop	C+P	C monocrop	C monocrop	C+M	C+M
Cassava yield (t ha^{-1})	17	17	10	4-6	20-21	15	12	11
Cassava utilization	animal feed/ starch	animal feed/ starch	pig feed	pig feed	starch/ pig feed	starch/ pig feed	human food starch	human food
Farm size (ha)								
-total	4-24	3.2-22	0.7-1.1	0.2-1.5	2.7-3.3	0.7-0.8	0.2-0.5	0.3-0.6
-cassava	2.4-3.2	1.6-9.6	0.07-0.1	0.15-0.2	2.0-2.7	0.3-0.5	0.1-0.2	0.1-0.2

1) C = cassava, M = maize, P = peanut

Table 2. Types and number of Farmer Participatory Research (FPR) trials with cassava conducted in four countries in Asia in 1995/96 and 1996/97.

1995/96 Type of trial	Thailand		Vietnam			China		Indonesia	
	Soeng Saang Nakorn Ratchasima	Wang Nam Yen Sra Kaew	Pho Yen Thai Nguyen	Thanh Hoa Phu Tho	Loung Son Hoa Binh	Baisha Hainan	Tunchang Hainan	Dampit Malang	Wates Blitar
Erosion control	9	6	6	7	3	12	-	10	7
Varieties	5	7	6	-	1	15	-	-	8
Fertilization	5	-	4	-	1	10	-	-	-
Intercropping	-	-	8	-	-	-	-	-	
Total	19	13	24	7	5	37	-	10	15
1996/97									
Erosion control	8	7	5	7	3	4	1	10	9
Varieties	3	6	11	3	3	4	1	1	5
Fertilization	8	-	6	4	3	4	1	1	-
Intercropping	-	-	11	-	-	-	-	-	-
Total	19	13	33	14	9	12	3	12	14

Farmers from the selected pilot sites who showed interest in the project visited previously established demonstration plots, to see and discuss a large number of soil and crop management options that will reduce erosion. These plots were laid out along a uniform slope. The eroded soil from each treatment collected in plastic-covered sedimentation channels that had been installed along the lower end of each plot. Sediments that had accumulated in these channels were weighed and a smaller sample dried to determine the amount of dry soil loss per ha in each treatment. During a field day organized at the time of harvest of the demonstration plots, farmers discussed and scored the various treatments, considering yield and total income obtained, as well as the amount of soil lost by erosion.

Participating farmers from each pilot site then selected 4-5 management practices that they considered most effective or most useful, in order to test these in simple trials on their own fields. Collaborating researchers or extensionists helped the farmers select the most appropriate sites for these FPR trials, and to lay out the erosion trials along contour lines. They also helped to install the plastic-lined sedimentation channels to allow the determination of soil losses by erosion in each treatment. Other farmers in the pilot sites also conducted FPR trials on new varieties, fertilization practices and intercropping systems. Table 2 shows the number and type of trials conducted in the eight pilot sites in Asia during the past two years. A total of about 130 farmers conducted these trials each year.

During the growth cycle the farmers maintained the trials, using practices similar to those used in their normal production fields. Researchers helped the farmers collect and weigh the eroded sediments, and at time of harvest to determine the yields of cassava and intercrops. Combined results of all the trials were then presented and discussed with the farmers, after which they selected the best treatments for further testing or adoption.

Results of FPR trials in Vietnam

In Vietnam cassava is grown in upland soils throughout the country (Figure 1), but its production is concentrated in the midland and mountainous areas of the Red River Basin, along the eastern coast and in the southeastern region near Ho Chi Minh city. In the south, it is used mainly for starch production and in the north mainly for on-farm pig feeding.

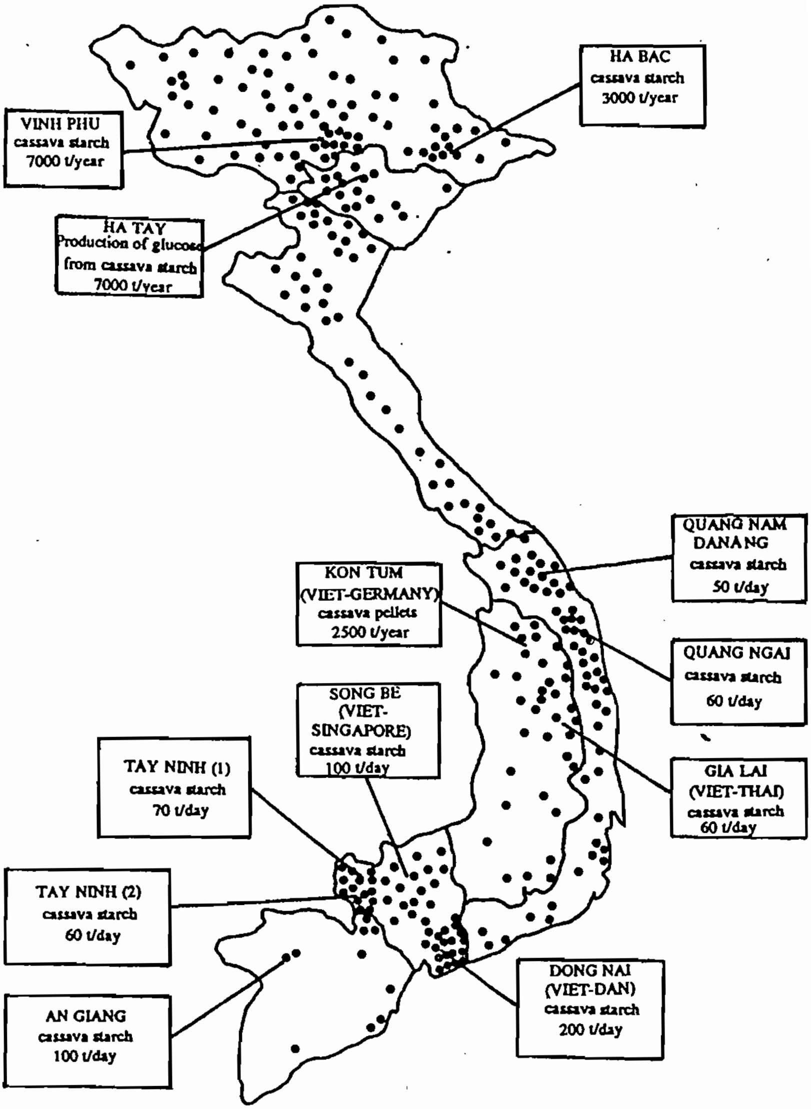

Figure 1. Cassava production and processing areas in Vietnam. Each dot represents 1000 ha of cassava 1995.

Source: adapted from General Statistical Office 1996 and Projects under promotion by State Committee for Cooperation and Investment (SCCI) 1986-1996.

The FPR project on Improving the Sustainability of Cassava-based Production Systems was executed in Vietnam in collaboration with the Agro-forestry College (A #3) of Thai Nguyen University in Thai Nguyen province, and with the National Soil and Fertilizer Institute (NSFI) located just outside Hanoi. AC#3 conducted RRAs in Pho Yen district of Thai Nguyen province and selected Dac Son and Tien Phong villages as the two most suitable pilot sites. These two villages are about 10 km apart and are generally considered as one pilot site. They are located about 25 km south of Thai Nguyen city. The FPR team of NSFI conducted RRAs in Thanh Hoa district of Phu Tho province and in Luong Son district of Hoa Binh province. They selected Kieu Tung village of Thanh Hoa district and Dong Rang village of Luong Son district as the most suitable pilot sites. These are located about 180 km west and 60 km southwest of Hanoi, respectively. A summary of the RRA results in Vietnam is shown in Table 3. In most sites cassava is traditionally grown in monoculture, but is sometimes intercropped with black bean (*Vigna unguiculata*), peanut (*Arachis hypogaea*), or taro (*Colacasia esculenta* L). It is grown on rather steep slopes in Thanh Hoa and Luong Son districts, but on more gentle slopes in Pho Yen district. Cassava yields tend to be low due to the use of low-yielding varieties and the inappropriate use of manure and fertilizers (Howeler, 1998b).

Table 3. Land characteristics, cropping systems, varieties and agronomic practices, as determined from Rapid Rural Appraisals (RRA) conducted in four Farmer Participatory Research (FPR) pilot sites in Vietnam in 1996/97.

Province	Hoa Binh Luong Son	Phu Tho Thanh Hoa	Thai Nguyen Pho Yen	
District Village	Dong Rang	Phuong Linh	Tien Phong	Dac Son
Land Characterization				
- lowlands (ha)	27	86		
- upland (ha)	95 (36 ha planted yr^{-1})	29		
- cassava (ha)	-	-	50	40
- slopes (%)	<25	<40	<20	<10
- soil type, fertility	clay, medium fertile	clay, low fertility	sandy loam	sandy loam
			low fertility	low fertility
- erosion	medium	high	medium	low
Upland cropping system[1]	C+T	C monocult.	C+P or C+B	C monocult. or
		C monocult.	C+P	or 2 yr C rot.
C-P rotation				
			M+P	with 2 yr fallow
or C-B, C-SP				

Varieties				
-cassava	Vinh Phu, local	Vinh Phu, local	Vinh Phu	Vinh Phu Du, Canh Ng
Cassava practices				
- planting time	early March	early March	Feb/March	Feb/March
- harvest time	Nov	Nov/Dec	Nov	Nov/Dec
- plant spacing (cm)	100x80	80x80; 80x60	100x50	100x50
- planting method	horiz./inc lined	horizontal	horiz./inc lined	horizontal
- land preparation	buffalo/cattle	by hand/cattle	buffalo	buffalo
- weeding	2 times	2 times	2 times	2 times
- fertilization	basal	basal+side[2)]	basal+side[3)]	basal+side[4)]
- ridging	mounding	flat	flat	flat
- mulching	rice straw	peanut residues	peanut residues	peanut residues
- root chipping	hand chipper	knife	small grater	small grater
- drying	3-5 days	3-5 days	2-4 days	2-4 days

Fertilization				
- cassava				
- pig manure (t ha^{-1})	5	5	3-5	8-11
- urea (kg ha^{-1})	0	50-135	83	83-110
- SSP (18% P_2O_5) (kg ha^{-1})	50-100	0	140	0-280
- KCl (kg ha^{-1})	0	0	55	280
Yield (t ha^{-1})				
- cassava	10-12	8-15	8.5	8.7
- rice (per crop)	3.3-4.2	4.2	3.0-3.1	2.7-3.0
- taro	1.9-2.2	-	-	-
- sweet potato	-	-	8.0	3.3
- peanut	0.8-1.2	0.5-1.1	1.4	1.3

1) C=cassava, P=peanut, B=black bean, T=taro, M=maize

C+P=cassava and peanut intercropped; C-P=cassava and peanut in rotation

2) urea at 2 MAP

3) urea when 5-10 cm tall; NPK+FYM when 20 cm tall

4) NPK when 30 cm tall; hill up

Table 4. Effect of various soil/crop management treatments on cassava yield, gross and net income as well as on soil loss due to erosion when cassava, cv Vinh Phu, was grown on 18-24% slope in the FPR demonstration plots at Agro-forestry College of Bac Thai, Thai Nguyen, Bac Thai, Vietnam in 1996. The last column indicates the farmers' preference for each treatment.

Fertilizer	Spacing	Intercrop	Tillage	Residue	Green manure	Hedgerow	Cassava yield ($t\ ha^{-1}$)	Gross income[5]	Fert. cost[7]	Net income	Dry soil loss($t\ ha^{-1}$)	Farmer preference[8]
								<——('000d ha^{-1})——>				
1. no	1.0x0.8	no	plow	removed	no	no	3.73	1,865	0	1,865	30.1	0
2. NPK[1]	1.0x0.8	no	plow	removed	no	no	15.50	7,750	1,195	6,555	25.4	0
3. FYM[2]	1.0x0.8	no	plow	removed	no	no	17.63	8,815	1,000	7,815	26.5	2
4. NPK+FYM	1.0x0.8	no	plow	removed	no	no	24.87	12,435	2,195	10,240	25.1	30
5. NPK	1.0x0.8	no	plow	removed	Tephrosia[3]	no	18.95	9,475	1,195	8,280	24.4	2
6. NPK	1.0x0.8	peanut	plow	removed	no	Teph+vetiver	20.63	14,065[6]	1,195	12,870	4.8	28
7. NPK	1.0x0.8	no	contour ridge	removed	no	no	21.18	10,590	1,195	9,395	18.5	12
8. NPK	1.0x0.8	no	plow	removed	no	Tephrosia	16.59	8,295	1,195	7,100	16.3	5
9. NPK	1.0x0.8	no	plow	removed	no	Flemingia	15.34	7,670	1,195	6,475	10.3	1

Table 4 – Continuous

10.	NPK	1.0x0.8	no	plow	removed	no	Vetiver	19.14	9,570	1,195	8,375	6.5	10
11.	NPK	1.0x0.8	black bean	plow	removed	no	Tephrosia	20.85	10,905[6]	1,195	9,710	10.2	2
12.	NPK	1.0x0.8	no	plow	incorp.	no	no	27.00	13,500	1,195	12,305	19.1	16
13.	no	1.0x0.8	no	plow	incorp.	no	Tephrosia	4.87	2,435	0	2,435	18.3	0
14.	NPK	1.0x0.8	no	plow	removed	Tephrosia[4]	no	21.00	10,500	1,195	9,305	21.3	0
15.	NPK	1.0x0.8	no	no tillage	removed	no	no	19.02	9,510	1,195	8,315	18.2	0
16.	NPK	0.6x0.8	no	plow	removed	no	no	22.18	11,090	1,195	9,895	19.0	2

1) NPK=60 kg N+40 kg P_2O_5+120 kg K_2O ha^{-1}
2) FYM=10 t ha^{-1} of pig manure
3) *Tephrosia* (about 6 t ha^{-1}) from outside
4) *Tephrosia* (about 1.5 t ha^{-1}) grown as intercrop between cassava, pulled and mulched at 4 MAP
5) Prices: cassava fresh roots: Dong 500 kg^{-1}
peanut dry pods: 5000 kg^{-1}
black bean dry grain: 6000 kg^{-1}
6) Peanut yield: 750 kg ha^{-1} of dry pods; black bean yield: 80 kg ha^{-1}
7) Cost fertilizers: urea (45%N): d3000 kg^{-1}
SSP (17%P_2O_5): 1000 kg^{-1}
KCl (60%K_2O): 2800 kg^{-1}
pig manure: 100 kg^{-1}
8) Number of farmers preferring the treatment.

*Demonstration plots*_In 1994, sixteen demonstration plots were laid out side-by-side on a 18-24% slope at AC#3 in Thay Nguyen. With minor modification in treatments these plots were replanted every year. At time of harvest, farmers from the pilot sites visited these plots to see and discuss the various treatments. Table 4 shows the results of the demonstration plots planted in 1996, as well as the farmers' preferences. In the non-fertilized check plots (T1) cassava yield and income was extremely low, while erosion was very high. Application of farm-yard manure (FYM) and/or fertilizers markedly increased yields and reduced erosion. Erosion was reduced most effectively by the planting of contour hedgerows of either vetiver grass or *Tephrosia candida*. Farmers preferred the treatment combining FYM and chemical fertilizers (T4), or the planting of hedgerows of both vetiver and *Tephrosia* in addition to intercropping with peanut (T6). From these preferences it is clear that farmers are mostly interested in maximizing their net income, but they are willing to adopt soil conservation practices if these are effective and do not reduce their income.

FPR trials Table 2 shows that in 1995 and 1996 farmers in Vietnam conducted 36 and 56 FPR trials, respectively, on varieties, intercropping systems, erosion control and fertilization practices. Table 5 shows the average results of five erosion control trials conducted in Pho Yen district of Thai Nguyen province in 1996. Soil losses by erosion were relatively low due to the gentle slopes in the area and low rainfall that year. Still, soil loss could be reduced by 50% by planting cassava intercropped with peanut on contour ridges and with hedgerows of vetiver and/or *Tephrosia candida*. Farmers overwhelmingly preferred this treatment, but with hedgerows of only *Tephrosia*, as the latter is considered more useful as a green manure and is more easily established than vetiver grass. Table 6 shows very similar results for Kieu Tung village in Thanh Hoa district. Due to the steeper slope, soil losses were much higher. None of the treatments reduced soil losses significantly in this second year of establishment, but it is expected that the contour hedgerows of vetiver, *Tephrosia* or pineapple will become more effective over time. Farmers preferred those treatments where cassava was intercropped with peanut, with or without hedgerows of vetiver or pineapple. Similarly, Table 7 shows that farmers in Dong Rang village of Hoa Binh province also preferred intercropping cassava with peanut and planting hedgerows of either vetiver or *Tephrosia*. Table 8 shows that farmers in Kieu Tung could increase their net income by 27% by combing the application of pig manure with that of chemical fertilizers that are relatively high in K and

N. Other trials showed that net income could be increased by intercropping with peanut and by planting of the new variety KM 95-3, instead of monocropping or planting the local variety Vinh Phu, respectively.

Adoption of soil conservation practices It is still too early to see any large-scale adoption of soil conservation practices in cassava fields anywhere in Asia. Still, after conducting these FPR erosion control trials on their own fields, about 15 farmers in Thailand and Vietnam are now trying out some of these practices on small areas of their regular production fields. Farmers in Thailand chose to plant contour hedgerows of vetiver grass or sugarcane (for chewing), while farmers in Vietnam chose to plant cassava intercropped with peanut, apply more chemical fertilizers (especially K), and plant hedgerows of vetiver and/or *Tephrosia candida.* In nearly all pilot sites, farmers have selected new higher-yielding varieties and are slowly increasing the area planted to these varieties. By involving farmers directly in the development and testing of new technologies, especially soil conservation practices, it is more likely that the selected technologies are effective and well-suited for the local bio-physical and socio-economic conditions, and will thus be adopted by farmers.

Table 5. Average results of five FPR erosion control trials conducted by farmers in Tien Phong and Dac Son villages of Pho Yen district, Bac Thai province, Vietnam in 1996s

	Dry soil loss[1] (t ha^{-1})	Yield (t ha^{-1})		Gross income	Production costs[4]	Net income	Farmers' preference(%)
		cassava[2]	intercrop[3]	<---------(10^6 Dong ha^{-1})------->			
1. Farmer's practice[5]	8.33	11.53	-	6.92	2.25	4.67	0
2. Tephrosia hedgerows, no ridging, peanut intercrop	6.62	11.02	0.372	8.47	2.30	6.17	0
3. Vetiver grass hedgerows, no ridging, peanut intercrop	6.34	12.82	0.280	9.09	2.30	6.79	39
4. Tephrosia hedgerows, contour ridges, peanut intercrop	4.85	12.30	0.318	8.97	2.30	6.67	58
5. Vetiver+Tephrosia hedgerows, no contour ridges, no intercrops	4.17	12.78	-	7.67	1.94	5.73	3

[1] dry soil loss during 1996.
[2] final yield of fresh roots
[3] dry pods
[4] includes cost of manure, fertilizers and peanut seed
[5] monoculture cassava with 15 t ha^{-1} of pig manure, 144 kg urea, 107 SSP and 95 KCl ha^{-1}

Table 6. Effect of various crop management treatments on the yield of cassava and intercropped peanut as well as the gross and net income and soil loss due to erosion in an FPR erosion control trial, conducted by six farmers in Kieu Tung village of Thanh Hoa district, Vinh Phu province, Vietnam in 1996.

Treatments	Slope (%)	Yield (t ha^{-1})		Gross income[2)]	Production costs[3)]	Net income	Dry loss soil (t ha^{-1})	Farmers' preference[4)] (%)
		cassava	peanut	<------(10^6 Dong ha^{-1})------->				
1. Cassava monoculture, no fertilizers, no hedgerows	40.5	15.3	-	7.65	2.60	5.05	27.9	0
2. C+peanut, no fertilizers, no hedgerows	45.0	16.8	1.434	15.57	2.80	12.77	27.4	0
3. C+peanut, with fertilizers, no hedgerows	42.7	14.6	1.670	15.65	3.72	11.93	28.1	61
4. C+peanut, with fertilizers, Tephrosia hedgerows	39.7	15.1	0.916	12.13	3.72	8.41	26.6	0
5. C+peanut, with fertilizers, pineapple hedgerows	32.2	21.6	1.033	15.96	3.72	12.24	26.9	71
6. C+peanut, with fertilizers, vetiver grass hedgerows	37.7	22.0	1.157	16.78	3.72	13.06	25.3	93
7. C+monoculture, with fertilizers, Tephrosia hedgerows	40.0	26.2	-	13.10	3.52	9.58	25.5	0

1) All plots received 10 t ha^{-1} of FYM; fertilizers = 60 kg N+40 kg P_2O_5+120 kg K_2O ha^{-1}

2) Prices: cassava fresh roots: Dong 500 kg^{-1} peanut dry pods: 5000 kg^{-1}

3) Production costs: cassava monoculture: 2.60 mil. Dong ha^{-1} peanut intercropping: 0.20 mil. Dong ha^{-1}
NPK application: 0.92 mil. Dong Ha^{-1}
hedgerows: no additional costs

4) Percentage of farmers preferring the treatment.

Table 7. Average results of an FPR erosion control trial conducted by three farmers on 16% slope in Dong Rang village of Luong Son district, Hoa Binh province, Vietnam in 1996.

Treatments[1]	Yield ($t\ ha^{-1}$)		Gross income[3]	Fertilizer costs[3]	Net income	Biomass incorp.[2] ($t\ ha^{-1}$)	Dry soil loss (%)	Farmers' preference
	cassava	intercrop	<——(10^6 Dong ha^{-1})		——>			
1. Cassava(C)+taro(T), no fertilizers, no hedgerows	9.00	2.260	6.99	0.74	6.25	-	43.13	-
2. C+T, with fertilizers, vetiver grass hedgerows	13.02	1.800	8.49	1.53	6.96	0.144	19.67	-
3. C+T, with fertilizers, Tephrosia candida hedgerows	14.09	1.800	9.02	1.53	7.49	0.864	15.95	-
4. C+peanut, with fertilizers, vetiver grass hedgerows	15.66	0.660	11.13	1.53	9.60	1.570	2.39	+
5. C+peanut, with fertilizers, Tephrosia candida hedgerows	14.29	0.693	10.61	1.53	9.08	2.165	3.99	+

1) All plots recceived 5 $t\ ha^{-1}$ of FYM; fertilizers = 40 kg N+40 kg P_2O_5+80 kg K_2O
taro or peanut received separately: 7 kg N+20 kg P_2O_5+20 kg K_2O in all treatments

2) Dry biomasss from peanut and leaves of hedgerows

3) Prices:

cassava fresh roots:	Dong 500 kg^{-1}
taro fresh corms:	1100 kg^{-1}
peanut dry pods:	5000 kg^{-1}
FYM:	100 kg^{-1}
urea (45%N):	3000 kg^{-1}
SSP (17%P_2O_5):	1000 kg^{-1}
KCl (60%K_2O):	2200 kg^{-1}

Table 8. Average results of five FPR fertilizer trials conducted by farmers in Kieu Tung village of Thanh Hoa district, Vinh Phu province, Vietnam in 1996.

Treatments	Yield cassava ($t\ ha^{-1}$)	Gross income[1)]	Fertilizer costs[1)]	Net income
		<-------(10^6 Dong ha^{-1})------->		
1. 10 t ha^{-1} of FYM (Farm Yard Manure)	15.93	7.96	1.00	6.96
2. 10 t ha^{-1} of FYM 60 kg N + 60 kg P_2O_5 + 120 kg K_2O	19.34	9.67	2.19	7.48
3. 10 t ha^{-1} of FYM 60 kg N + 60 kg P_2O_5 + 80 kg K_2O	18.67	9.33	2.05	7.28
4. 10 t ha^{-1} of FYM 60 kg N + 40 kg P_2O_5 + 120 kg K_2O	21.89	10.94	2.07	8.87

[1)]Prices:cassava fresh roots: Dong 500 kg^{-1}

FYM:100 kg^{-1}

urea (45%N):3000 kg^{-1}

SSP (17%P_2O_5):1000 kg^{-1}

KCl (60%K_2O):2200 kg^{-1}

Training in FPR methodologies In 1997 CIAT organized two Training-of-Trainers courses in FPR methodologies in which about 25 Thai and 27 Vietnamese researchers and extensionists participated. The training of local officials in the use of these participatory methodologies will make it possible to extend the FPR approach to many more sites in the future, and will likely result in the more widespread adoption of sustainable production practices.

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Integrated nutrient management for rice-based cropping systems in the Red River Delta

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Introduction

The Red River Delta (RRD) has an area of 1.25 million ha, of which 721,300 ha is agricultural land. In 1992, it provided 5.1 million tons of paddy, about 28% of the national production and accommodated 10.7 million people. Rice is a suitable crop for the soil and climatic conditions and is the most important crop in the farming system of the Red River Delta. The average rice yield increased from 2.70 t ha^{-1} in 1985 to 4.68 t ha^{-1} in 1993. However, trends of declining productivity in intensive irrigated rice systems in the RRD have become severe along with the gains in rice production. Fertilization with nitrogen (N) is one of the most important factors affecting rice production (Mikkelsen, 1987) and N accounts for about 75% of the total fertilizer applied to rice (Vlek & Burnes, 1986). Low efficiency of N-fertilizer use is a cause for concern. In most studies on transplanted flooded rice, only 20-40% of the applied N is recovered by the crop because of N losses and poor fertilizer management (De Datta et al., 1988).

In Acid Sulfate Soils (ASS), a key yield-limiting factor is nutrient deficiency. Recent research has demonstrated good response of rice to phosphorus application, which is further improved by abundant N supply (Mengel & Kirkby, 1987).

Because nutrients were inadequately replenished in the past, the soils of the Red River Delta have become seriously degraded. Productivity of these soils may be enhanced, maintained, or restored by integrated management of nutrient inputs in conjunction with appropriate soil and crop management practices. The key issues in improving the efficiency of applied fertilizers are:

- Effective management of inorganic fertilizer;
- Effective integration of organic and inorganic fertilizers;
- Use of economical fertilizer rates; and
- Use of appropriate and responsive varieties.

Of these issues, we will discuss the management of nutrients.

Materials and methods

Method of urea incorporation

The field experiment was conducted during the 1989 summer and 1990 spring seasons, as a randomized complete block design (RCB) with eight treatments, where four methods of basal urea incorporation in factorial combination with two flood water depths, 0 and 5 cm, during fertilizer incorporation.

N-rates and N-timing

The field experiment was conducted over three seasons: spring 1992, summer 1992 and spring 1993. The experiment was laid out in an RCB with 12 treatments and four replications (Treatments 1 - 6: N-rates from 0 to 150 kg N ha^{-1}; Treatments 7 - 12: differences in N timing with basal on 60 kg N ha^{-1}).

Integration of organic and inorganic fertilizer

The field experiment was conducted during 1993 - 1994 with a rice - soybean - rice cropping system on degraded soil at Ha Bac.

For the rice crop, the treatments consisted of 4 x 2 factorial combinations in RCB with N-rates as the first factor (4 N-rates) and farmyard manure (FYM) as the second factor (2 FYM-rates). The third factor is a summer soybean crop (2 N-rates). The summer design field experiment was conducted during 1992 - 1994 with rice - rice - winter maize cropping system on alluvial soil at Ha Tay province.

Farmyard manure and urea timing

The field trial was conducted during the 1990 summer and 1991 spring seasons using an RCB with six treatments and four replications. The treatments were a factorial combination of two FYM rates: 0 and 6 t ha^{-1} and three urea treatments, no applied urea, 30 kg urea-N ha^{-1} as basal incorporation and 30 kg urea-N ha^{-1} delayed broadcast into flood water at 14 - 16 day after transplanting (DAT).

Effect of different P sources and rates

The effect of P-rates and P-sources on rice grain yield, nutrient uptake in acid sulfate soil of Do Son - Hai Phong was determined in the spring and summer seasons of 1989. Single superphosphate (SSP), diammonium phosphate (DAP), thermophosphate (FMP) or rock phosphate (RP) were used as P-sources and applied at 0 - 30 - 60 - 90 kg P_2O_5 ha^{-1}. Two rice varieties were used: DT10 and Chiem bau in the spring seasons.

Results and discussion

Effect of the growing season on potential for NH_3 loss through volatilization

In the Red River Delta, two rice crops can be grown each year. The first crop (February to June) is established and initially fertilized when the temperature is still low. It then grows under conditions of increasing temperature and solar radiation. The second crop (July to October) is established when the temperatures are higher and it grows during the period of highest rainfall.

Floodwater temperature after each urea-N application was 4 - 22 °C higher in summer (July) than in spring (February). During the 5 days after the basal urea-N application, floodwater-pH at 1400h was higher in summer than in spring. The high floodwater temperature and pH in summer resulted in a much higher urea p NH_3 following urea incorporation in summer than in spring. High partial pressures of ammonia (p NH_3) after basal N-application suggest a higher potential for NH_3 loss through volatilization during summer than the spring season.

The p NH_3 in summer was comparable to or slightly greater than p NH_3 in the Philippines' dry season (January) following urea incorporation by two treatment common for both sites.

The degraded soils have very low sorption capacity of NH_3 (CEC, 4 - 8 meq/100 g) so that heavy rainfall and greater floodwater depth after N application resulted in diffusion of NH_4-N from the soil into the floodwater. These results show that runoff losses of N could be high in the farmers' fields after N application during both summer and spring seasons.

The results from the incorporation study showed some reduction in p NH_3 during the first 4.2 days after urea application. However, these effects were not consistent over both seasons.

Effect of N-rates and N-timing

With increasing dosage of urea-N, the number of panicles increased in all three seasons and the fertility of grains (percentage of filled grains) showed negative response to addition of urea-N, particularly at 90 - 150 kg N ha^{-1}, in all seasons. Despite the better growth (higher plant biomass and N accumulation) in summer, the grain yield was statistically similar to the spring 1992 and 1993 yields. In spring and summer 1992, the optimum N-rate was 90 kg ha^{-1}, whereas in spring 1993 it was 60 kg ha^{-1} (Tables 1 and 2).

The economical N-rates were 60 - 90 kg ha^{-1} for degraded soil, and 100 - 120 kg ha^{-1} for alluvial soil, depending on rice varieties and season. Agronomic efficiency of nitrogen is 2.1 - 16.5 kg rice per 1 kg N-applied depending on doses of nitrogen application, soil types, rice varieties and season (Table 3).

On degraded soil, the lost urea management is a three equal split application of urea as basal incorporation, at maximum tillering stage, and at 5-7 d before panicle initiation (Table 2).

Apparent recovery of applied N was high in alluvial soil (12.5 - 46.5%) and low in degraded soil (11.4 - 48.3%) (Table 4).

Integration of organic and inorganic fertilizer

In regions of Asia, such as China, India, and Northern Vietnam, nutrients are applied through animal wastes to rice fields. In the Red River Delta, without FYM application it cannot use high rates of industrial N fertilizers and can not give high yields of rice.

Application of FYM, in the absence and presence of urea, increased rice grain yield in both seasons (Table 5).

Table 1. Panicle number, percent filled grains, 1,000-grain weight, and grain yield of CR 203 in three seasons (spring 1992, summer 1992, and spring 1993).

Season and N rate (kg ha^{-1})	Panicles (no. m^{-2})	Filled grains (%)	1,000 grain weight (g)	Grain yield (t ha^{-1})
Spring 1992				
0	289b	94ab	23.5ab	2.74c
30	289b	95a	23.7ab	2.73c
60	276b	96a	23.9a	3.24b
90	304b	95ab	23.3ab	3.73a
120	290b	92b	22.7b	3.89a
150	354a	86c	21.4c	3.22b
Summer 1992				
0	295d	86a	19.1a	2.47d
30	323cd	85b	18.9a	2.93c
60	377bc	85b	18.9a	3.32b
90	372bc	84bc	18.9a	3.52ab
120	395ab	82c	18.7a	3.74a
150	434a	78d	19.1a	3.58ab
Spring 1993				
0	331b	93a	25.5a	2.97c
30	357b	93a	25.3a	3.68ab
60	388b	93a	25.0a	4.10a
90	357b	91ab	24.9ab	3.97ab
120	397a	89bc	24.9ab	3.83ab
150	393ab	88c	24.0b	3.61b

Within a column, means followed by the same letter do not differ significantly at the 5% level by Duncan' Multiple Range Test

Table 2. Effect of urea timing and number of split applications on grain yield and N accumulation.

Season and treatment	Grain yield (t/ha)	Straw weight (t/ha)	Grain	N (kg/ha) Straw	Total	Biomass (t/ha)	Filled grain (%)	1,000 grain weight (g)
Spring 1992								
Three N split								
Basal, Max T, PI	3.67a	2.74	37.5a	18.7ab	56.3a	5.91	95a	23.8
15 DAT, Max T, PI	3.24b	2.87	30.8b	17.6b	48.3b	5.67	96a	23.8
15 DAT, PI, Head	3.24b	2.73	34.1ab	21.0a	55.1a	5.52	90b	23.5
Summer 1992								
Three N split								
Basal, Max T, PI	3.91a	5.31	39.4	31.4	70.8	8.67	84a	18.9b
15 DAT, Max T, PI	3.32b	5.42	34.4	30.6	65.0	8.28	84a	18.9b
15 DAT, PI, Head	3.45b	5.04	38.1	31.4	69.5	8.00	80b	19.9a
Spring 1993								
Three N split								
Basal, Max T, PI	3.74	3.23	35.1	19.4	54.4	7.25	92	25.2
15 DAT, Max T, PI	4.10	3.38	36.1	18.6	54.7	7.72	93	25.0
15 DAT, PI, Head	3.75	3.02	38.0	18.5	56.5	7.00	94	25.3
Spring 1992								
Two urea-N split	3.21	2.49b	32.0b	16.7c	48.7c	5.25b	93	23.8
Three urea-N split	3.38	2.78a	34.1ab	19.1b	53.2b	5.70a	93	23.8
Four urea-N split	3.41	2.78a	37.1a	20.9a	58.0a	5.71a	93	23.9
Summer 1992								
Two urea-N split	3.42	3.09	35.9	28.5	64.4	8.00	82	19.7a
Three urea-N split	3.56	3.21	37.3	31.1	68.4	8.32	83	19.2ab
Four urea-N split	3.52	3.24	36.6	28.2	64.7	8.01	83	19.0b
Spring 1993								
Two urea-N split	3.64	3.09	35.5	20.0	55.6	7.01	91b	24.5b
Three urea-N split	3.86	3.21	36.4	18.8	55.2	7.32	93a	25.2a
Four urea-N split	3.78	3.24	39.2	18.9	58.1	7.32	92a	25.1a

N treatments were basal, at 15d after transplanting (15 DAT), maximum tillering (Max T), 5-7 d before panicle initiation (PI), and at heading (Head).

Within a column, means followed by the same letter are not significantly different at the 5th level by Duncan's Multiple Range Test.

Table 3. Agronomic efficiency of nitrogen, phosphorus and potassium fertilizers

	Crops	Alluvial soil	Degraded soil	Acid sulfate soil
Nitrogen	Spring rice	16.5 - 5.0	9.5 - 3.5	10.7 - 4.2
	Summer-Autumn Rice	12.5 – 2.5	7.2 - 2.1	8.8 - 2.5
Phosphorus	Spring rice	23.5 - 9.3	35.8 - 18.5	55.5 - 25.7
	Summer-Autumn Rice	17.6 - 6.2	24.5 - 12.3	38.2 - 17.5
Potassium	Spring rice	7.8 - 2.5	22.5 - 9.5	5.5 - 1.5
	Summer-Autumn Rice	10.5 - 3.2	21.0 - 8.2	3.5 - 0.0
Potassium + FYM	Spring rice	2.8 - 1.0	13.5 - 6.8	1.6 - 0.0
	Summer-Autumn Rice	1.2 - 0.0	11.7 - 5.2	0.7 - 0.0

Table 4. Apparent recovery of N (%) at maturity.

Season	Alluvial soil (80 - 240 kg N ha^{-1})	Degraded soil (30 – 150 kg N ha^{-1})
Spring rice	18.5 - 46.5	15.5 - 48.3
Summer-Autumn rice	12.5 -38.5	11.4 - 36.8

Table 5. Effect of farmyard manure (FYM), urea timing, and growing season on dry weight and N accumulation of lowland rice at 31 d after transplanting (DT) in summer and 33 DT in spring.

		Plant dry weight (Mg ha^{-1})	Plant N (kg ha^{-1})
FYM			
		1.5	20
		1.6	22
Urea timing			
		1.6	21
		1.6	21
Season			
		1.4	18
		1.8	24
Source of variation	*df*		Mean squares
FYM (F)	1	0.1387*	40.89
Urea timing (T)	1	0.0116	11.64
F x T	1	0.0063	14.18
Season (S)	1	1.5480**	421.86**
F x S	1	0.0833	38.70
T x S	1	0.0053	0.02
F x T x S	1	0.0185	1.95

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 6. Effect of farmyard manure (FYM), urea, and growing season on yield and N accumulation of lowland rice at maturity.

Season	Grain yield ($Mg\ ha^{-1}$)		Straw yield ($Mg\ ha^{-1}$)		Grain N ($kg\ ha^{-1}$)		Straw N ($kg\ ha^{-1}$)	
	No urea	Urea	No urea	Urea	No urea	Urea	No urea	Urea
Spring								
No FYM	2.0	2.3	2.6	2.8	23	25	20	21
with FYM	2.2	2.7	2.8	3.2	27	31	21	23
Summer								
No FYM	2.4	3.0	2.8	4.2	23	31	18	29
with FYM	2.9	3.4	4.1	4.0	32	35	27	30

Source of variation	*df*	Mean squares			
Urea (U)	1	1.812**	3.312**	185.6**	214.8**
FYM (F) x U	1	0.003	0.410**	9.2*	32.9**
U x Season(S)	1	0.173**	0.827*	18.8*	78.8*
U X F x S	1	0.043	0.706**	29.4**	53.4*

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

The increase in yield averaged for the plus and minus urea treatments was 0.3 t ha^{-1} in spring and 0.5 t ha^{-1} in summer these yield gains for 23 kg added FYM-N ha^{-1} correspond to agronomic efficiencies of 13 and 20 kg grain per kg FYM-N in spring and summer, respectively (Table 6).

When FYM was applied, rice yields in both seasons were higher for delayed than basal application of urea (Table5).

Application 10 t FYM /ha had a significant effect on available N (Total - N: NH_4^+ + NO^3-) in the soils, resulted increase of total dry matter, grain yield and total N - uptake in both soil types - Alluvial soil and degraded soil in the Red River Delta.

Effect of different P sources and rates

On Acid Sulfate soil at Do Son - Hai Phong, new rice variety (DT_{10}) was respond to P rates application better than that local rice variety (Chiem Bau) in the spring season.

Phosphorus fertilizer application increased grain yield almost four folds 1.20 to 4.55 t ha^{-1} with DT_{10} but only from 1.82 to 3.42 t ha^{-1} with Chiem Bau.

Among P sources, DAP was superior to FMP, SSP and RP in terms of yield and nutrient uptake (Table 7).

With N application, rice yield, nutrient uptake and nutrient recovery was responded to P rates added better than that without N application (Table 8).

Effect of potassium fertilizer

Potassium efficiency was very high on degraded soil. Agronomic efficiency of potassium fertilizer was from 9.5 to 22.5 kg rice per 1 kg K_2O in the spring rice and 8.2 to 21.0 in the summer rice season. When FYM was applied, potassium efficiency decreasing (Table 3).

On the alluvial soil of the Rèd River Delta potassium efficiency was very low in the past but now, to achieve spring rice yields of 6.5 - 7.0 t ha^{-1}, and summer crop of 4.5 - 5.0 t ha^{-1}, potassium must be applied at 30 - 45 kg K_2O ha^{-1} in an NPK ratio of 1,0 : 0,5. 0,5.

Cropping pattern

Changes of cropping pattern structure, such as the development of summer - autumn rice crop to be harvested by August in the Red River Delta can expand the area for winter crop. In practice farmers, cropping system Rice - Rice - Winter maize with high level of input can give yield of 17.0 - 18.0 t ha^{-1} of food per year on alluvial soil and on degraded soil too. Although, degraded soil has low soil fertility compared to alluvial soil, the productivity of winter maize on these soils is higher due to the early sowing of maize the first September.

Economic efficiency of rice production

According to assessment of economic of rice in the Red River Delta, the cost of land prepared and labour is from 58 - 70%, in total expenses investment in fertilizers, seeds and pesticide accounts only from 18 - 33%. If the yield on alluvial soil is 5,310 kg ha^{-1}, the benefit from rice production will be only 1,227,000 (Vietnamese Dong) equivalent 110 US$ per crop and on the degraded soil it is only 21,600 (Vietnamese Dong) equivalent 2 US$ with a grain yield of 3,300 kg ha^{-1}.

Rice production on saline soil and Acid Sulfate Soil is loss, especially on Acid Sulfate Soil (Table 11).

The Mega project on reversing trends of declining productivity (RTDP) is entering its second phase (1997-2000). During this phase II, on farm research will be conducted at 8 sites in the Philippines, Thailand, Indonesia, India, Vietnam and China.

Table 7. Effect of different phosphorus sources and rates (kg P_2O_5 ha^{-1}) on agronomic efficiency (AE, kg kg^{-1} P_2O_5), total uptake (kg P) and apparent recovery (A.R.) of P_2O_5 for different rice varieties on acid sulfate soil at Hai Phong.

P source	P-rates	DT 10				CHIEM BAU				MOC TUYEN			
		Yield (t ha^{-1})	AE	P-uptake	A.R	Yield (t ha^{-1})	AE	P uptake	A.R	Yield (t ha^{-1})	AE	P uptake	A.R
SSP*	0	1.20	0	8.6		1.82	0	12.4		14.2		10.8	
	30	2.35	38.3	17.4	29.3	2.35	17.7	16.4	13.3	1.67	8.3	13.3	8.3
	60	3.24	34.2	22.0	24.2	2.86	17.3	20.3	13.2	1.84	7.0	14.9	6.8
	90	3.80	28.9	27.6	21.1	3.23	15.7	23.2	12.0	1.90	5.3	15.6	5.3
DAP	0	1.20	0	8.6		1.82	0	12.4		1.42		10.8	
	30	2.78	52.7	17.9	36.6	25.5	24.3	18.0	18.7	1.64	7.3	13.5	9.0
	60	3.52	38.7	25.6	28.5	27.6	15.7	21.2	14.7	1.83	6.8	15.7	8.2
	90	4.25	33.9	32.3	26.3	3.27	16.1	24.5	13.4	1.92	5.6	16.4	6.2
FMP	0	1.20	0	8.6		1.82	0	12.4		1.42		10.8	0
	30	2.62	47.3	18.1	31.7	2.62	26.7	18.5	20.3	1.66	8.0	13.3	8.3
	60	3.86	44.3	24.3	27.8	2.85	17.2	21.2	14.7	1.85	7.2	16.3	9.2
	90	4.55	37.2	31.7	25.7	3.42	17.8	25.6	14.7	1.94	5.8	16.7	6.6
RP	0	1.20	0	8.6		1.82	0	12.4		1.42		10.8	
	30	1.68	16.0	12.4	12.7	2.52	23.3	17.4	16.7	1.70	9.3	14.1	11.0
	60	2.36	19.3	16.0	14.1	2.75	15.5	18.6	10.3	1.91	8.2	16.5	9.5
	90	3.25	22.7	24.2	17.3	3.02	13.3	22.5	11.2	1.97	6.1	17.2	7.1

*single superphosphate (SSP), diammonium phosphate (DAP), thermophosphate (FMP) and rock phosphate (RP)

Table 8. Effect of integrated P and N input on rice yield and total P and N uptake for different rice varieties on acid sulfate soil at Hai Pong.

Rates kg ha^{-1}		Spring Rice (DT_{10})	Summer Rice (Moc Tuyen)				
N	P_2O_5	Yield t ha^{-1}	Uptake (kg ha^{-1}) P_2O_5	N	Yield t ha^{-1}	Uptake (kg ha^{-1}) P_2O_5	N
0	0	1.25	9.2	20.5	1.50	11.5	23.4
	30	1.53	11.2	25.6	1.62	12.6	25.8
	60	1.60	12.5	26.5	1.60	12.0	26.1
	90	1.85	13.6	32.1	1.95	15.0	32.2
60	0	1.95	15.4	32.9	2.22	16.0	37.3
	30	2.38	18.4	42.1	2.35	18.2	39.9
	60	2.75	20.1	49.3	2.53	19.0	44.9
	90	3.25	23.5	58.1	2.75	21.2	49.2
120	0	0.95	12.5	31.9	1.35	13.7	29.9
	30	1.85	15.5	39.7	1.72	16.2	34.6
	60	3.26	24.5	63.5	2.65	19.0	49.5
	90	3.75	28.0	71.4	2.84	21.8	56.8
	LSD 0.05	0.48 t ha^{-1}			0.42 t ha^{-1}		

Table 9. The fertilizer input and the yielding abilities of the Rice-Rice-Maize system of the Red River Delta

Soil types input	Level of FYM T/ha	Spring rice Fertilizers input N kg/ha	P_2O_5 kg/ha	K_2O kg/ha	T/ha	Summer-Autumn rice Yield FYM T/ha N kg/ha	Fertilizers input P_2O_5 kg/ha	Yield	Winter Maize Fertilizers Input K_2O kg/ha	Yield T/ha
Alluvial	High	12-15	120-150	90	70	>7.0	12-15		100-120	60
soil	Fair	8-10	100-120	60	40	6.0-7.0	8-10		100	45
Average	6-8	75-100	45	0	4.5-5.0	6-8	80		0	0
Low	5-6	60-80	0	0	<4.5	5-6	60		0	0
Degraded	High	10-12	110-130	90	100	5.5-6.0	10-12		80-100	60
soil	Fair	8-12	100-120	601	70	5.0-5.5	8-10		80-100	60
Average	6-8	80-100	60	40	4.0-5.0	6-8	64-77		45	40
Low	<6	65-77	60	20	<4.0	<6	<64		0	

Table 10. Fertilization doses and grain yields of Rice-Rice-Winter maize system on Degraded soil of the Red-River Delta.

Treatment	Area under cultivation (m^2)	Crops	Dose fertilization FYM t ha^{-1}	N kg ha^{-1}	P_2O_5 kg ha^{-1}	K_2O kg ha^{-1}	Extension Experiment Grain yields t ha^{-1} Highest	Lowest	Av.
Farmer practices	700	Spring Rice	8	80	90	30	5.01	3.95	4.48
		Summer Rice	8	60	60	60	4.06	3.52	3.79
		Winter Maize	8	120	60	60	5.94	4.28	5.11
Maximum Yield Research	2100	Spring Rice	8	120	90	90	6.16	5.22	5.51
		Summer Rice	8	90	60	90	5.85	4.16	4.82
		Winter Maize	8	180	100	120	8.37	6.02	7.53
Maximum Economic Yield	7496	Spring Rice	8	100	90	60	5.97	4.84	5.32
		Summer Rice	8	60	60	60	4.96	4.16	4.59
		Winter Maize	8	150	90	90	7.33	5.89	6.86

Table 11. Economic efficiency of rice production in the Red River Delta (in 1000DVN)

Input	Alluvial soil	Saline soil	Acid sulfate soil	Degraded soil
Cost of seed	180.0	180.0	180.0	180.0
Cost of fertilizers	372.0	396.0	222.0	276.0
	266.7	262.5	291.2	291.2
	172.5	137.5	-	137.5
Cost of Pesticides	258.4	185.6	97.0	416.0
Labour	3184.0	2480.0	4000.0	2224.0
Other expenses	119.0	13.5	12.2	12.0
Tax of Agriculture	354.0	356.0	171.0	249.0
Cost of Irrigation	240.3	244.0	235.0	152.7
Total Input	5146.6	4255.1	5208.4	3938.4
Output: Yield kg ha^{-1}	5312.0	3400.0	1944.0	3300.0
* 1200 dong kg^{-1}	6374.4	4080.0	2332.8	3960.0
Benefit	+1227.5	175.1	-2875.6	+21.6

1200d 1kg^{-1} Rice
2000d 1kg^{-1} Urea
700d 1kg^{-1} SSP
2500d 1kg^{-1} RCI
8000d Labourday^{-1}
1800d 1kg^{-1} Rice of Seed

In the Red River Delta (RRD), on farm research will be conducted at 24 sites (12 sites on degraded soils at Tam Dao district, Vinh Phuc province, 12 sites on alluvial soils at Dan Phuong and Phuc Tho district, Ha Tay province.

The future

General project objectives for the immediate future are:

1. Continue biophysical and socioeconomic monitoring using FFP and total -F plots to establish trends in total factor productivity (TFP) partial factor productivity (PFP), and indigenous nitrogen supply (INS)

2. Develop and validate site-specific nutrient management + (SSNM) technology for intensive rice systems.

3. Improve understanding of processes governing soil nutrient supplying capacity (SOM, microbial processes)

4. Integrated (SSNM) with integrated pest management (IPM) to establish site-specific crop management (SSCM) practices

Design details and fertilizer rates

Design:

PK, NP, NK and FFP plots 1997

PK, NP, NK SSBN and FFP plots 1998

Fertilizer rates (all in kg ha^{-1}, on elemental basis)

Treatment	Element	Alluvial			Degraded soil		
		Spring R	Summer R	Winter R	Spring R	Summer R	Winter R
PK	N	0	0	0	0	0	0
	P	30	30	50	30	30	50
	K	50	50	80	50	50	80
NP	N	150	120	200	130	100	200
	P	40	40	60	50	50	60
	K	0	0	0	0	0	0
NK	N	150	120	200	130	100	200
	P	0	0	0	0	0	0
	K	120	120	180	150	120	180

Data to be collected

*Initial soil: OC %, N %, P %, K %

particle size (Clay, silt, sand)

CEC, exchangeable K. Na

Ca. Mg. Olsen- P. pH

* Soil sample 30 DAT

PK plot OC%, N%, available N

NP lot. Olsen-P

NK plot

* Resin Capsule

PK plot NH_4 - N

NP plot - K

NK - P

*Plant sampling

PI : nutrient uptake

PM : yield, yield components and nutrient uptake

* Chlorofhyll meter

* Socioeconomic data

*Weather data : Rainfall, Maximum and minimum temperature solar radiation.

Grain yield in the PK plots ranged from 2.5 to 6.1 t h^{-1} a on Alluvial soil and from 3.1-5.2 t ha^{-1} on degraded soil, and suggest a higher effective indigenous nitrogen supply of alluvial soil comparable with degraded soil.

Levels of effective P and K on rice yield was the same on alluvial soil. However effective K was higher on degraded soil (Table 12).

Table 12. Spring rice yields in on-farm monitoring in the Red River Delta (t ha^{-1})

Soil type location	N° of farmers	FFP	PK	NP	NK
Alluvial soil DAN PHUONG	101	9.2	6.1	7.2	8.1
	102	10.2	5.4	7.1	6.3
	103	9.4	5.5	7.4	7.3
	104	7.7	5.3	6.9	6.6
	X	9.1	5.6	7.2	7.1
Alluvial soil PHUC THO	205	6.1	5.0	6.6	6.2
	206	5.7	4.5	6.0	6.3
	207	6.6	5.5	6.4	6.1
	208	5.6	4.7	5.8	5.2
	209	6.6	2.5	5.8	5.9
	210	6.1	3.7	4.5	4.1
	211	5.5	4.3	4.8	5.8
	212	5.9	4.2	5.7	5.4
	X	6.0	4.3	5.7	5.6
Degraded soil TAM DAO	301	5.2	5.0	6.0	5.9
	302	5.7	5.3	6.0	6.0
	303	6.1	4.5	6.2	6.5
	304	5.5	4.4	5.1	5.9
	305	4.0	3.2	4.0	3.7
	306	5.7	3.1	4.9	5.4
	307	6.0	3.3	4.4	4.7
	308	4.5	3.5	4.3	5.0
	309	5.3	3.9	4.4	4.4
	310	5.8	4.2	5.7	5.7
	311	5.8	5.2	6.2	6.3
	312	4.9	4.3	5.0	5.2
	X	5.4	4.1	5.2	5.4

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Integrated Water Management in the irrigation pumped systems in the Red River Delta

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Introduction

The Red River Delta is one of the seven economic regions of the country and comprises nine provinces and cities: the provinces of Hai Duong, Hung Yen, Nam Dinh, Ha Nam, Ha Tay, Thai Binh, Ninh Binh and the cities of Ha Noi and Hai Phong. The total natural area is 1,250,000 ha and the area under cultivation is 667,005 ha. The population in the delta is about 14 million inhabitants, with a high rate of population growth. The Red River Delta has a triangular shape, one point is the capital Ha Noi and the base is the coastal line from Hai Phong to Ninh Binh. The topography is relatively flat and slopes toward the sea. Part of Ha Tay province and Ha Noi City is referred to as the transitional land between the highlands and the delta.

The soil in the Red River Delta is mainly alluvial soil deposited by the Red River and the Thai Binh River networks. This soil is considered to be suitable for agricultural development, especially for rice cultivation. Some areas affected by hydrology and climate suffer from salinity problems, and these are mainly distributed in Hai Phong (strong and moderate saline soil is about 45,000 ha) while acid sulfate soil, occupies about 200,000 ha, mainly in Thai Binh, and Hung Yen. Water management is one of the key measures to manage these soils.

The Red River Delta is located in the tropical monsoon region characterized by alternating dry and wet seasons. According to data from the HaNoi meteorological station, the annual average temperature is 23.4°C, humidity is rather high, over 80%, and annual rainfall is about 1700 mm.

Traditionally, most of the agricultural land are used for rice cultivation, and this accounts for 585,284 ha of total annual cultivated land out of 643,021 ha. As a result of completion of irrigation schemes, the Red River Delta has 45,426 ha for triple rice cropping, 450,817 ha for double cropping, and only 55,516 ha for mono cropping. The coefficient of cultivated land use reached 1.77 in 1993. Average rice yield in 1993 was 8.3 t ha^{-1} $year^{-1}$. Rice yield is anticipated to increase in the course of time. Apart from rice, the diversified cropping pattern in the Red River Delta includes maize, potatoes, and vegetables, which have been introduced on a large area, even during the transition period from the rice summer crop to the rice winter-spring crop.

The Red River Delta has two river systems. The Red River and Thai Binh River provide the main courses for irrigation and drainage. The flow of these rivers is greatly affected and regulated by the Hoa binh reservoir; water level in the rivers increases in the dry season to create favorable conditions for gravity irrigation directly or indirectly by pumping stations for irrigation. This is possible as water level in the suction basin is higher than that before operation of the Hoa Binh reservoir. However, the regulatory role of the Hoa Binh reservoir has an adverse impact on the gravity drainage schemes in the rainy (wet) season in the lower parts of the Red River Delta. This is a problem of interest to all the government agencies concerned. The water in the Red River is generally of good quality and high alluvial cntent, and consequently, is useful for land improvement (Table 1).

Table 1. Change of soil properties in the saline soil in Hai Phong.

Items	Physical clay (%)	pH KCl	Humus (%)	Total NH_4 (%)	Total P_2O_5 (%)	Attractable NH_4 (mg/100 g-soil)	Attractable P_2O_5 (mg/100 g-soil)
Before irrigate with alluvial water	51.4	5.7	3.1	0.22	0.055	6.5	2.50
After irrigate with alluvial water	70.7	6.1	3.3	0.24	0.060	7.0	5.75

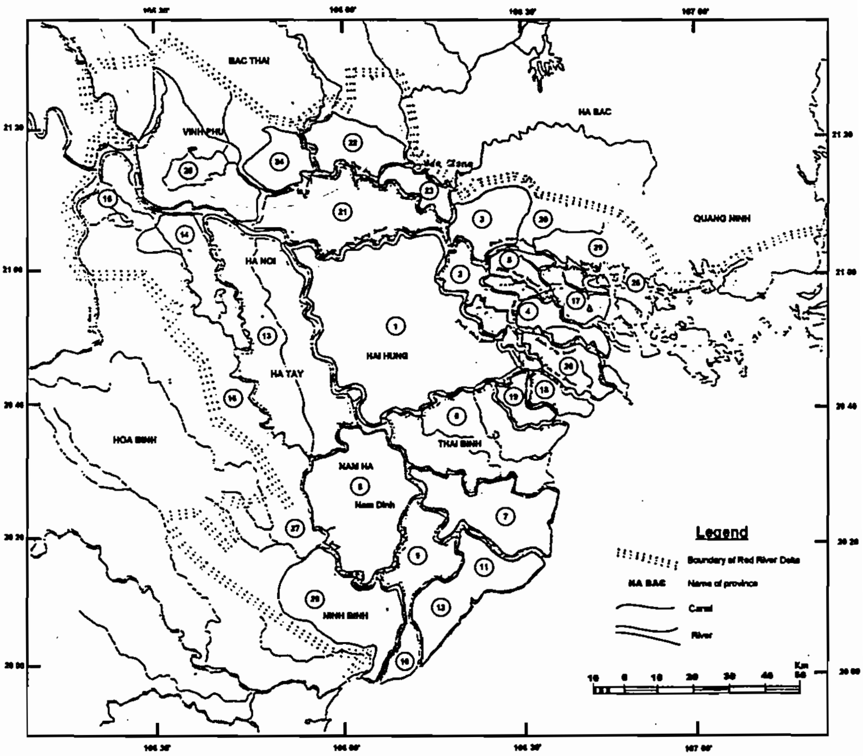
When discussing water management, the term deals with irrigation, drainage and flood protection. Water management herein will deal with irrigation and drainage due to its close interaction. Even though the rainfall in the Red River Delta is high, as noted above, it is distributed unevenly throughout the year; 70-75% of total rainfall falls in 3-4 months of the wet season. About 30% of annual rainfall falls in one critical month. As a result, this causes severe flooding. In contrast, 5-8% of annual rainfall occurs in the dry season and can lead to drought or shortage of water for cultivation.

Excess or shortage of water is controlled in association with the irrigation schemes. To cope with the goal of self-sufficiency in rice and to meet requirements in food for people, the priority is given to water management as a key measure in agricultural development by the government. Attention is paid to completion of a numerous irrigation schemes in the Red River Delta. The schemes were constructed for water supply in the dry season and drainage of floodwater in the rainy season. The most common feature of the schemes is that the schemes have been designed for dual purpose irrigation/drainage. The agency manages the headwork, primary and secondary channels. The important role is exemplified by the North of Hung Yen province, where 9 droughts occurred in 10 years. This area is currently one of the areas with the highest intensive farming in the Red River Delta, and achieved this since the Bac Hung Hai scheme was completed.

There are currently 25 irrigation systems in the Red River Delta with capacity to irrigate about 618,723 ha and to drain about 839,356 ha (see figure 1 and table 2). Most of the irrigation and drainage in the Red River Delta is effected by pumping stations (80% of cultivation area). At present, there are some 1700 pumping stations with 7600 pump sets with installed total capacity of 261,000 Kw. In any irrigation scheme in the Red River Delta, pumping stations of different scales have been constructed for individual aresa where irrigation/drainage cannot be accessible from the main channel. The pumped irrigation scheme which were introduced later is a scheme where the headwork is a pumping station. The biggest pumped irrigation scheme in the Red River Delta is the Northern Nam Ha scheme; its main purpose is drainage.

Since the hydroelectric plan in Hoa Binh was put into operation, the electric supply to the pumping stations has been considerably improved, and power cut-offs are now rarely seen in most pumping stations.

Attention should be paid to energy consumption in the pumped irrigation schemes. Energy consumption is at a high level of 250-300 Kw-h/ha, which accounts for 40-50% of the total operating cost. Such a high level of power expenditure precludes the operating agencies from maintaining an appropriate level of maintenance expenditure and thus reducing the long-term sustainability of the schemes. The reason for high energy consumption are:



1. BAC HUNG HAI
2. NAM THANH
3. CHI LINH
4. AN KIM HAI
5. KIM MOM
6. NORTH THAI BINH
7. SOUTH THAI BINH
8. BAC NAM HA
9. NAM NINH
10. NGHIA HUNG
11. XUAN THUY
12. HAI HAU
13. SONG NHUE
14. PHU SA
15. BA VI
16. MI DUC
17. THUY NGUYEN
18. TIEN LANG
19. VINH BAO
20. AN THUY
21. BAC DUONG
22. SONG CAU
23. NAM YEN DUNG
24. SOC SON
25. LIEM SON
26. SOUTH NINH BINH
27. NORTH NINH BINH
28. YEN LAP
29. UONG BI
30. DONG TRIEU

RED RIVER DELTA MASTER PLAN

IRRIGATION SCHEMES

Binnie SMEC AACM Delft

Figure 1: Irrigation on schemes in the Red River Delta

- The equipment is obsolete after long service.

- The system is not run on operational rules; the irrigation rotation in reaches is not implemented. Consequently, agreed service levels at the end reach of canals is difficult to command.

- The farmers at the upper part of main or secondary canals take water freely and/or take water illegally for their fields. This causes flooding in low fields, or water flow into drains, and water waste is unavoidable; and

- Lack of water control structures.

Problems in water management

Most pumped irrigation schemes have been completed for 20-50 years. At that time, most crops in general and rice in particular were traditional varieties, not sensitive to water. The economic development of the country was also at a low level. The proper drainage design coefficient at that time was only 3-4 l $(s.ha)^{-1}$. This led to the fact that initial investment was low at 1,000 US$/ha while this value is 3,000-5,000 US$ ha^{-1} in other countries with the same conditions. At present, a diversified cropping pattern is widely practised in the Red River Delta, and new varieties of crops are very sensitive to water. It is therefore necessary to construct additional pumping stations for discharging excess rainy water. For example, in the Song Nhue scheme, an additional pumping station with total capacity of some 300 m^3/s has been constructed that conveys excess water to the Nhue River, but the outlet at Phu Ly has a capacity of 180-200 m^3 s^{-1}. This creates problems in management activities. In addition, the climate seems to have changed. Therefore, it is necessary to consider the adequacy of the current situation and to replan water managfement in accordance with cropping pattern diversification in the Red River Delta.

The irrigation schemes in the Red River Delta have been improved twice, but only 47% of irrigated areas are at the agreed level of service. This portion could be rather higher, but it can apparently not reach a design value. The main reason is poor infrastructure and management. It is envisaged that inevitably the need for rehabilitation and modernization of large sections of the irrigation infrastructures and pumped irrigation schemes will have to be done. As noted above, in the pumped irrigation systems, the high energy cost required to operate these systems (typically 40-50% of the total operating cost) is a cause of great concern to operators and managers of these systems. The water fee is a real problem for the agencies concerned, and they cannot be collect these fully. This substantially reduces the ability of irrigation agencies to maintain an adequate level of expenditure on maintenance, leading to a rapid decay of the irrigation infrastructure. An inadequate delivery infrastructure creates widespread problems of unreliable and untimely supply of water to irrigators. This will become more critical as farmers seek to diversify by incorporating new dry-footed crops into their rotation systems, in addition to rice.

As identified in the Master Plan for the Red River Delta, there are a number of physical constraints related to water management. Foremost among these is the inadequate database on which to base operating decisions throughout the irrigation system, including farm level water demand pattern, hydraulic behavior of the delivery network and lack of understanding of the impact of operational decisions. This can be corrected with the help of computer programs in combination with experienced operators and managers.

It is known that rice accounts for the bulk of the irrigation area and of water use. However, dry-footed crops are becoming increasingly important because of self-sufficiency in rice production and better market prices especially for maize, potatoes, and vegetables. The increasing adoption of a cropping pattern composed of three crops per year in the majority of the irrigation area creates new demands for both quantity and flexibility of supply. This new pattern of demand at the farm level must be thoroughly understood to develop appropriate farm management and delivery strategies. An important new feature of irrigation is the application of new government land tenure policy under which farmers can cultivate and manage their own land. The management of irrigation thus far has taken place along well-established relations between irrigation agencies and cooperatives to avoid illegal water removal. The allocation of land units to farmers through a new system will change this situation dramatically and new management arrangements between agencies and farmers must be developed. Cooperatives, then water management groups still have an important role in water management, but the overall range of functions performed by cooperatives is changing rapidly. Some of their former functions are now no longer necessary, and there are new needs on the part of farmers which the cooperatives will have to meet.

At present, the water fee is usually collected in the area under irrigation based on calcu;ations done by cooperatives and the water agencies. It does not seem to be correct for all cooperatives or farmers, the farmers at the upper parts of canals take more water than the ones at the end, but they pay the same water fee. The water measurement structure is not the same in all pumped irrigation schemes, and under such conditions it may be proper to install an appropriate water measurement scheme for each cooperative. Water fee then will be collected on volume of use. Consequently, it is envisaged that there will saving of irrigation water.

Water level is one of the components of any agreed level of service; regulation of the water level mainly depends on opening/closing the control gates manually. It is difficult to set the correct opening of the gate. This needs much labor, and it is frequently difficult to get the desirable water level: either too high or too low. So, an automatic water level control structure should be used.

The secondary canal involves two or more cooperatives, and at critical times, water disruption usually happens. To solve this problem, a water user association/water advisory committee should be set up in order to run the water distribution system throughout the canal.

Conclusion

Water management in the pumped irrigation schemes played and will continue to play an important role in agricultural development of the country and in achieving food security and poverty alleviation. However, these schemes have actual problems that require solving so that the schemes operate more efficiently. These are:

- Irrigation development funding, cost-sharing and recovery and water pricing;

- Sustainable operation and drainage; and

- Irrigation/drainage institution and participation of farmers in water management.

To solve the actual arising problems in integrated water management in the pumped irrigation schemes, international cooperation is necessary and of great significance. International organizations and foreign countries could assist Vietnam with the techniques and finance to carry out research, professional exchanges and staff training.

Some opinions on land and water resource management in the Red River Delta, Vietnam

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Introduction

The Red River Delta (RRD) plays a significant role in the socio-economic, political and cultural life of the Vietnamese people. It is the second largest rice production area after the Mekong Delta in our country, but it is the focal point for rice production in the north.

The RRD consists of nine provinces --- Ha Noi, Hai Phong, Thai binh, Nam Dinh, Ha Nam, Ninh Binh, Ha Tay, Hai Duong, Hung Yen --- with a total natural area of 1.251 million ha and population of over 14 million inhabitants (1995). This accounts for 19.59% of Vietnam's population, of which 82% of this regional population is in rural areas. The average population density is 1,124 inhabitants km^{-2}, but in some localities such as former Hai Hung (1,747 inhabitants km^{-2}), is even higher.

The ecological unsustainability in RRD is mainly due to the over exploitation of land and water resources for the development of agriculture and rural non-farm activities as well as urban development. This problem is more and more crucial and requires a strategy for the protection and utilization of these natural resources, not only for present but also for future generations. This paper concentrates on the main policy issues related to the said natural resource management.

The potential

The RRD consists of land resource of seven different land groups for agricultural production, in which 70% is alluvial soil with high and medium fertile grade. The regional climate consists of a hot and humid summer as well as a cold winter. The average rainfall is 1,600-1,700 mm, providing abundant water resources including surface water and underground water. Natural conditions are favorable for many high value tropical and subtropical crops. This region has abundant and highly educated labor resources in which 56% and 13% are graduates from secondary schools and high schools respectively. This labor resource consists of hard working people who want jobs with good incomes to enable them to improve their lives.

The RRD is the best development region of Vietnam in terms of rural infrastructure. The hydrological system is relatively completed and can provide irrigation for 70.1% and drainage for 66.7% annual cropping areas. Rural electrification is nearly finished with 98.1% communes and 89.4% households having access to the National electrical network, respectively. The regional transport network is expanded and improved. Currently, 94.9% communes and 3 provinces have 100% of communes with roads usable by cars, to commune centers. The local markets, health care stations and schools are also fast developing.

Land use

The most notable issue in RRD is the relatively small area with high population density; the average land per household and inhabitant is 2,856 m^2 and 577 m^2, respectively. It is very low. For the whole region, 45.5% of households have less than 0.2 ha; 50.4% households have 0.2-0.5 ha; 3.2% households have 0.5-1 ha and 0.12% households have over 1 ha (General Statistical Office, 1994). With this land structure, farmers in RRD have to exploit land intensively with 2-3 crops per year. In the suburban areas, farmers sometimes have four crops annually with high levels of chemical fertilizer and pesticide application, having great impact on land degradation and pollution.

For implementation of the government's decision on land allocation to farmer households, up to now, 90% of arable land area has been allocated to 95% of regional farmer households. Thanks to the stable land allocation, farmers are encouraged to produce more. Annually, the total production of agriculture is increasing by 7-8%. However, for fair assurance, land is scarcely divided into very small plots. For example, in Ha Tay province, each farmer household has 10-15 plots on average, some even have 25-30 plots, each of several tens of square meters. In Vinh Tuong district, and Vinh Phu province, similarly, each farmer household has 9.7 plots on average and each plot is an average of 2?5 m^2. The small land plot is just suitable for manual labor but it is big constraint for agricultural mechanization. Small land plots with a small plot surrounding line has prevented farmers from fertilizer and pesticide investment since it will be partly wasted in neighbor's plots.

Due to high growth rates of natural population, industry and urban areas as well as the expansion and improvement of transport system, etc., the regional arable land is decreased from time to time. During the past 10 years (from 1985 to 1995), the regional arable land decreased by 44,957 ha, in particular, the rice growing area decreased by 23,122 ha. On the other hand, the quick establishment of industrial zones has had adverse impact on the regional ecological environment. In order to overcome these challenging constraints, we should

- Assist farmers on land plot exchange to prevent scattering situation;

- Have land planning and reservation for social welfare and infrastructure development in order to use land resource appropriately and away from waste land; and

- Provide favorable conditions to promote diversification and intensive farming for high yield and farmer's income improvement through land use regulation reform, credit provision, technology transfer, provide market information, rural infrastructure improvement, namely transport road, irrigation system, electric and water supply systems, etc.

Utilization of water resources

From 1955 up to now, Bac Hung Hai hydraulic station and various medium and small hydraulic stations have been constructed in the RRD. The ratio of irrigated land over arable land area in RRD is the highest in our country. Currently, the hydraulic system in RRD has a design capacity of 860 thousands ha on irrigation and 700 thousands ha on drainage. In 1995, 1.29 millions ha were irrigated, for which 628,000 ha were winter-spring rice, 562,000 ha were summer rice and 0.2 million ha owere winter vegetable and food crops.

In RRD, hydraulic stations have very low irrigation efficiency (0.8 l s^{-1} ha^{-1}) whereas the requirement is 1.2 l s^{-1} ha^{-1}. The active irrigation area is low and only accounted for 50% actual area, i.e. about 250,000 ha. Water pumping is main approach for drainage in RRD. If very high rainfall leading to floods occurs, and since water pumping station's capacity is not enough or high electrical fee, crop failure or low yield will occur on several 10,000 ha.

After the Solution No. 10, the full time hydraulic teams in the communes no longer existed, where as there isn't' any other form for effective replacement. Therefore, in communes and villages, the irrigation, drainage and system maintenance are not good. This is the main reason for the degradation of hydraulic systems.

For the development of hydraulic systems which can sufficiently supply water for agriculture and will encourage farmers to be reasonable in their utilization of water resource, we should:

- Have good maintenance of the present hydraulic systems; construct some new hydraulic works for actual improvement of irrigation and drainage capacity (currently, irrigation and drainage reach 64% and 54% of other designed capacities respectively);

- Improve operations of hydraulic companies; encourage farmers to join into water utilization groups and have a mechanism for farmers to take the ownership and responsibility for the maintenance and management of the hydraulic systems;

- Strengthen durably the existing hydraulic systems, where the conditions are suitable, to reduce the rate of land occupation as well as water loss; and

- Adjust water fee to encourage reasonable water utilization and prevent water resources from pollution.

In general, land and water are the two most important natural resources in the RRD. The renewal policies have created a dynamic force to encourage farmers in effective utilization of these resources. However, some policies should be further adjusted to improve efficiency of these resources' management and utilization in present as well as near future.

An interdisciplinary study of a rice-growing village: History and contemporary changes

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Introduction

In order to carry out a successful village or rural development programme, an understanding of the village or the area is first needed. It is, however, doubtful if many programmes have been initiated only after sufficient understanding and knowledge of the village or the area are obtained. We can observe everywhere in the world many failures of rural development programmes initiated without sufficient understanding of the background.

The purpose of this study is to develop basic understanding of a single village in the Red River Delta (RRD). In terms of collecting basic data and clarifying mechanisms of village structure, this is a kind of basic science. Studies of rural development are included in applied science, which can only be carried out effectively if it is based on the basic science. This means that both contributes to each discipline and makes research results useful to the village. For example, we aim to contribute to the following disciplines -- Vietnamese modern history, sociology on Vietnamese society, agricultural system in Vietnam, etc. At the same time, we aim to make the findings of our project useful to the village. This exemplifies a rural development programme taking advantage of the traditional network system of the village or the traditional handicraft industry of the village.

Methodology

In order to understand a village, we adopted an area study method. It is an interdisciplinary research approach where many researchers with different disciplines study a village together from various viewpoints, discuss and

1 This project was started in 1993 by Dr. Sakurai Yumio, who is a professor on Southeast Asian history, University of Tokyo, Japan. This association is organized for all researchers who participate this village study. The report series '*Thong Tin Bach Coc*' (No.1-7, September 1997).

exchange their ideas and choose key terms which are needed for understanding the village in its own context. We consider that it is difficult to get total village understanding if researchers do research only in terms of their specific disciplines. We should put each discipline into the village context and, relatively, reconsider the meaning and role of our own discipline. The nature of the area determines the research themes and disciplines, not *vice versa* (Sakurai, 1997). Although we are still on the way to identify all the subjects that must be included to understand the village, we so far consider history, social institutions, and agriculture, mainly rice cultivation, as key topics. Without understanding of these fields, it is impossible to know the village, and rural development programmes can only succeed after we accumulate sufficient research results at least on these fields.

Research organization

In this study, we do interdisciplinary research as a group. The disciplines of the researchers in our team include history, sociology, anthropology, politics, and archeology from social science, and hydrology, plant nutrition, horticulture, and agronomy from the science of agriculture. From the Vietnamese side, the Center for Vietnamese Studies (*Trung Tam Nghien Cuu Vietnam*) and Department of History (*Khoa Su*), Hanoi National University, are cooperating in our study. From the Japanese side, it is mainly researchers from the University of Tokyo, whose major focus is social science and from Kyoto University, whose major focus is agriculture. The total number of researchers is more than seventy.

Progress of research

This study has been done in three steps: general survey, collection of basic data, and specific survey.

General survey

In 1993, one year before the full-scale research was started, we had carried out a general survey in the Red River Delta. The survey purpose was to select the study village. At the same time, we sought to understand if the village had any special characteristics or peculiarities compared to other villages. The Coc Thanh cooperative in Thanh Loi commune, Vu Ban district, Nam Dinh province (Nam Ha province in 1994) was chosen for the study village (Figure 1). The reasons for its selection are:

- Its location in the central part of the Red River Delta and, topographically, it is on the complex area of new delta, back swamp, natural levee and sand dune;

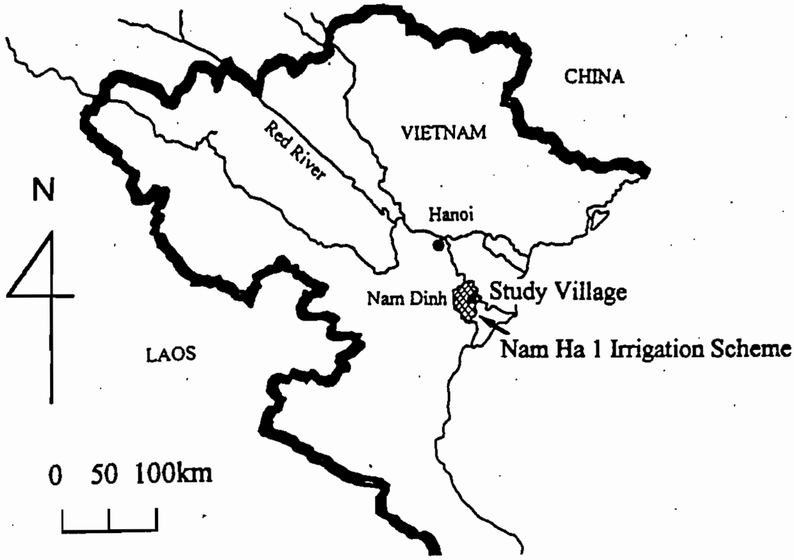

Figure 1: Location of study village.

- Landholding scale is near the average of that in the Red River Delta[2],

- Village level organizations such as cooperatives are still active, and

- There are some historical documents and academic achievements of the village, which is essential to do historical research (e.g. Sukarai, 1987).

Basic survey and some results

The basic survey included two surveys, one is a land survey and the other one is an interview about household activities.

Land survey: We made topographical maps of the village through an on-the-ground land survey in the first year, because a detailed map of the fields and houses is quite useful for village study. Although such maps could be made using remote sensing, there is still real value in doing on-the-ground surveying. For example, visiting each house and walking around each paddy field made us understand the villagers' spatial perception of the village. This

2 The average landholding in the Coc Thanh cooperative is 630 m2/person (1994), compared to 612m2 per person in Nam Ha province (Nam Dinh and Ha Nam provinces since 1996) , and 556 m2 per person in the Red River Delta as a whole (Tong Cuc Thong ke, 1995).

can be a great help for us in doing specific research at full-scale for the next year. Between 1994 and 1997, a total of 36 persons contributed to making a field map on a scale of 1 to 1,000 and a residence map of 1 to 500. We presented a copy of the residence map to the Coc Thanh cooperative in 1997.

Interview: In 1995, we conducted an interview of all farmers belonging to one production brigade. Researchers brought a questionnaire directly to farmers and asked them questions. 113 out of 152 farm households (74.3%) respomded to our questionnaire (152 households for 1996).

The questionnaire was divided into three categories, namely, agricultural management, personal information, and household economy. Headings of the questionnaire are as follows:

Agricultural management

landholding, official payment of the winter-spring season, official payment of the summer season, purchase of rice seed, selling rice seed to cooperative, cost of nitrogen fertilizer, cost of phosphorus fertilizer, cost of potassium fertilizer, input of organic manure, cost of insecticide and pesticide, cost of agricultural tools, payment to the cooperative, cost of plowing and threshing, production cost and the amount of selling rice, labor day and exchange labor for rice cultivation, name of the winter-spring season vegetables, selling the winter-spring vegetables, selling white potato, name of the summer season vegetables, selling the summer vegetables, hog raising, cattle raising, poultry and dog raising, fish cultivation, fruits cultivation

Personal information

personal information (including family name, date of birth, place of birth, married year, age of married year), educational background, participation in social organizations, business, handicraft, migrant workers, wage worker, sending money to the village

Household economy

Residence (including year of house construction, housing space, building material, who constructed, cost of construction), plan of newly-build house, repair of house, geomancy (*phong thuy*), clothing, foods, seasoning, food expenses, fuel, consumer durable, furniture, educational expenses, cultural activities, funeral expenses, health care, medicinal expenses, total expenses in 1994 .

Some results of the basic survey: Some findings of the agricultural management survey are:

Agriculture

- Importance of vegetables cropping;

- Main cash income sources are from vegetables, hog raising and fish raising;

- Lack of rice market;

- New seedling methods for rice cultivation spread in recent years; and

- White potato production managed by the cooperative is one of the special characteristics of the Coc Thanh cooperative.

Specific research

Research themes and activities: Based on the basic surveys in 1994 and 1995, specific research was carried out in 1996 and 1997. Main research themes and activities were as follows:

- *village history:*

- Interview with head of the old production brigade;

- Interview on personal history of an old person;

- Effect of famine in 1945;

- Identification of old fields (*xu*) to present ones (*xu dong*): comparative study of land register in 1804 and present name of the fields;

- Collecting and analyzing old Chinese documents in the village;

- Research on traditional custom (*tuc le*) in the village; and

- Research on traditional education system.

- *archeology:*

- Collecting and analyzing cultural remains in the village (including excavation)

- *sociology:*

- Activity of village level medical station; and

- Population dynamics in the village.

- *architecture:*

- Measurement of traditional houses.

- *agriculture:*

- Changes in land use and the technical background before and after renovation policy (*Doi Moi*);

- Changes in agricultural productivity in the village;

- Roles of cooperatives in agricultural production;

- Soil analysis (joint research with the Vietnamese Agricultural Science Institute);

- Ecological research on ponds (*ao*) near the residences; and

- Setting up a meteorological station for field experiment in the village.

Some results of the specific survey: Based on the findings from the basic survey, we started some specific research[3]. The themes in agriculture are:

- Changes in cropping pattern before and after renovation policy, *Doi Moi*;

- Changes in agricultural productivity, especially changes in rice productivity; and

- Roles of cooperatives in agricultural production.

Changes in cropping pattern: As a result, the biggest changes before and after *Doi Moi* in terms of cropping pattern, is that the vegetable area has expanded 16.9 times from 2.7 ha in 1985 to 45.5 ha in 1995, especially in the winter - spring season (Figure 2). The technical reasons why the vegetable area has expanded, are:

- New seedling techniques for winter-spring season rice in order to shorten seedling period and rice growing period in the field were diffused. This technique, called *ma nen* or *ma san,* was improved and spread by farmers;

- The cooperative purchased three diesel pumps and carried repair work of the main drainage canal for security of irrigation water for vegetable cropping in the winter-spring season; and

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3 This section is based on Yanagisawa & Kono, 1997.

1985			1996		
cropping pattern(*)	cropping calendar J F M A M J J A S O N D	planted area and its change(**) (unit ; ha)	cropping pattern	cropping calendar J F M A M J J A S O N D	planted area (unit ; ha)
VEG	VEG	2.7 (2.7) → VEG	VEG	VEG	11.9
GN-RR	GN / RR	23.9 { (9.2) → VEG; (14.7) → VEG-RR }	VEG-RR	VEG / RR /	15.7
2R	WSR / RR	151.5 { (1.0) → VEG-RR; (9.6) → 2R-VEG; (140.9) → 2R }	2R-VEG	/ WSR / RR / VEG	9.6
			2R	WSR / RR	140.9
NB	NBRR NBWSR	17.8 (17.8) → NB-2R	NB-2R	NBRR NBWSR / WSR / / RR /	17.8
2R,GN-RR	WSR,GN / RR	8.3 (8.3) → SP	SP	/ PO / VEG / RS / VEG	8.3
(Pond)		0.1 (0.1) → 2R	2R	WSR / RR	0.1

(*) VEG: vegetables, RR: rainy season rice, GN: groundnut, 2R: double cropping of rice, WSR: winter-spring rice, NB: nursery bed, SP: production managed by the cooperatives, PO: potato, RS: rice for seed

(**) ⟶ indicates the changes of planted area. For example, cropping area of vegetable (VEG) in 1995 was 11.9 ha, of which 2.7 ha was VEG and 9.2 ha was GN-RR in 1986.

Figure 2: Changes in cropping pattern of the Coc Thanh Cooperative.

Source: This table is estimated from land register of the Coc Thanh Cooperative 1984-1992 and results of field survey.

- New crops and varieties for winter - spring crops were introduced by the cooperative.

Changes in agricultural productivity: Figure 3 shows changes in actual rice yield of the cooperative. Actual yield is composed both of a climatic factor and of a technical factor. It can be considered that the fluctuation of the actual yield is affected by both of them. In order to evaluate the changes in agricultural productivity from a technical viewpoint, fluctuation affected by the climatic factor should be removed from the actual yield. In order to do this, at first, we calculated a potential yield estimated by climatic factors, and obtained the ratio of potential yield to actual yield. This can be considered as a technical index of rice cultivation, because the effect of climatic factor was offset (Kotera, 1996).

Figure 4 shows changes in the technical index. Since 1989, the technical index of both the rainy season and the winter-spring season rice began to increase. And, in the case of the winter-spring season rice, technical index from 1986-88 is 35-40%, from 1989-1992 is 60-70 %, and after 1993 is about 80 %.

These changes were caused by diversification of rice varieties and diffusion of new seedling techniques for summer rice. Figure 5 shows the changes in rice planted area by rice variety group in the village.

Another reason why the technical index changed is diffusion of new seedling technique, called *ma kho am*. This technique was improved by farmers in order to avoid water logging injury during the seedling period and after transplanting by planting tall seedling with height of more than 30 cm.

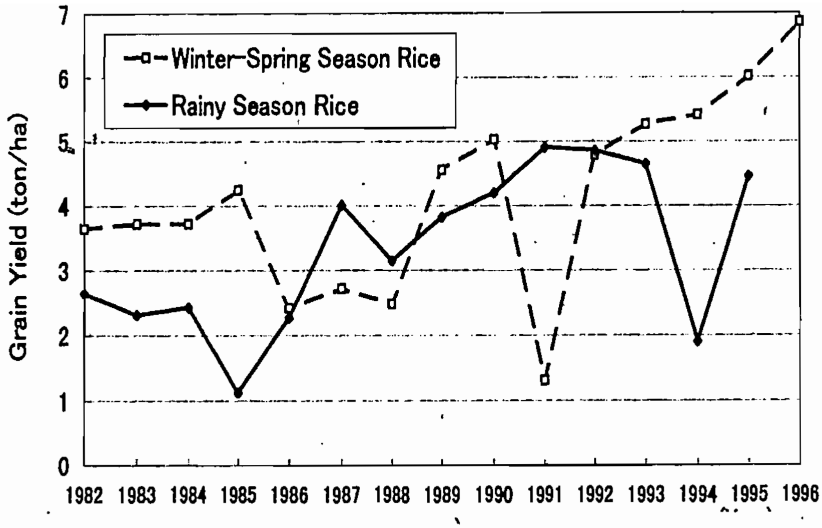

Figure 3: Actual rice yield of the Coc Thanh Cooperative since 1982.

Source: Coc Thanh Cooperative.

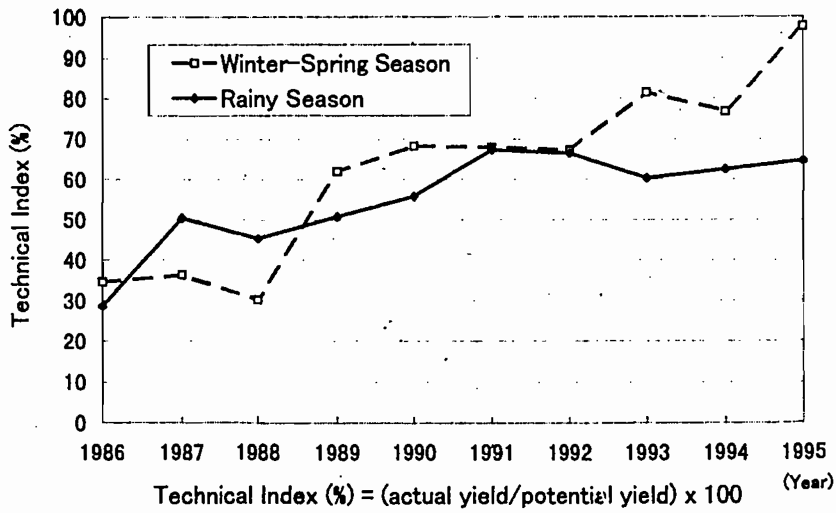

Figure 4: Changes in technical index of rice yield.

Source: Kotera, 1997.

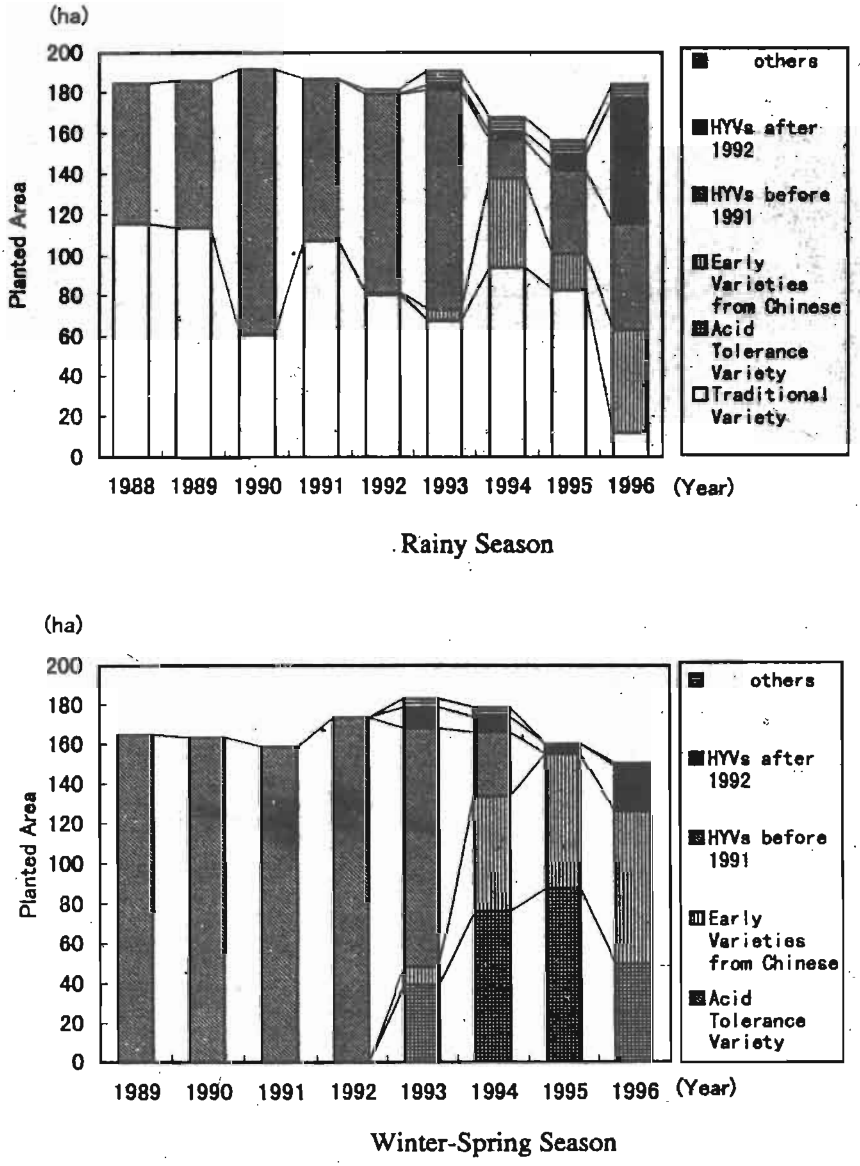

Figure 5: Rice planted area by rice variety group in the Coc Thanh Cooperative.

Source: Coc Thanh Cooperative.

Roles of the cooperative in case of potato production: In these changes both in cropping pattern and agricultural productivity, not only the farmers but also the cooperative played a key role, although it is said that the function of cooperatives is decreasing after *Doi Moi.* Furthermore, in case of the Coc Thanh, we can observe another activity managed by the cooperative. It is potato production in winter-spring season.

The cooperative determined three fields as specific fields for potato production to be managed by the cooperative since they started potato production in 1986. When the land was distributed to the farmers in 1988 and 1992, the cooperative did not distribute these fields to the farmers who did not want to plant potato in these fields. They were kept as specific fields for potato production.

In these fields, the cooperative does not allow farmers to plant other crops than potato during the winter-spring season. Farmers have to keep the planting methods, such as fertilizer application, planting varieties, and summer crops and so on, throughout the year. It is guided by the cooperative.

Regarding the potato market, about 25% of the total potato production in the Coc Thanh cooperative (about 60 tons of potato), is sold to outside merchants through the cooperative.

In the spring of 1997, the cooperative constructed a cold storehouse for potato seed. It keeps four centigrades all the year. They store a maximum of 35 tons of potato seed and sell it when the price is highest in the year. This shows that the cooperative is managing a kind of enterprise.

It can be said that cooperatives in the Red River Delta have been changing since the second half of the 1980s. It is true that privatization brought spontaneous technology improvement by farmers themselves, but cooperatives also played key roles in terms of changes in cropping pattern and agricultural productivity and potato production, as above mentioned. The different roles of the cooperative are summarized in the Table 1.

Table 1. Roles of the Cooperative in the changes after Doi Moi.

Changes in cropping pattern and Productivity	Supporting technologies	Who introduced the technologies		
		Farmer	Cooperatives	Outside
Expansion of vegetables	Young seedling method	x		
	H1 drainage-canal	x	x	x
	Diesel pump		x	
	New varieties and crops		x	
Highly-used nursery beds	New varieties	x	x	x
Introduction of winter crops	Introduction of maize		x	
Potato production managed by The Cooperative	Introduction of spring potato		x	x
Increase in rice yield	New rice varieties		x	x
Decline in traditional varieties	kho am method	x		

Future research plan

Some interdisciplinary research questions mentioned below may be future research themes.

- Restoration of the land use and the changes since 19th century;
- Formation of the village and the topographical condition;
- Social roles of family lineage (*dong ho*);
- Roles of agricultural cooperatives to village society and welfare;
- Agricultural production before *Doi Moi*;
- Population dynamics of the village;
- Relationship between population and agricultural productivity; and
- Subdivision of land and agricultural productivity.

Report series for information exchange

Since 1994, the report series '*Thong Tin Bach Coc*' has been published in order to exchange information and discuss new ideas among all of research members[4]. Although it is written in Japanese now, we plan to publish it in Vietnamese and English, too.

Funding

This study is, so far, supported by two research funds from the Ministry of Education, Government of Japan. The title and the leader of the research fund are as follows.

- 'Landholding, agriculture and rural society in modern history of Vietnam', S. Momoki, (University of Osaka).

- 'Social and historical study of family lineage group (*dong ho*) in the Red River Delta', M. Simao, (Keio University).

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4 This study is generally referred to as the *Bach Coc* study. The Coc Thanh cooperative, which is composed of eight hamlets at present, was created in the 1960s from three villages of *Bach Coc, Duong Lai,* and *Phu Coc.* We named our report series *Bach Coc*, because the historical viewpoint is viewed as one of the important factors in understanding the present village.

Village-level irrigation systems in the Command area of the Nam Ha 1 Irrigation Scheme

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Introduction

This paper aims to describe infrastructural development and management of village-level irrigation and drainage systems in the command area of the Nam Ha 1 Irrigation Scheme located in the Red River Delta of northern Vietnam. Introduction of a market economy and privatization of agricultural resources from the mid-1980s, called *doi moi*, encouraged farmers to invest more in agricultural production and resulted in increased agricultural productivity. Improvement of irrigation and drainage conditions played an important role in this agricultural development. However, it is not known in detail how irrigation and drainage facilities were improved and who managed the improvement and the operation and maintenance of the improved facilities, particularly at the village level. This lack of information results in ambivalent domestic and international policies for future irrigation development, whether system-level oriented or farm-level oriented, government-managed or farmer-managed. The primary objective of the present study is, therefore, to provide information on the present situation and dynamics of the village-level irrigation systems for policy-making in support of further development of irrigation and drainage.

Farmer's contributions to the improvement of irrigation and drainage conditions in the Red River Delta are, compared with other deltas in Southeast Asia, quite significant and unique. In other areas of Tropical Monsoon Asia, governmental efforts to encourage farmers to take part in irrigation system management have not yielded satisfactory results. These experiences suggest the need for deeper consideration of the ecological and historical settings of areas as a background to irrigation system management (Kono, 1996). Experiences in the Red River Delta, in general and the command area of Nam Ha 1 Irrigation Scheme in particular, may provide a key to rethinking the social aspects of irrigation system management, because this delta has a unique ecological and historical setting in Southeast Asia: a cooler climate in winter, more severe flooding in summer, frequent rice shortage, a much longer history of human settlement and higher population density, which has resulted in smaller farm size, and a stronger rural community.

The command area of Nam Ha 1 Irrigation Scheme is located at the lowest part of the delta and faces both irrigation and drainage problems. Twenty villages, two communes and eighteen cooperatives scattered in the five districts of the command area were selected for intensive survey. We conducted field surveys in 1995 and 1996, visiting the survey villages early in the morning, meeting the head of the commune government and/or director of the cooperative and, in most cases, staying until the late afternoon. Interviews were carried out on an *ad hoc* basis, and no organized questionnaire was prepared. This unsystematic means of information collection forced us to estimate missing data from relevant information, but allowed us to collect a wide range of information within a limited time.

Study area

Outline

The Red River Delta, having a total area of 1.5 million ha and an irrigated area of 766,000 ha, is divided into 30 irrigation schemes (Stacey & Chinh, 1993). Nam Ha 1 Irrigation Scheme covers the southern part of Ha Nam province and the northern part of Nam Dinh province, and has a total command area of 85,326 ha, being one of the biggest schemes.

The area is surrounded by four rivers, namely the Red River on the northeast, the Dao (Nam Dinh) River on the southeast, the Day River at the west and the Chau Giang River at the north (Figure 1). Its topography is a complex of natural levees and backswamps in the upper reaches, and of sand ridges and lagoons downstream. More than half of the area is lowland with elevation of less than 1.25 m above mean sea level, while the water level of the surrounding rivers reaches more than 3 m in summer. This has forced people to construct embankments along the rivers since early times. The embankments were reinforced during the French colonial period, but dike-breaks and overflow from surrounding rivers still frequently hit the area, such as in 1985 and 1994 in recent times, causing severe damage not only to rice cultivation but also to human settlements and public infrastructure.

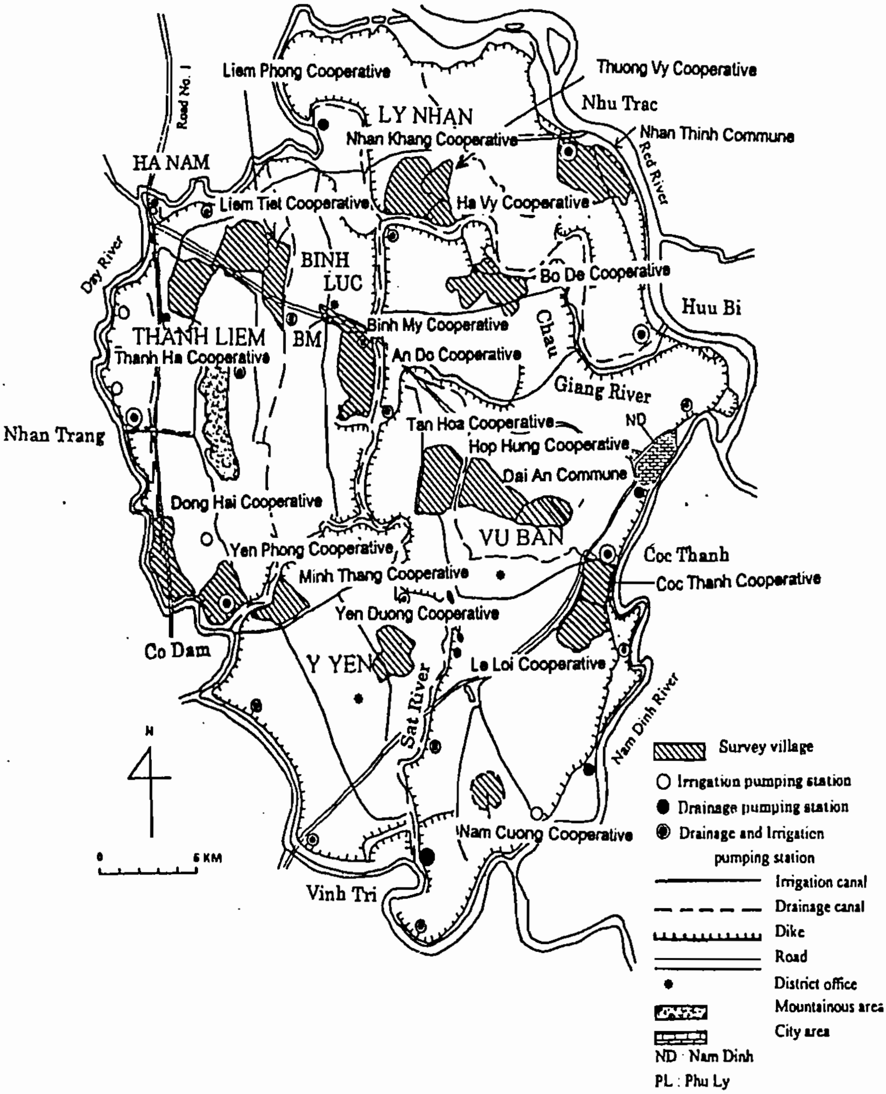


Fig 1: Yasuyuki et al.

The agricultural year is divided into three cropping seasons, winter-spring, summer, and winter, which fall roughly in January to May, June to September, and October to December, respectively. Rice, the dominant irrigated crop and principal food of the farmers, is grown in the winter-spring and summer seasons. Mean annual rainfall at Nam Dinh is 1720 mm, of which 380 mm is distributed in winter-spring, 1040 mm in summer and 290 mm in winter (VASI, 1996). The major constraints of winter-spring rice are water deficit and low temperature, which often hit nurseries and newly transplanted plants, while that of summer rice is flooding.

The local administration system is as follows. The country is divided into provinces, each consisting of one or more cities and towns and several districts. Each district has several communes, and each commune has several hamlets. Population size is approximately one million at the provincial level, one hundred thousand at the district level and ten thousand at the commune level. The study area covers most of Nam Dinh City, Ha Nam town and the districts of Binh Luc, Ly Nhan, Thanh Liem, Vu Ban and Y Yen.

Traditional hamlets were reorganized and one or more cooperatives were established in each commune during the 1950s and 1960s under the strong political leadership of the central government. The cooperatives performed as production-management bodies and grassroots administration systems during the Vietnam war, under which a brigade was organized in each hamlet. After *doi moi*, however, the cooperatives became service organizations for the member villagers and now tend to be more independent from the government in terms of finance, human resources and activity (Iwai, 1996).

Main system development and management

Before the 1960s, there were no irrigation and drainage facilities other than the river embankments and water gates along the surrounding rivers. Rice was grown in winter-spring under rainfed conditions. In summer, most of the area was covered with deep water and little paddy cultivation was observed. Boats were the major means of transportation in this season.

Since the 1960s, the government has constructed pumping stations, at first of large scale and later of medium and small scale, along the surrounding rivers, and canal systems for irrigation and drainage spreading from the pumping stations (Table 1). This expanded rice planted area in summer as well as in winter-spring, stabilized rice yields and intensified cropping pattern.

In the early 1970s, the Nam Ha 1 Irrigation and Drainage Management Company (*Cong Ty Quan Ly Khai Thac Cong Trinh Thuy Loi 1 – Nam Ha*) was established, taking over irrigation system management in the study area from the provincial irrigation department. The company is officially in charge of operation and maintenance from the pumping stations up to the tertiary canals, but these functions have been transferred to cooperatives where a single cooperative occupies the whole command area of the facilities. The company has a branch office in each district. Each district is divided into three to six areas (*cum*), and a member of staff is appointed to each cooperative to coordinate between the company and the cooperatives. The company collects irrigation fees from the farmers through the cooperatives, and these provide 50 to 60% of its necessary income. The shortfall is subsidized by the central government.

The large-scale pumps are operated based on the water level of the main drainage canals at the pumping stations. Irrigation is carried out if the water level is less than the standard. The standard water level is, in most cases, 1.2 m in winter-spring and 0.8 m in summer (Table 2). Two factors were considered in deciding the standard water level. One is the balance between water deficit in higher fields and water excess in lower fields, and the other is the capacity of the drainage canals and pumping efficiency. When a typhoon or heavy rainfall is predicted, precautionary drainage is carried out to lower water levels.

The present pumping capacity is 2.9 liter s^{-1} ha^{-1} for drainage and 0.81 liter s^{-1} ha^{-1} for irrigation. It is planned to increase this to 4.1 liter s^{-1} ha^{-1} and 1.25 liter s^{-1} ha^{-1}, respectively, in the near future.

The survey villages

Location in the irrigation scheme

Because of the complexity of the system, the quality of irrigation and drainage service provided by the company to each village is difficult to judge based simply on its distance from the pumping station. Some villages have alternative courses of irrigation and/or drainage. Drainage, in particular, is affected more by the elevation of paddy fields than by the distance to the drainage pumping station. Therefore, the survey villages are classified as head, middle or tail reach villages, principally from the irrigation viewpoint, but considering related information such as the water deficit or excess and the means of irrigation (Table 3).

Table 1. Company-managed pumping stations

Scale	Station name	Location	Year constructed	PUMPS					Design command area (ha)		No. of pumps for operation of	
				No. of units	Per unit capacity (m³/ha)	Total capacity (m³/ha)	Produced by	Actual capacity (%)	Irrigation	Drainage	Irrigation	Drainage
Large	Coc Thanh	Vu Ban	1966	7		224.000	USSR	70	12.221	19.863	3	7
	Co Dam	Y Yen	1966	7	32.000	224.000	USSR	70	8.338	21.207	3	7
	Huu Bi	Nam Dinh	1968	4	32.000	128.000	USSR	70	8.312	11.255	2	4
	Vinh Tri	Y Yen	1968	5	30.000	150.000	USSR	80-85	0	14.782	0	5
	Nhu Trac	Thanh Liem	1972	6	10.000	60.000	USSR	65-68	13.650	6.470	6	6
	Nhan Trang	Thanh Liem	1972	6	10.000	60.000	USSR	70	5.447	6.256	3	6
Medium	Song Chanh	Y Yen	1977	34	4.000	136.000	Vietnam	n.a.	n.a.	n.a.	0	34
	Trieu Xa 2	Thanh Liem	1991	3	3.600	10.800	Vietnam	n.a.	n.a.	n.a.	n.a.	3
	Quang Trung	Ly Nhan	1988	19	2.500	47.500	Vietnam	n.a.	n.a.	n.a.	2	19
	Quy Do	Y Yen	1992	12	3.600	43.200	Vietnam	n.a.	n.a.	n.a.	2	12
Small	16 stations	-	-	129 in total	-	-	-	-	-	-	-	-

Source: Interview with staff of Nam Ha 1 Irrigation Company

Table 2. Standard water level of the main drainage canals.

(m above msl)

Station	Summer season (July-September)	Winter-spring season
Coc Thanh	0,8	1,2
Huu Bi	0,8	1,2
Nhu Trac	0.7-0.9	1,2
Vinh Tri	0.7-0.8	1.5-1.8*
Co Dam	0.7-0.8	0,8
Nham Trang	0.8-0.9	0.8-0.9

Note: *This value was obtained in an interview with a pump operator of Vinh Tri station, whereas headquarters staff of the company cited a figure of 1.2 m above msl.
Source: Interview with staff of Nam Ha 1 Irrigation Company.

Another key to evaluate the quality of the company's service is the irrigation fee. This is basically set as a fixed proportion of actual rice yields. This proportion is decided by the central government and has been fixed at 7.5% for winter-spring rice and 6.5% for summer rice since 1984. Evaluation of actual rice yields is difficult because they show a wide range of spatial variation and year-to-year fluctuation. Therefore, the average yield is estimated, applied to the whole command area and revised every few years. The present average yield has been applied since 1992 and is annually 4,952 kg ha^{-1}, of which 60% is allocated to winter-spring rice and 40% to summer rice. Thus, the standard irrigation fee is 223 kg ha^{-1} (8.0 kg sao^{-1}, 1 *sao* = 0.036 ha) for winter-spring rice and 129 kg ha^{-1} (4.6 kg *sao*$^{-1}$) for summer rice. The company does not collect irrigation fees for non-rice crop cultivation.

In addition, paddy fields are classified into three types, which reflect differences in the quality of the irrigation and drainage services. Type A fields, called *chu dong hoan toan*, can be irrigated and drained by gravity. Type B fields, called *chu dong mot phan*, sometimes require village-level lifting irrigation and/or drainage. Type C fields, called *tao nguon*, always require village-level lifting irrigation and/or drainage. The irrigation fee for each type is 100%, 70% and 40% of the standard fee, respectively. The area of each type of paddy fields is agreed between the district branch office of the company and each cooperative every rice cropping season. The agreement is reached before the rice cropping season and reviewed after the season, if necessary, before the cooperatives pay irrigation fees to the company.

Table 3. Location and proportion of paddy field types of the survey villages.

Location	Cooperative/ Commune	Winter-spring season					Summer season				
		Proportion (%)				Ratio of the average irrigation fee to the standard (%)	Proportion (%)				Ratio of the average irrigation fee to the standard (%)
		Type A	Type B	Type C	Outside*		Type A	Type B	Type C	Outside*	
Head	Coc Thanh	73,8	14,4	11,8	0	88,6	74	11	11,5	3,6	86,3
	Dai An	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Le Loi	79,8	4,7	15,5	0	89,3	80,4	4,5	15,1	0	89,6
	Minh Thang	89,6	0	10,4	0	93,8	83,3	0	16,7	0	90
	Nhan Thinh	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Middle	Binh My	33,3	41,7	25	0	72,5	33,3	41,7	25	0	72,5
	Bo De	32,9	22,6	44,4	0	66,5	32,9	22,6	44,4	0	66,5
	Ha Vy	43,4	22,2	28,9	5,6	70,4	51,5	14,5	32,8	1,3	74,8
	Hop Hung	30,9	27,6	30,3	11,2	62,3	31,6	28,3	39,6	0,5	67,2

Table 3 - Continuous

1	2	3	4	5	6	7	8	9	10	11	12
Tail	Liem Tiet	49,1	22	28,9	0	76	46,6	20,7	32,7	0	74,2
	Nhan Khang	62,1	18,2	11	8,7	79,2	48,4	21,2	26,3	4,1	73,8
	Thanh Ha	22,9	30,6	39,3	7,2	60	24	21,8	50,2	4	59,4
	Thuong Vy	85,8	2	8,8	3,4	90,7	84,7	4	11,3	0	92
	An Do	22,9	0	77,1	0	53,7	22,9	0	77,1	0	53,7
	Dong Hai	14,9	6,6	63,6	14,9	45	25,4	29	29,3	16,3	57,4
	Liem Phong	9,1	9,1	69,4	12,5	43,2	15,1	19,7	47	18,2	47,7
	Nam Cuong	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Tan Hoa	13,4	3,1	58,7	24,8	39,1	8,4	2,6	48,5	40,5	29,6
	Yen Duong	37,8	2,5	16,4	43,3	46,1	29,1	1,9	12,6	56,4	35,4
	Yen Phuong	1,8	0	88,9	9,3	37,3	1,8	0	88,9	9,3	37,3
	Overall	35,4	13,1	42,1	9,4	61,4	34,8	13,7	40,1	11,3	60,5

Note: *Areas where no irrigation fee is levied because they lie outside the command area or have a problem causing low productivity.

Source: Estimated from field survey results.

Proportion of paddy field types and the ratio of the average irrigation fee to the standard fee of the survey villages is summarized in Table 3. The ratio is calculated by the following equation.

$$R = 1/At \times (Aa + Ab \times 0.7 + Ac \times 0.4)$$

Here, R is the ratio of the average irrigation fee to the standard fee (%), and At, Aa, Ab and Ac are the areas of total, type A, type B and type C paddy field, respectively.

The difference in the proportion of paddy field types among the survey villages clearly supports the head-middle-tail classification. The ratio is more than 80% in the head reach, 60 to 80% in the middle reach and less than 60% in the tail reach in both seasons, except in the Thnah Ha and Thuong Vy cooperatives (Table 3). Therefore, the classification is thought to be effective in representing quality of the irrigation and drainage services provided by the company.

Agriculture

Table 4 summarizes the land and population of the survey villages. Paddy fields are the dominant type of agricultural land except in a few villages located on natural levees. The average farm size varies from 0.16 to 0.45 ha per household, a typical size in the Red River Delta, and shows no significant differences between the head, middle and tail reaches.

In all reaches, the most dominant cropping pattern is double cropping of rice in winter-spring and summer and fallow in winter, which occupies two-thirds of the agricultural land on average (Table 5). This is followed by triple cropping of two rice and one upland crop such as maize, sweet potato, potato or vegetables in winter. Winter cropping is rapidly expanding in the study area as a method to intensify agriculture an raise cash income (Yanagisawa & Kono 1997). In winter, the company's pumping stations are occasionally operated to maintain the water level of the drainage canal about 1.2 m above mean sea level. Irrigation water is rarely supplied by gravity. This causes water shortage in elevated fields and poor drainage in low-lying fields. Village-level pump development, as mentioned later, improved this situation and promoted expansion of winter cropping.

The average rice yields of the survey villages in the recent years are summarized in Figure 2. Summer rice suffered from severe flooding in 1994, and the survey villages were exempted from land tax and the company's irrigation fee. These yields were omitted from the calculation of the average rice yields. In general, summer rice yields are about 80% of winter rice yields.

Table 4. Land and population of the survey villages.

Location	Commune/ Cooperative	Agricultural population		Agricultural land* (ha)			Average farm size (ha)			
							per person		per household	
		Population	Household	Paddy field	Upland field	Total	Paddy field	Agric. land	Paddy field	Agric. land
Head	Coc Thanh	3.650	943	185,6	11,9	197,5	0,05	0,05	0,2	0,21
	Dai An	6.300	1.615	639	35	674	0,1	0,11	0,4	0,42
	Le Loi	5.196	1.345	287	8	295	0,06	0,06	0,21	0,22
	Minh Thang	2.842	729	247	0	247	0,09	0,09	0,34	0,34
	Nhan Thinh	9.250	2.372	590	126	716	0,06	0,08	0,25	0,3
Middle	Binh My	2.350	603	120	0	120	0,05	0,05	0,2	0,2
	Bo De	6.483	1.693	486	48	534	0,07	0,08	0,29	0,32
	Ha Vy	2.961	785	113,5	59,8	173,3	0,04	0,06	0,14	0,22
	Hop Hung	5.452	1.398	580	0	580	0,11	0,11	0,41	0,41
	Liem Tiet	4.653	1.175	373,5	0	373,5	0,08	0,08	0,32	0.32
	Nhan Khang	8.649	2.186	254,3	100	354,3	0,03	0,04	0,12	0,16
	Thanh Ha	8.890	2.400	486	0	486	0,05	0,05	0,2	0,2
	Thuong Vy	3.899	1.000	148	97	245	0,04	0,06	0,15	0,25
Tail	An Do	7.889	1.813	523,9	0	523,9	0,07	0,07	0,29	0,29
	Dong Hai	7.288	1.946	332,8	18	350,8	0,05	0,05	0,17	0,18
	Liem Phong	4.547	1.139	330,1	0	330,1	0,07	0,07	0,29	0,29
	Nam Cuong	5.586	1.441	n.a.	n.a.	n.a.				
	Tan Hoa	4.559	1.116	497	0	497	0,11	0,11	0,45	0,45
	Yen Duong	8.526	2.348	511,5	27,8	539,3	0,06	0,06	0,22	0,23
	Yen Phuong	5.649	1.365	337,2	59,5	396,7	0,06	0,07	0,25	0,29
	Mean	6.292	1.595	422,1	17,6	439,6	0,07	0,07	0,28	0,29

Note: *This includes home gardens and ponds.

Source: Estimated from field survey results.

Table 5. Cropping patterns of the survey villages.

Location		S·ingle cropped (%)				Double cropped (%)					Triple cropped (%)				Cropping intensity*
	Winter-spring season	paddy	upland crops	fallow	Total	paddy	nursery	upland crops; vegetables	upland crops	Total (excluding nursery)	paddy	upland crops; vegetables	upland crops; vegetables	Total	
	Summer season	fallow	fallow	upland crops		paddy	nursery	paddy	upland crops		paddy	paddy	upland crops; vegetables		
	Winter season	fallow	fallow	fallow		fallow	fallow	fallow	fallow		uplandcrops; vegetables	uplandcrops; vegetables	upland crops; vegetables		
Head	Coc Thanh	0	0	0	0	74,2	5,9	0	0	74,2	4,6	9,7	5,7	20	2,08
	Dai An	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
	Le Loi	0	0	0	0	69,8	7,5	2,4	0,7	72,9	17,6	0	2	19,7	2,05
	Minh Thang	0	0	0	0	78,1	0	0	0	78,1	21,9	0	0	21,9	2,22
	Nhan Thinh	0	5	5	5	62,8	0	12,6	12,6	88	7	0	0	7	2,02
Middle	Binh My	0	0	0	0	66,7	0	0	0	66,7	33,3	0	0	33,3	2,33
	Bo De	0	0	0	0	70,5	0	0	0	70,5	20,5	0	9	29,5	2,29
	Ha Vy	0	0	0	0	39,1	5,6	0	0	39,1	20,8	0	34,5	55,3	2,44
	Hop Hung	2,4	0	0	2,4	91,4	0	0	0	91,4	6,2	0	0	6,2	2,04
	Liem Tiet	0,2	0	0	0,2	69	0	0	0	69	30,8	0	0	30,8	2,31
	Nhan Khang	0	0	0	0	36,9	0	12,7	0	49,6	22,1	0	28,2	50,4	2,5
	Thanh Ha	0	0	0	0	76,5	5,7	0	0	76,5	17,8	0	0	17,8	2,06
	Thuong Vy	0	0	0	0	60,4	0	0	34,4	94,9	0	0	5,1	5,1	2,05
Tail	An Do	0	0	0	0	66,6	0	0	0	66,6	33,4	0	0	33,4	2,33
	Dong Hai	0	5,1	0	5,1	57,5	8,8	0	0	57,5	28,5	0	0	28,5	2,06
	Liem Phong	0	0	0	0	78,2	0	0	0	78,2	21,8	0	0	21,8	2,22
	Nam Cuong	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	n.a.	n.a.	n.a.	n.a.	n.a.	
	Tan Hoa	0	0	0	0	75,8	1,7	0,8	0	76,6	21,7	0	0	21,7	2,18
	Yen Duong	0,5	0	0,5	0,9	46,7	7,6	0	2,9	49,6	19,6	20,5	1,8	41,9	2,26
	Yen Phuong	0	11,8	0	11,8	62,4	4,5	0	0	62,4	18,2	0	3,2	21,4	2,01
	Overall	0,2	1,4	0	1,7	66,7	2,4	2,1	2,8	71,6	18,6	1,9	3,7	24,3	2,18

Note: *Nurseries excluded from the calculation of cropping intensity.

Source: Estimated form field survey results.

Rice yields in the tail reach villages are significantly lower than those of the other reaches in both seasons, though there is no significant difference between the head and middle reaches. This reflects inundation in summer and water shortage in winter-spring, in addition to problem soils such as acid sulfate soils, which are widely distributed in tail reach villages.

Present situation of the village-level systems

Irrigation and drainage facilities

Village-level irrigation and drainage facilities have been rapidly developed since the mid-1980s, when *doi moi* started. This is clearly reflected in the construction of pumping stations (Figure 3). Besides lifting devices, canal systems and embankments for flood protection have been improved and constructed at the village level. These are summarized in Table 6.

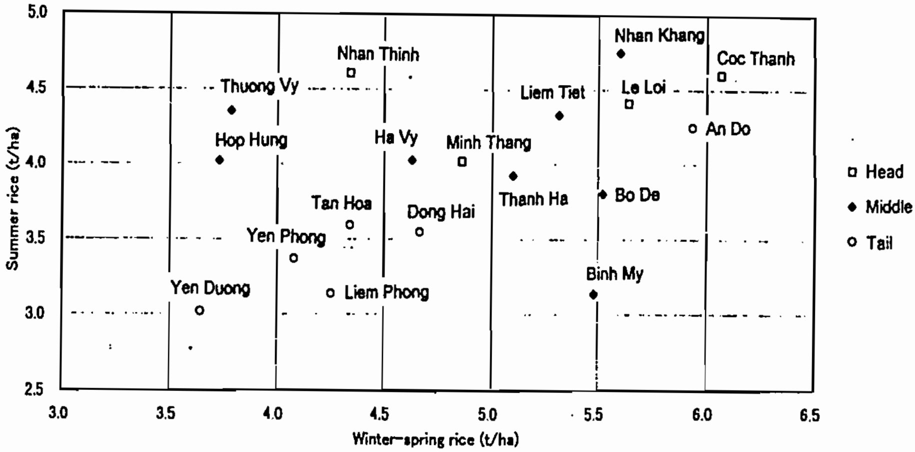
The present pumping capacity per unit area is 4.0 liter s^{-1} ha^{-1} for irrigation and 2.6 liter s^{-1} ha^{-1} for drainage on average of all the survey villages. This irrigation capacity is enough for rice cultivation if a stable water supply is available. However, the drainage capacity is too small to cope with heavy rainfall. This implies that the village-level investment has focused more on irrigation than on drainage.

The head, middle and tail reach villages show significant difference in the pumping capacity for irrigation, with averages of 2.6, 3.8 and 5.7 liter s^{-1} ha^{-1}, respectively, while no significant difference in the capacity for drainage was found. This is partly because the distribution of poor drained areas is closely related with micro-topography and less related with location in the irrigation scheme. It also reflects the difficulty of solving drainage problems at the village level.

Embankments, including partial embankments, surrounding the village area, called *vo bung*, have been constructed at 12 villages. One of the biggest embankments in the survey villages can be found at An Do cooperative. It was first completed in 1975 and renovated in 1986, and at present has a height of 1.8 m from the soil surface, 2.2 m above mean sea level, and a top width of 1 m.

Organizational setting

Three types of organizational setting are found in the survey villages from the viewpoint of sharing of roles between cooperative and brigade. The first, here called type A, has no organization at the brigade level, the



Note: Rice yields are the three-year average from 1994 to 1996 for winter-spring rice and the two-year average of 1993 and 1995 for summer rice.

Fig. 2. Yasuyuki et al.

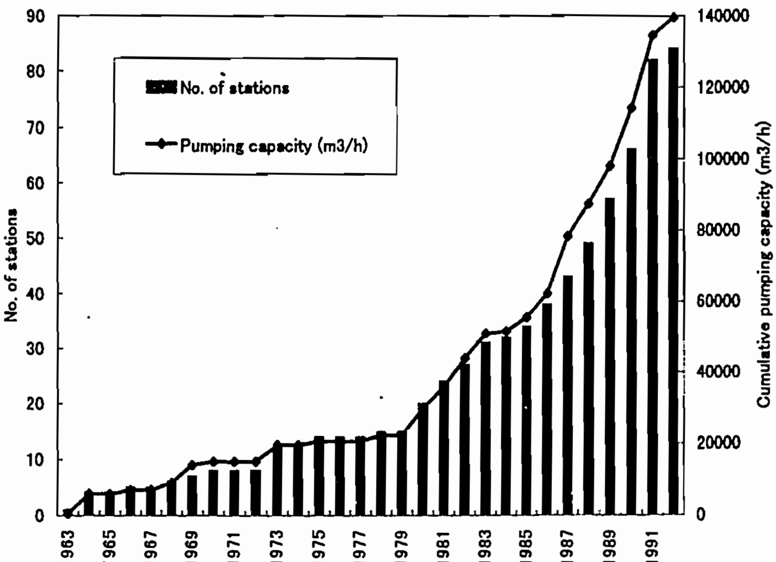


Fig. 3. Yasuyuki et al.

Table 6. Village-level irrigation and drainage facilities.

Location	Commune/ Cooperative	Pumping station					Mobile pump		Pump capacity per unit area (l/sec/ha)		Embankment	
		Year construction started	No. of stations	Capacity (m^3/h)			No. of unit	Total capacity (m^3/h)	Irrigation	Drainage	Spatial unit	Complete/ Partial
				Irrigation	Drainage	Multi-purpose						
Head	Coc Thanh	-	0	0	0	0	3	1180	1,66	0,85	-	-
	Dai An	1978	8	3400	13000	0	7	3150	2,7	4,87	commune	complete
	Le Loi	1983	2	0	0	4000	0	0	3,77	2,6	-	-
	Minh Thang	1984	2	2000	0	2000	1	500	5,06	1,92	cooperative	partial
	Nhan Thinh	-	0	0	0	0	0	0	0	0	-	-
Middle	Binh My	-	0	0	0	0	0	0	0	0	-	-
	Bo De	1978	4	0	0	11400	1	450	6,16	4,07	-	-
	Ha Vy	1979	3	2000	3800	0	0	0	3,21	4,25	cooperative	partial
	Hop Hung	1975	5	0	10600	3000	8	2560	2,66	5,17	cooperative	complete
	Liem Tiet	1986	7	0	0	9360	0	0	6,96	4,67	brigade	complete
	Nhan Khang	1983	4	3500	2500	2000	3	960	5,06	2,56	cooperative	partial
	Thanh Ha	1976	13	8750	0	1450	0	0	5,83	0,52	brigade	complete
	Thuong Vy	n.a.	1	450	0	0	0	0	0,51	0	cooperative	partial
Tail	An Do	1970	15	0	0	16000	0	0	8,48	5,51	irrigation block	complete
	Dong Hai	1978	4	2540	1080	1000	3	2500	4,78	2,65	-	-
	Liem Phong	1982	9	0	2450	6800	0	0	5,72	4,77	irrigation block	partial
	Nam Cuong	n.a.	5	0	0	5000	0	0			-	-
	Tan Hoa	1991	7	0	0	8500	0	0	6,56	3,6	cooperative	complete
	Yen Duong	1990	2	n.a.	0	0	3	960		0,38	-	-
	Yen Phuong	1988	8	3680	3000	540	0	0	2,95	1,76	cooperative	partial
	Mean	1981,4	5	1385	1822	3553	1,5	613	4	2,64	-	-

Source: Estimated from field survey results.

cooperative being in charge of operation and maintenance of all the village-level facilities including the canal system and pumping stations. The second, called type B, has organizations at both cooperative and brigade levels. The cooperative operates and maintains the pumping stations, while each brigade is in charge of the canal system of its allocated land. The third, called type C, also has organizations at both cooperative and brigade levels. However, the cooperative is only in charge of large-scale repair works to the pumping stations, and the brigades are fully in charge of the daily Operation and Maintenance (O & M) of the village-level facilities. Cooperatives of type A, B and C number 6, 11 and 1 respectively, though the management type of two cooperatives is unknown.

Both cooperatives and brigades collect irrigation fees from the member farmers for their O & M works, in addition to the irrigation fees collected by the company. In type A, the cooperatives collect the company's irrigation fees at the same rate from all member brigades, regardless of distribution of paddy field types in each brigade. They also collect their own irrigation fees at the same rate from all the brigades, while the brigades do not collect irrigation fees for themselves. Therefore, all the member farmers in a cooperative equally share the cost of irrigation and drainage services.

In type C, the cooperative collects the company's irrigation fees from the member brigades based on the distribution of paddy field types in each brigade. The cooperative also collects the electricity fee of the pumping stations from the brigades. This fee is calculated based on the consumption of electricity of each pump station, so that the more a brigade uses pumps, the more it has to pay. The brigade's irrigation fee also differs among the brigades. Therefore, all three kinds of irrigation fee differ among the brigades. The principle of irrigation fee payment is that the recipient of a service should pay for it.

Type B is further classified into three types, B1, B2 and B3, from the viewpoint of irrigation fee payment. The payment system of B1 is the same as that of type A, except that the brigades of type B1 cooperatives collect their own irrigation fees at the same rate for all the brigades in the cooperative. Thus, the cost of irrigation and drainage service is equally shared among the member farmers in this type.

In Type B2, the company and cooperative irrigation fees are levied at the same rate for all the brigades, but the brigade fees are levied at different rates. This type is intermediate between types A and C from the viewpoint of irrigation fee payment.

Type B3 has a similar system to type C. Two cooperatives, Liem Phong and Tan Hoa, are classified as type B3. The payment system of Liem Phong is the same as type A, except that the brigade fees are set at the same rate. In Tan Hoa, the company fee is not calculated based on the distribution of paddy field types in each brigade, but on the same fixed rate.

Thus, all the survey villages are classified into five types, A, B1, B2, B3 and C (Table 7). The head reach has type A and B1 villages, while the tail reach has type B1, B2 and B3 villages and no type A village. The middle reach has villages of all type except B3. These results imply that, in the head reach villages, the cooperative is the operating unit of the village-level system and all members of the cooperative share equally the costs of system management, whereas in the middle and tail reaches, the spatial unit is smaller and costs are met based on the principle that the recipient of a service should pay for it.

The numbers of cooperative and brigade staff in charge of irrigation and drainage management are also summarized in Table 7. The tail reach villages apparently have larger staff, which leads to higher cooperative and brigade fees.

Irrigation fee

The irrigation fees of the company, cooperative and brigade are summarized in Table 8. The cooperative and brigade fees are mostly used for O & M of village-level facilities; and funds for the construction of new facilities are usually raised from other sources, such as sale of cooperative property to farmers and infrastructure development fees collected from member villagers. After 1990, the provincial government stopped providing cooperatives with subsidies for constructing pumping stations.

The company's fee is significantly higher in the head reaches and lower in the tail reaches. On average, it is 206 kg ha^{-1} (3.9% of the average rice yield), 161 kg ha^{-1} (3.4%) and 98 kg ha^{-1} (2.2%) for winter-spring, and 123 kg ha^{-1} (2.8%), 101 kg ha^{-1} (2.5%) and 60 kg ha^{-1} (1.7%) for summer in the head, middle and tail reaches, respectively. However, the cooperative and brigade fees show the reverse tendency. The cooperative and brigade fees on average total 48 kg ha^{-1} (0.5% of the average rice yield), 132 kg ha^{-1} (2.8%) and 212 kg /ha^{-1} (4.7%) for winter-spring, and 71 kg ha^{-1} (1.5%), 159 kg ha^{-1} (4.0%) and 236 kg ha^{-1} (6.8%) for summer in the head, middle and tail reaches, respectively. However, compared to the head reach farmers, the tail reach farmers pay less than half as much to the company and three to four times more to the cooperative and brigade, resulting in 20 to 50% higher total payment.

Table 7. Management type and number of staff

Location	Commune/ Cooperative	Management type	Number of staff	
			Cooperative	Brigade
Head	Coc Thanh	A	as	0
	Dai An**	B1	3 x 3	3 x 12
	Le Loi	B1	0	2 x 10
	Minh Thang	A	n.a.	0
Middle	Binh My	B2	n.a.	n.a.
	Bo De	B1	n.a.	n.a.
	Ha Vy	A	5	0
	Hop Hung	A	12	0
	Liem Tiet	B2	n.a.	3 x 7
	Nhan Khang	A	23	0
	Thanh Ha	C	1	3-5 x 7
	Thuong Vy	A	10	0
Tail	An do	B2	n.a.	n.a.
	Dong Hai	B1	15	5 x 6
	Liem Phong	B3	13	n.a.
	Tan Hoa	B3	more than 20	2-4 x 6
	Yen Duong	B2	5	5-6 x 6
	Yen Phong	B1	9	2 x 11

Note: *Yen Duong and Dai An have a member of staff in the communue government who is in charge of irrigation system management.

**Dai An Commune consists of three cooperatives, for which the totals are shown here.

Table 8. Irrigation fee payment

Location	Commune/ Cooperative	Irrigation fee (kg/ha of unhusked rice) and its proportion to the average rice yield (%, number in parenthesis							
		Winter-spring season				Summer season			
		Irrigation company	Cooperative	Brigade	Total	Irrigation company	Cooperative	Brigade	Total
Head	Coc Thanh	211 (3.5)	61 (1.0)	0 (0.0)	271 (4.5)	120 (2.6)	61 (1.3)	0 (0.0)	181 (3.9)
	Dai An	n.a.	28~111 (n.a.)	14 (n.a.)	n.a.	n.a.	28~111 (n.a.)	14 (n.a.)	n.a.
	Le Loi	198 (3.5)	n.a.	n.a.	n.a.	124 (2.8)	n.a.	n.a.	n.a.
	Minh Thang	208 (4.3)	0 (0.0)	0 (0.0)	208 (4.3)	125 (3.1)	69 (1.7)	0 (0.0)	194 (4.8)
Middle	Binh My	161 (2.9)	83 (1.5)	0~42 (0~0.8)	244~286 (4.5~5.2)	101 (3.2)	83 (2.7)	0~42 (0~1.3)	183~225 (5.9~7.2)
	Bo De	148 (2.7)	131 (2.4)	56 (1.0)	334 (6.0)	92 (2.4)	186 (4.9	56 (1.5)	334 (8.8)
	Ha Vy	156 (3.4)	39~67 (0.8~1.4)	0 (0.0)	194~222 (4.2~4.8)	104 (2.6)	92~119 (2.3~3,0	0 (0.0)	194~222 (4.9~5.5)
	Hop Hung	138 (3.7)	175 (4.7)	0 (0.0)	313 (8.4)	93 (2.3)	211 (5.3)	0 (0.0)	305 (7.6)
	Liem Tiet	169 (3.2)	47~108 (0.9~2.0)	56~83 (1.0~1.6)	272~361 (5.1~6.8)	103 (2.4)	36~231 (0.8~5.3)	56~83 (1.3~1.9)	194~417 (4.5~9.7)
	Nhan Khang	176 (3.1)	214 (3.8)	0 (0.0)	390 (7.0)	102 (2.2)	203 (4.3)	0 (0.0)	305 (6.4)
	Thanh Ha	133 (2.6)	n.a.	42~56 (0.8~1.1)	n.a.	82 (2.1)	n.a.	42~56 (1.1~1.4)	n.a.
	Thuong Vy	202 (5.3)	42 (1.1)	0 (0.0)	243 (6.4)	130 (3.0)	42 (1.0)	0 (0.0)	171 (3.9)
Tail	An Do	119 (2.0)	214 (3.6)	56~83 (0.9~1.4)	389~417 (6.6~7.0)	75 (1.8)	258 (6.1)	56~83 (1.3~2.0)	389~417 (9.1~9.8)
	Dong Hai	100 (2.1)	122~206 (2.6~4.4)	28 (0.6)	250~333 (5.4~7.1)	80 (2.2)	142~225 (4.0~6.3)	28 (0.8)	250~333 (7.0~9.4)
	Liem Phong	96 (2.3)	125~178 (2.9~4.2)	56 (1.3)	277~330 (6.5~7.7)	66 (2.1)	156~211 (5.0~6.7)	56 (1.8)	278~333 (8.8~10.6)
	Tan Hoa	87 (2.0)	197~225 (4.5~5.2)	14 (0.3)	297~325 (6.9~7.5)	41 (1.1)	197~225 (5.5~6.3)	14 (0.4)	253~281 (7.0~7.8)
	Yen Duong	102 (2.8)	119 (3.3)	64 (1.8)	286 (7.8)	49 (1.6)	144 (4.8)	56 (1.8)	249 (8.3)
	Yen Phuong	83 (2.0)	167 (4.1)	14 (0.3)	264 (6.5)	52 (1.5)	197 (5.8)	14 (0.4)	263 (7.8)

Source: Estimated from field survey results.

Conclusions

The irrigation and drainage system of the Nam Ha 1 Irrigation Scheme has two management organizations, Nam Ha 1 Irrigation and Drainage Management Company, and farmers associations. This dual system of management enabled proper and prompt improvement of irrigation and drainage facilities under the rapidly growing demands by farmers for better water conditions. It has, however, resulted in duplicating irrigation and drainage by the company and village-level systems. It is, therefore, necessary that efficiency of the whole system, particularly from the viewpoint of water resources and energy use, should be carefully examined for future development.

The other problem observed in the study area is an unequal benefit allocation between head, middle and tail reach villages. Head reach villages have invested less in their own system development and pay smaller irrigation fees than middle and tail reach villages, but enjoy higher rice yields. Moreover, there is neither coordination nor an institutional framework for coordination among the village-level systems for irrigation and drainage practices, causing severe water shortage and long and deep water logging at tail reach villages. Socially fair cost and benefit allocation is, therefore, one of the key questions raised for economically sound irrigation system management.

The management body of the village-level system, in other words, the spatial unit where equity must be maintained, differs between head, middle and tail reaches. Cooperatives are maintained as the sole managing body of the village-level system in the head reach villages, where irrigation costs are shared equally at the cooperative level. In the tail reach villages, on the other hand, village-level system management is devolved to the brigades, as in other areas in the Red River Delta (Toan et al., 1996), and fees are levied according to service received.

The management body of village-level system is also closely related with infrastructure development. In Thanh Ha cooperative, the sole cooperative of management type C, all village-level pumping stations were previously operated and maintained by the cooperative, under an organization of type B. This work was transferred to the brigades in 1987, when at least one pumping station was constructed in each brigade, embankments enclosing each brigade's land were completed, and each brigade became able to irrigate and drain independently. Full turn-over of a village-level system from a cooperative to brigades has to wait for infrastructure development.

Village-level systems are expected to be developed further in the near future, because of a growing demand for cultivation of high-yielding rice varieties, which require stricter farm-level water control, and for commercial cultivation of upland crops and vegetables, which require better drainage and different seasonal patterns of irrigation from rice cultivation. Moreover, farm mechanization also necessitates more flexible and reliable irrigation and drainage in terms of both time and volume. Importance of the village-level systems as a bridge between the company's service and the growing demands of farmers should not be overlooked, and development and management of the village-level systems should be institutionally and financially supported, regardless of whether it is carried out either by cooperatives or brigades. Proper reduction of the company's irrigation fee on the basis of the distribution of paddy field types in each cooperative is one reasonable method for financially supporting the village-level systems.

From the viewpoint of management of the irrigation company, the development of the village-level systems may appear to be a degradation of the main system, particularly because it tends to change paddy field types to lower grades and to reduce the income of the company. However, the change of paddy field types should be considered as a subsidy for village-level systems, as mentioned above, and an increase in rice yields, resulting in an increase in irrigation fee payment to the company, should be emphasized more as an effect of the development of the village-level systems.

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Activities of the Interministerial Centre for Spatial Application (ICSA): Action plan and perspective

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Introduction

Established in 1997 after one year of preparation, ICSA is a joint and interministerial laboratory of the Ministry of Agriculture and Rural Development (MARD) and the National Centre for National Science and Technology (NCST) of Vietnam. ICSA has been created through the joint initiative of two laboratories: Centre for Remote Sensing and Geomatics of the NCST. The main cooperative objective of the ICSA is to integrate the research and application potentials of both institutions in the field of remote sensing and GIS technology applied to Agriculture and Rural Development. The main development objective of ICSA is to shorten the existing distance between research and application in remote sensing and GIS technology applied to Agriculture and Rural Development and to participate in the management decision making process of the country.

Activities planned for the next five years

Based on the issues of priority in the agriculture and rural development domains, ICSA intends to carry out three main programs focusing on application, research and training.

Development applications

- Forest Fire and Sea Surface Temperature Monitoring by NOAA imagery (1997-2000).

This program has been set up jointly by ICSA and the Monitoring of Tropical Vegetation Unit of the Joint Research Centre of Europe in Ispra, Italy. Two study areas have been chosen: Lai Chau and Dac Lac provinces of Vietnam where fire occurs frequently and causes intensified deforestation. The provincial authorities are also involved in this programme. At the same time, the ICSA has been chosen by the Ministry of Sciences, Technology and

Environment (MOSTE) for the implementation of a project entitled: 'Setting up a NOAA receiving station and Processing of NOAA Imagery for Forest Fire Monitoring and Sea Surface Temperature Monitoring'. In the framework of this national project, the ICSA has to install a portable receiving station (Fixed Mode) in October 1997. Two software which will be used for NOAA image processing are PCI ESA/Pace (Canadian technology) and PANAIS (MTV). The fire pixel maps will be integrated with others data such as DEM, demographic, ethnographic, forest coverage and reserved areas etc. to analyse fire activity impacts.

The sea temperature data acquired by the receiving stations of NOAA will be exploited in collaboration with the Institute for Marine Resources (Ministry of Sea Product) and the Marine Hydrometeorological Centre (General Department of Hydrometeorology of Vietnam). The purpose of this collaboration is to introduce NOAA imagery interpretation in fishing and sea current monitoring in these institutions.

- Forest resource inventory mapping (1998-2000).

This mandate is related to the rapid dynamic changes of the forest coverage caused by different factors including burning and itinerant cultural practices. In this application, both image and GIS based processing will be used involving the existing database of CFIC and FIPI. For the first 3 years, one region considered priority by Vietnam will be selected (Central Plateau or North West Vietnam) depending on the governmental policy of planning for this period.

- Upgrading the spatial information infrastructures in MARD (1998-2002)

This application will be structured with a very big national program for the long term and is characterized by its interdisciplinary nature (Agro-forestry Ecology, Land used, Human Settlement, Water Conservation, Disaster Mitigation, Image Processing, Spatial Data Integration, Network Information Diffusion etc.). Different Vietnamese agencies might be involved in this program. The regional and international co-operation must be envisaged as the major dynamics of the program not only in terms of budget but also in terms of expertise. The ICSA has already represented the project profile to MARD and other concerned agencies and laboratories from which ICSA has obtained a very positive feedback.

Research

- Multi-resolution and multi-sensor (NOAA, SPOT, TM and Radar) analysis applied to vegetation and rice monitoring

This is an ambitious research program that ICSA tends to develop for different applications where only one satellite imagery source cannot provide the data as required by the user. Thus, it is indispensable to use at the same time or in the same territory different satellites to cover the application requirements. New technics of image processing have to be introduced in this context such as: Neural Network Classifier, Spectral Unmixing, Change Detection and Measurement etc. for both optical and microwave data.

As for rice monitoring, the ICSA intends to carry out the research based on NOAA capacity to combine with Radar backscattering, the discriminating capacities for different growth stage of rice.

- Modelling of spatial data applied to forest resource management

This research program is very important for using spatial data collection, handling and analysis, under the aegis of spatial modelling, to help in decision-making. The multi-criteria fire modelling will be one of the most important topics of research due to the necessity for comprehensive impact evaluation. Other modelling research such as optimized solution for human settlement in mountainous regions, will be in the priority list for research. By this orientation, the ICSA will also pay its attention and efforts to some fundamental issues of spatial data such as multi-scale data modelling, and eometry homogenization in spatial modelling.

- Elaboration and development of spatial data analysis tools

This program of research is launched to profit the CFIC's experiences in programming of new additional tools for data capture, statistical analysis and data modelling. Much effort will be invested for the data capture both in scanning (vectorization) and digitizing mode due to the pressing need in data capture not only inside the ICSA but also in other agencies.

Training

- Upgrading of training and know-how transfer inside MARD and its relevant agencies; and

- Training of trainer for the concerned sectors inside or outside MARD.

How does ICSA see its perspectives

Recently built, ICSA is now getting much support from the community using Remote Sensing and GIS technology both in Vietnam and abroad. It is generally thought that this initiative meets the common needs of interdisciplinary co-operation and would satisfy some essential applications in agro-forestry management. This joint centre forther allows associated laboratories to enlarge their research and application activities. Strategically, ICSA will estáblish its priority collaboration relationship with other laboratories inside the MARD (NIAPP, FIPI) and inside the NSCT (Institute of Physics, Institute of Information Technology, Institute of Geography, Institute of Ecology and Natural Resources). On the other hand, MTV of JRC, CARTEL (Centre d'application et de recherche en teledetection of the University of Sherbrooke Quebec Canada) and REGARDS (National Centre for Scientific Research and ORSTOM, Bordeaux France) will also become partners.

In the regional scale, ICSA will initiate its contact with IRRI, and the Expert Group in Remote Sensing of the ASEAN, to explore the possibilities for further collaboration.

In this context, it is hoped that that ICSA will be placed in a favourable and strong positon for its initial start and further development.

From Farming Systems Research to a Community-Based Natural Resource Management (CBNRM) Research Agenda: Current activities of the Vietnam Farming Systems Network in Northern Vietnam

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The setting: Endangering natural and human ecology

Under Vietnam's *doi moi* policy, economic development has been made remarkable. In the agricultural sector farmers now tilling their original land and are free from the exploitation of the old-style cooperatives. With increasing agricultural production throughout the country during the last several years, agriculture now contributes to more than 50% of the GDP. Unfortunately, farmer's incomes continue to be low compared to those of the industrial or commercial sectors, and poverty in rural areas of all the nine agro-ecological zones is a concern of both local and national governments. The poor farmers continue to depend on natural resources for subsistence. In mountainous regions, they have been slashing bushes and trees to give space for food production; in the coastal areas, mangrove forests were taken away for firewood as well as for shrimp farming. Wildlife continues to be endangered by wanton exploitation of forest scavengers. As the resources in the northern mountainous region became exhausted, during the past five years since 1991, an exodus of nearly 1.5 million persons have migrated to the central highlands to find the remaining natural resources to exploit. At the new settlements, these people continue to clear the land, not much for food production but more for illegal logging and wildlife hunting. In addition, the pressure of the lowlanders has driven the ethnic minority people even to higher elevation. Demoralized, the ethnic people lost their arable land, have to live in new settlements where lack of food and clean water, poor shelter, poor education and health care, and inadequate other infrastructures compelled them into exploiting the natural resources for subsistence. Their technical knowledge, largely primitive, must rely on natural resources as means of survival. In early April 1997, the problem posed such a serious threat to all watershed areas of the country, that it prompted the Central Government to issue an order to close the forests, ban all slash-and-burn practices in hilly areas, and speed up the assignment of land user's title to the indigenous farmers. What will happen to the livelihood of the inhabitants of these areas? How could they meet the demand for daily food and other necessities when the forests are closed? Could the forests be successfully closed after all? Such are the problems in the uplands.

On the other end –in the lowland– favourable irrigation and drainage have been giving farmers better opportunities for food and other crop production. The lowland farmers have been undergoing successive periods of collectivization and decollectivization. The present result is an individualistic crop production system on fragmented land that each small farmer tends to compete with his neighbours for more water and better crop yield by applying agrochemicals as much as he can afford, causing a host of problems in crop and water management, and environmental pollution, and using up the meagre income from their under-priced paddy and other produce.

On the other hand, fortunately, there are farmers who have learned improved and appropriate systems suited to their natural and social conditions that could bring better income as well as safeguard their immediate micro environment. But these experiences often are isolated and cannot be expanded widely due to financial difficulties and rigid government land use policy. In order to provide the government with a framework of agricultural policy for sustainable rural development, the farming systems research and extension approach has been implemented by various organizations both from the public sector and the informal sector. Since 1990, the Vietnam Farming Systems Network (VNFSN), a consortium of 9 agricultural universities and research institutes located at all the agro-ecosystems of the country, with major assistance from IDRC (International Development and Research Center), carried out a nation-wide on-farm participatory research program. Eventually, we ran into resource-use conflicts between farm households that could hardly be settled by individual persuasion. This paper reports some salient experiences of the VNFSN that lead to the need for modifying our research strategy to adopt the community-based natural resource management approach. Within the scope of this workshop, the report will only be confined to activities in the northern part of Vietnam.

Farming systems approach in poverty alleviation

Farming systems development concepts and approaches have been introduced to all Network members. The nine institution Network involved 111 scientists of which the three northern institutions, the Vietnam Agricultural Sciences Institute, the Hanoi Agricultural University, and the College of Agriculture and Forestry of the University of Thai Nguyen, inputted more than 40 scientists. At each institution a multi-disciplinary research group has been formed. We gathered scientists, faculty members, researchers and research assistants, extension workers, etc. from various institutions and various backgrounds into a large network promoting approaches and methods in farming systems research and extension methods (FSR/E). This approach was applied to determine research priorities and to further develop appropriate agricultural systems that are both economically and environmentally sustainable and further increase farm household income, nutrition and welfare. There are 28 research sites covering the six different agro-ecological zones of Vietnam where this research was conducted.

Research highlights

In the northern mountainous region, research activities focused on sloping agricultural land technologies (SALT), as an alternative for slash-and-burn practices. Hedgerows on the contour efficiently reduced soil erosion and this resulted in a higher soil fertility, reflected in higher yields of corn, peanut and mungbean grown on the alleys. Fruit trees were planted on the upper alleys to provide a mini-watershed. On the infertile upland soils the diversification into livestock, crops and aquaculture gave higher profits than earlier practices and improved the soil fertility as compared to the monoculture of cassava commonly practiced in this area.

In the Red River Delta (RRD), we found that soybean, (Irish) potato and high value vegetables could replace corn to give higher incomes and to preserve the soil fertility during the winter to follow a very short duration high yielding rice variety (instead of the six-month IR8 rice crop as normally practiced by farmers) before the second (main) rice crop is planted. On the low lying part of the delta, profitable farming systems involving rice, cash crops, fish, livestock and fruit trees are possible. Economic returns from these improved systems increased farm income 2.5 times, indicating that diversification of agriculture in the Red River Delta is both feasible and profitable.

Farming Systems Research impacts and policy implication

Progress in research and their findings has been reflected in various party and government policy guidelines on sustainable agriculture and rural development, particularly the Party Resolution of the Fifth Plenary session. Successful results such as the application of the SALT system in Trang Xa village, Vo Nhai district in the mountainous province of Bac Thai (now Thai Nguyen) were promoted by local authorities. They organized farmer's and politician's field days for all 12 mountainous provinces in northern Vietnam.

Network members work closely with related research centers and institutes through research and policy meetings, through national workshops, conferences and other meetings. They presented their results, approaches, methods, and techniques used in farming systems development. Results obtained at the research sites were shown to provincial officials of departments of agriculture, to the departments of agricultural extension, the departments of science, technology, and environment and others, in order to extend the results to other and similar areas.

From these results we believe that options for each agro-ecological region in Vietnam exist that allow for more profitable development in terms of income and employment generation while the environment is still maintained in good condition. These options and approaches need to be promoted and understood by both local and central governments. Such development options need to be supported and accompanied by appropriate extension programs as well as flexible farm credit programs. Farmers will not be able to apply improvements to their methods and production system without support. However, as mentioned earlier, there are problems that the farming households are constantly in conflict with each other, particularly when it comes to sharing common resources such as land and water.

The need to move beyond the household boundary

Land and water use conflicts

In the uplands: although the government is trying to assign land use rights to hilly and mountainous farmers, the process is too slow to stop the slash-and-burn practice and especially the illegal logging. Some individual farmers in northern mountainous provinces attempted to reforest their newly assigned hills but were soon discouraged by the destructive ranging of the water buffalo or cattle herds of their neighbours.

In the lowland: several new conflicts develop as individual farm households are trying to compete for the advantages. Some examples:

- Annual crop producers (rice, corn, soybean, vegetables, etc.) are aiming for high yields, using every possible agro-chemical that they have, regardless of the environmental effect on their own or their neighbours' land and crops.

- Individual farmers often deliberately break the dike of irrigation canals in order to take water into their own field, without thinking of the shortage of water for those located down the line.

Competitiveness wanted: As Vietnam joins ASEAN, and eventually AFTA and WTO (World Trade Organization), certain commodities/products for export to foreign buyers will need to be produced in large quantity at a uniform quality, delivered on a pre-determined time and sold at the least expensive price. Surely, individualist farming will not be able to meet those criteria. Some form of community-based production must be organized and the farmers will have to be organized for doing so.

Improvement of interdisciplinary research: Our research so far has paid more attention to the integration of crops into the existing farming systems of individual farm households than on integration of livestock and forestry research. Further research should put more emphasis on the integration of livestock and forestry into existing farming systems within the boundary of an appropriate community, in order to enhance the mutual benefits of each household.

Since farming systems research within a community can be complex, there is also a need to improve researchers' skills related to experimental designs, statistical methods and extension strategies as these relate to CBNRM-FSR/E. Social scientists should participate more in the research. They should try to find out how a community of farmers adapt to new technologies and how FS technologies have an impact on the community's well-being in and outside the research sites.

The role of women in farming systems: Women are often neglected in agricultural research and extension activities. They plan an important role, particularly among ethnic minority groups. Female farmers have much potential to help improve the production systems. With the help of social scientists, more attention should be paid to gender analysis studies in the generation of new farming systems and technologies. These innovations and their impacts on the life of women should be evaluated.

Application of findings through farmer groups: The implementation of results of improved farming systems are mote limited in the Red River Delta due to problems of fragmented land tenure. Likewise, in hilly or mountainous areas farmers live in scattered and isolated houses. In these situations, it is difficult to apply uniformly improved farming systems because of the diversity in their socio-economic or biophysical environments. Therefore, the organization of these farmers into groups in order to spread results should be given attention.

Development of agricultural services, marketing and food processing. Agricultural extension activities, credit supply, food processing and marketing institutions are very important as these relate to the development of diversified farming systems within each community.

Farming systems approach for community based natural resource management. Common experiences showed that in some research sites, local administrators and farmers groups play very important roles in the implementation of results to the larger community. Interdisciplinary research teams, local administrators and local community organizations could be organized to work together more efficiently to apply scientific and technological innovations in direct response to community priorities in a way that reinforces the sustainability of agro-ecosystem productivity. More in-depth research along these lines in all agro-ecosystems is encouraged in the immediate future. Participatory system research approaches for community based natural resource management based on skills and experiences learnt by the Network could be a focus for designing further research activities.

Preliminary experiences with the CBNRM approach

After receiving the approval for a second phase of research from IDRC, the VNFSN members prepared for an initial workshop to discuss strategies for implementing research on CBNRM in the respective agro-ecosystems. We used various technical materials featuring CBNRM, including the training materials prepared by IRRI and publications from a similar CBNRM program in Senegal conducted by the Virginia Tech University.

Network training on CBNRM: Our main emphasis is placed first on network training for participating scientists of the concepts and practical components of the CBNRM approach. The first 40 Network scientists (of whom 9 were from the northern institutions) were introduced to the concepts and they thoroughly discussed the possibilities of applying these concepts in actual situations. Everyone recognized the necessities of organizing and involving a sizable community into a participatory research scheme, which will be preceded by a benchmark participatory rural appraisal (PRA) of the selected location by a multidisciplinary team of natural and social scientists. Based on the PRA analysis, a community within the location will be chosen and a detailed participatory appraisal planning (PAP) will be worked out and implemented with the community members. The execution of the program will be monitored and evaluated by both the researchers and the participating community according to the following criteria --- soil and water resource conservation; labor use; income generation; and stability of the community.

Representatives of agro-ecological systems: From the existing maps of soil and water resources and land use, our national program has selected 16 approximate locations for our local CBNRM programmes at 6 out of 9 major agro-ecological zones. The selected locations of the 6 zones represent 15 out of a total of 62 sub-ecosystems, and 19 out of 40 soil types. There are about 20 out of a total of 59 ethnic groups involved in these locations. In the northern region, we selected the irrigated alluvial zone of the RRD and the mountainous and slopping lands inhabited by some ten ethnic minorities.

Ecosystem analysis and choice of sustainable farming system in the northern region. To date, our northern Network members have completed the benchmark surveys in:

Trang Xa village, Vo Nhai district, Thai Nguyen province;

Dac Son village, Pho Yen district, Thai Nguyen province;

Phu Thuy village, Gia Lam district, Hanoi; and

Trong Quan cooperative, Dong Hung district, Thai Binh province,

to determine the available soil, water, climate, plant and animal resources, local indigenous knowledge, and their respective socio-economic environments. The existing social and governance structure of the communities were duly noted. We tried to trace the historical development of the existing communities and the state of their environment. On open-access natural resources, we will try to analyse each situation to identify the strong and weak aspects in their management by the community, from there attempts in designing research with the community in sustainable agricultural development will be made mainly for generating the most appropriate integrated farming system. A number of farming systems based on local indigenous knowledge and experiences from the Phase I of the VNFSN may fit into the design at each location: rice-based cropping with annuals (cash crops, short duration industrial crops), and/or with perennials (fruit trees, forest species on hills and mountains, and coastal area) integrated with livestock and/or aquaculture.

Credit scheme: Our hypothesis is that in order for an individual farming system to be successful, the component enterprises within a household's farming system should fit well within the community. The planned enterprises will need sufficient finance in order to enable the farmers to apply appropriate technology under the guidance of our technicians. But as farmers are mostly poor, we shall have to form a credit group at each location to administer the credit scheme, thus the need for working with the whole community. We plan to involve the provincial Vietnam Agricultural Bank to join this program. Hopefully, this approach will yield a better way for the government to give credit to farmers – not to individual farmers but to united communities of farmers. The farmers will not shy away from bank loans, as many of them do at present, for fear of being unable to repay because they do not know how to make that money grow successfully. With the CBNRM approach they know what technology to apply and the loan will be needed and used appropriately under the guidance of the participating scientist in their community.

Community size: How large should be the selected community? We decided preliminarily that depending on the available credit at each location, as well as the uniformity of the area in terms of human ecology and geographical characteristics, a group of 20-40 households will be invited to participate in our CBNRM program. Within a household, we shall see to it that the distribution of labour to participate in various activities of the program should be appropriate; the role of rural women will be placed in a more effective way.

Upland life improvement: within the framework of the Upland Rice Consortium coordinated by IRRI, the farming systems group of the University of Thai Nguyen is testing various improved upland rice varieties, studying their resistance and tolerance to drought, blast, studying upland rice-based farming systems at Cho Don district, Bac Kan province; Nguyen Binh district, and Cao Bang province. Their plan is to extend some of these studies to Son La and Lai Chau provinces if financial conditions allow.

Integrated sustainable development of Ha Giang province: The northern VNFSN members and the Network coordinators participated in designing a province-wide project to improve the sustainable agricultural development for ethnic minorities in Ha Giang province, the northernmost and most mountainous province of Vietnam. Our design is based on the above CBNRM approach to provide farmer's groups or communities opportunities to develop. The project is expected to be supported technically by local and international scientists and financially by a consortium of the United Nations Development Programme (UNDP), Swedish International Development Agency (SIDA), UNICEF, ? UNFDA and IFAD.

Looking ahead

As the Vietnamese government is preparing the minds of all farmers to return to collectivization anew, to provide opportunity for poverty alleviation and hunger eradication, as well as to empower the Vietnamese agricultural producers against tough competition in regional and world trade, a sound policy to encourag farmer communities to manage their own natural as well as human resources must be in place as soon as possible. We believe that in the next three years the CBNRM programme of our VNFSN will generate important examples to policy makers to decide.

Improving technologies for sustainable groundnut-based cropping systems in Vietnam

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Introduction

Vietnam is a humid-tropical country with a total geographical area of 33 m ha, out of which only 7 m ha are cultivated. Agriculture is the most important economic sector in Vietnam contributing about 40% to the national income. More than 70% of Vietnam's population earns its livelihood from agriculture. There are varying estimates of potentially cultivable area: these range between 5 and 6 m ha. Except for valley bottoms or terraced land, the rest of the land (1-2 m ha) presents serious constraints for sustained upland crop production. These lands represent a fragile eco-environment and are located in the upper reaches of the toposequence. It is reported that during the past 40 years, 6.5 m ha of forest land have been cleared in the country. Although the Government of Vietnam has taken intensive steps to reforest the fragile steep mountain lands, some of these are occupied by people. In 1984, Vietnam had only 7.8 m ha of forests. The deforestation has led to many problems including soil erosion (in some cases the estimated soil loss averages over 30 t ha^{-1} yr^{-1}), land degradation, and water scarcity. All these problems have lowered the production potential of soil particularly located in the mid- and high-lands of the toposequences. These soils need to be rehabilitated urgently in order to safeguard the production potential of the valley bottom-lands where rice is grown, which is the staple food of the population.

Among the 25 groundnut growing countries in Asia, Vietnam is the fifth largest groundnut country after India, China, Myanmar, and Indonesia. Groundnut is one of the main foreign exchange earning crops in Vietnam apart from being the main source for oil, protein, and food for people and fodder for cattle. Spring and autumn can be considered two main seasons. The spring season is by far the most important for the commercial production of the crop. The autumn crop is mainly for obtaining high quality seed for the spring crop. Groundnut cultivated during the spring season (February-June) is grown under rainfed production systems in northern Vietnam while, in the southern part of Vietnam, it is mostly grown under irrigation. Groundnut is predominantly grown as a sole crop but in some cases it is intercropped with sugarcane, maize, cassava, and upland rice. When intercropped, 2 rows of groundnut are planted between 2 rows of sugarcane while 3 rows of groundnut are planted between 3-5 rows of corn, cassava, or upland rice. Groundnut is also to some extent grown in orchards, and rubber or coffee plantations.

A Consultant of the Food and Agriculture Organization, United Nations, visited Vietnam during 1987 and made the following comments on groundnut cultivation in Vietnam (Reddy, 1987):

- Groundnut is predominantly grown in degraded soils (podzols) which are poor in both macro- and micro-nutrients. To some extent the crop is also grown in gley soils which yield less because of water logging and poor aeration.

- All the varieties grown in the country possess low yield potential and belong to the spanish group, do not posses fresh seed dormancy, become excessively vegetative due to humid conditions and lose seed viability quickly.

- All the varieties are susceptible to major diseases and pests.

- No improved cultural practices such as seed treatment, timely weeding, control of major diseases and insects, and gypsum application are practiced.

- Non availability of quality seeds because of inadequate seed multiplication programs.

- Improper choice of varieties even under suitable agro-ecological conditions.

- Very poor resource allocation to groundnut research and absence of a donor agency to support groundnut research.

However, groundnut cultivation in Vietnam has increased by 112% since 1976. Currently 265,000 ha are under this crop, with much of the increased groundnut area in the Red River basin and in the eastern zone of southern Vietnam. Although groundnut production in Vietnam in 1990 had increased by 108% over the 1976 production, the overall productivity had decreased by 4%. The main reason for decreased groundnut productivity has been a rapid increase in groundnut area in the unsuited, degradation-prone, sloping midlands, which represent a fragile ecosystem.

In order to cater to both export and domestic needs, groundnut production needs to be increased many fold. Any assessment of the available land resources suggest that about 75% of the extra food supply will have to come from higher crop productivity since there is very limited scope for expansion of the cultivated area. In turn, this yield improvement will require major investments in crop intensification programs together with major increases in the use of credit and farm inputs, including improved seeds, fertilizers, and chemical pesticides. Agricultural research also needs to be intensified to develop improved technologies and high-yielding varieties adapted to different soils and climatic conditions.

To achieve sustainable agricultural development, there should be an increase in agricultural productivity without jeopardizing land and water resources. The development of agriculture technology must take into account agro-ecological, socio-economic, and policy issues. Such location specific and situation specific technology should be refined locally through on-farm research so that it may be adopted by farmers with minimum risks.

On-farm adaptive research

The urgency of improving the productivity of small-farm agriculture, particularly in the developing world, is widely recognized. Technology transfer activities to increase productivity and production were successful in the green revolution era in the highly productive and homogenous areas. However, the adoption of technologies has been slow in more diverse, less productive and heterogeneous conditions. This resulted in questioning of the ability of researchers and extensionists to effectively provide appropriate technology to resource-poor farmers in the diverse, less productive, and risk prone areas (Tripp, 1991). The earlier contention that farmers in these areas were ignorant and not willing to adopt new technology has been effectively challenged. The problem appears to be neither the farmer nor the farm, but the technology itself and the process of generating it (Chambers et al., 1989). This has lead to testing of technologies in farmers' fields using a participatory, problem-oriented approach to planning agricultural research, generally referred to as on-farm adaptive research.

The on-farm adaptive research (OFAR) perspective encourages a problem-solving approach to agricultural research. Efforts are made to understand farming conditions and problems as a basis for planning research, and to involve participation of farmers in identifying research priorities and planning of experiments to test the adaptability of technology solutions. OFAR can be used for developing technologies that (*i*) improve the efficiency of crop management, (*ii*) require significant changes in cropping systems, or (*iii*) depend on single components (such as crop varieties) that can have a large effect on both crop management and cropping systems.

Asian Grain Legumes On-farm Research (AGLOR)

The Ministry of Agriculture and Rural Development (MARD), and the Cereals and Legumes Asia Network (CLAN) started a collaborative on-farm research project, under the aegis of the Asian Grain Legumes On-farm Research (AGLOR) aimed at improving groundnut production in Vietnam. Project implementation began in early 1991 and continued until 1995. The activities are being continued under CLAN to consolidate the gains. This paper reviews the activities of the AGLOR and the results obtained.

Diagnostic surveys on constraints to groundnut production

An initial first step of the project was the identification of constraints to groundnut production through field diagnostic surveys and interviews with farmers. Diagnostic surveys were conducted in the major groundnut growing areas of both northern and southern Vietnam to identify major constraints to groundnut production (Ngo The Dan et al., 1993). Nghe Tinh and Ha Bac in the north, and Tay Ninh and Long An in the south, the four largest groundnut-growing provinces of Vietnam, were selected as target areas for AGLOR.

The main characteristics of the surveyed provinces are given in Table 1. Nghe Tinh province, which was recently divided into Nghe An and Ha Tinh provinces, is located in the north-central part of Vietnam. Ha Bac province is located north of Hanoi. In both Ha Bac and Nghe Tinh provinces, groundnut is grown mostly in spring (Feb-Jun). In high elevation areas (midland and slopping areas), it is also cultivated in autumn (July-November), mainly for seed production for the spring season crop.

Table 1. Main characteristics of provinces in Vietnam in which the Asian Grain Legume On-farm Research (AGLOR) activities have been conducted.

Province	Location (°N)	Cultivated area of groundnut (ha)	x	Monthly temperature range (°C)	Major soil types	Main cropping season of groundnut
Nghe Tinh	18-20	29000	2060	17.3-29.5	Sandy, Sandy loam	Feb-Jun
Ha Bac	21-22	22000	1750	13.0-29.0	Alluvial red soil, Degraded soil	Feb-Jun
Tay Ninh	11-12	19000	1910	24.9-28.8	Alluvial gray soil, Sandy, Sandy loam	Nov-Mar
Long An	10-11	11000	1520	26.0-29.5	Acid sulphate soil	Nov-Mar

Both Tay Ninh and Long An provinces in southern Vietnam have a tropical monsoon climate. The rainy season is from May to October and the dry season from November to April. Groundnut is grown mainly in the winter-spring season (November-March) with irrigation, but also in summer (June-October). Diagnostic surveys were conducted by multi-disciplinary teams of scientists from national agricultural research systems and ICRISAT in selected districts and cooperatives of these four provinces. They were selected on the basis of groundnut area cultivated, possibilities for expansion of area, and discussions with the agricultural department staff. These diagnostic surveys helped researchers to become acquainted with the local farming practices, agro-ecosystems, agronomic and crop management practices, and to identify the reasons for low yield.

Scientists identified the farmer-perceived constraints and prioritized them according to the spatial and temporal occurrence of each problem and the extent of yield loss caused (Table 2). The constraints were grouped into socioeconomic, biotic, and abiotic constraints. Unstable and low price of groundnut was identified as an important socioeconomic constraint in northern Vietnam. Among the biotic constraints, lack of high yielding varieties with suitable maturity period and resistance to major diseases and pests was a first priority problem. Leaf-eating insects, soilborn and foliar diseases, and weeds were also identified as constraints by the farmers. Suggestions were made to the concerned local administrative units and Government to address the socioeconomic constraints.

Table 2. Constraints to groundnut production in the major groundnut-growing provinces of Vietnam.

Constraints	Priority ranking*			
	Nghe Tinh	Ha Bac	Tay Ninh	Long An
Socio-economic				
Lack of cash inputs	1	1	1	1
Unstable/low price of groundnut	2	1	-	3
Lack of drainage system	2	3	-	-
Lack of irrigation water	2	2	3	2
Abiotic				
Poor soil fertility	-	2	-	-
Drought	3	2	-	-
Biotic				
Lack of high-yielding varieties	2	1	1	1
Leaf eaters/other insect pests	2	2	1	1
Soilborne diseases	2	3	2	2
Foliar diseases	3	2	2	2
Yellow leaf disease	3	-	3	3
Weeds	-	-	2	2

* 1=high, 2 = intermediate, and 3 = low priority, - = constraint not identified.

Research plans

The joint teams of scientists planned on-farm experiments to address and alleviate the biotic and abiotic constraints. In northern Vietnam, high priority was given to disease tolerant improved varieties, *Rhizobium* inoculation to augment nitrogen supply of the degraded and poor soils; lime application to improve the soil and supply of nutrients; and seed and soil treatments and chemical sprays to control major diseases and pests.

In southern Vietnam, considering the already high yield level obtained by farmers (average farmers harvest up to 1.5 t ha^{-1}, while good farmers harvest over 2.5 t ha^{-1}) there was a need for fine tuning of the technology to increase its effectiveness. Emphasis was given to reallocation of input costs to maximize the profits to farmers. For on-farm trials in southern Vietnam, high priority was given to optimum spacing, split application of nitrogen, seed treatment, and control of major pests and diseases.

All the on-farm trials were conducted in farmers' fields. The farmers laid out the experiments in their fields with the guidance of researchers and extension personnel. On control plots, the farmers followed their usual cultivation practices. The farmers harvested groundnut from equal areas of each plot separately. Technology assessment was conducted through observation, sample and data collection during vegetative growth, and through comparison of dry pod yield of control and treatment plots.

Results of On-farm trials

Single Factor Diagnostic Trials, Northern Vietnam

Lime application. Lime application consistently increased pod yield of groundnut (Table 3). Split application of lime (200 kg ha^{-1} as basal and 200 kg ha^{-1} at flowering), gave highest yields, amounting to a 26% increase over the control (no lime) when averaged over five trial sites and two seasons.

Rhizobium seed treatment. Although the effect of *Rhizobium* inoculation varied from site to site, there was a significant effect of inoculation on pod yield at most sites (Table 3). Overall, inoculation increased pod yield by 15% over the control. Combination of *Rhizobium* inoculation with the basal application of 60 kg ha^{-1} urea increased groundnut pod yield by 24% on average.

Seed and soil treatments with chemicals. Treatment effects obtained were determined by incidence of soil insects and soil borne diseases (Table 3). Overall, seed treatment alone increased pod yield of groundnut by 11% while seed and soil treatment applied together increased yield by 19% in Nghe An province. Under high disease pressure, Bavistin gave the most effective control, resulting in increased pod yield of up to 45%.

Foliar disease and pest control. Sprays with chemicals applied when necessary significantly reduced disease and pest incidence and increased groundnut yield (Table 3). Under high incidence of foliar diseases, two sprays of Daconil increased pod yield by 24% compared with unsprayed control. More than 20% yield increase was obtained with application of Methylparathion spray to control foliage-feeding insects. One spray of Methylparathion at flowering combined with one spray of Daconil at 80 days after sowing increased groundnut pod yield by 35% in Nghe An province.

Table 3. Effect of various treatments on dry pod yields of groundnut grown in the 1991 and 1992 spring seasons at different test sites of northern Vietnam. Yields in control plots (first row in each treatment) are shown together with treatment values as a percentage of the control (figures in parentheses are numbers of fields averaged).

	Nghe An Province						Ha Bac Province						
	Nghi Loc		Nam Dan		Dien Chau		Viet Yen		Tan Yen		Tien Son		
Treatment	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	Mean
Lime Treatment													
Control Yield (t ha^{-1})	2.10(3)	2.74(2)	1.83(3)	1.54(4)	1.77(4)	1.57(6)	1.06(4)	1.19(6)	1.10(3)	1.12(3)	-	-[1]	
400 kg ha^{-1} (basal)	140	111	107	116	100	110	-	111	-	112	-	-	113
200 kg ha^{-1} (at flowering)	-	111	-	109	-	115	116	111	115	110	-	-	112
200 kg ha^{-1} (at basal)+200 kg ha^{-1} (at flowering)	180	122	114	131	103	119	-	118	-	121	-	-	126
Rhizobium inoculation													
Control yield (t ha^{-1})	2.00(3)	1.79(5)	1.83(3)	1.52(4)	-	1.76(6)	1.00(4)	1.10(6)	1.11(3)	1.08(3)	-	1.19(3)	
Inoculation	168	110	109	110	-	117	126	110	104	105	-	93	115
Inoculation + 60 kg ha^{-1} urea	-	128	-	117	-	128	-	-	-	-	-	-	124
Seed and soil treatment													
Control yield (t ha^{-1})	2.67(3)	2.09(3)	1.87(3)	1.55(4)	1.77(3)	1.64(6)	-	-	-	-	-	-	
Falizan® (1-2 g kg^{-1} seed)	100	107	105	107	125	121	-	-	-	-	-	-	111
Falizan® + Basudin (20-50 kg ha^{-1})	125	107	120	114	125	122	-	-	-	-	-	-	119
Bavistin® (1 g kg^{-1} seed)	-	-	-	-	-	145	-	-	-	-	-	-	
Thiram (1 g kg^{-1} seed)	-	-	-	-	-	130	-	-	-	-	-	-	

Table 3 – Continuous

	Nghe An Province						Ha Bac Province						
	Nghi Loc		Nam Dan		Dien Chau		Viet Yen		Tan Yen		Tien Son		
Treatment	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	Mean
Sprays against foliar disease													
Control yield ($t\ ha^{-1}$)	2.00(3)	2.05(4)	-	1.57(4)	-	2.08(6)	1.30(3)	1.15(6)	1.40(3)	0.94(3)	-	1.05(3)	
Daconil® (0.25%) one spray at 50 DAS[2]	134	119	-	111	-	117	105	-	121	-	-	-	118
Daconil® (0.25%) one spray at 70 DAS[2]	-	103	-	111	-	128	105	101	125	101	-	113	111
Sprays at 50 and 70 DAS	134	-	-	-	-	-	106	-	131	-	-	-	124
Sprays against insect pests													
Control yield ($t\ ha^{-1}$)	2.25(3)	-	1.16(4)	-	1.83(3)	-	1.23(3)	1.14(6)	-	1.08(3)	-	0.79(3)	
Methylparathion (0.2%) one spray	126	-	-	-	106	-	112	113	-	153	-	111	120
Methylparathion (0.2%) two spray	-	-	121	-	-	-	-	-	-	-	-	-	121
Insect and disease control													
Control yield ($t\ ha^{-1}$)	-	2.04(4)	-	1.62(4)	-	1.73(5)	-	-	-	-	-	-	
Methylparathion 0.2% (at flowering)	-	109	-	110	-	124	-	-	-	-	-	-	115
Daconil® 0.25% (70 DAS)	-	109	-	109	-	115	-	-	-	-	-	-	111
Both sprays	-	120	-	113	-	135	-	-	-	-	-	-	123

1. Not tested
2. DAS = Days after sowing

Single Factor Diagnostic Trials, Soutern Vietnam

Number of seeds per hill. Normally the farmer sows two seeds per hill as insurance against nongermination and seedling mortality. In Duc Hoa district in Long An province, seed was treated with Captan (2 g kg^{-1} seed and sown at one seed per hill (20 x 15 cm spacing). Pod yield increased by 11% over the control yield (farmers' practice of two seeds per hill) of 3.0 t ha^{-1}. In Trang Bang district of Tay Ninh province, sowing of selected seeds at one seed per hill (20 x 20 cm spacing) gave similar pod yield to the control (2.65 t ha^{-1}). The results established that it was more economical to sow just one seed per hill, preferably with seed treatment as it will reduce the seed cost by 50% and thereby increase profits to farmers.

Purification of local varieties. Farmers had identified lack of pure varieties as one of the production constraints. The presently cultivated variety 'Ly' is high yielding, but was found to be a mixture of 2-3 different types. Hence a program of purifying the variety was undertaken. In Trang Bang district where the purified seed was compared with the bulk seed (mixture), 12-18% higher yields were obtained with the purified seed.

Replacement of coconut ash for groundnut cultivation. South Vietnamese farmers usually apply 3-4 t ha^{-1} coconut ash to groundnut field prior to land preparation to higher yields. Considering the scarcity and high cost of coconut ash, trials were conducted to replace this with inorganic fertilizers. Addition of 30 kg N, 90 kg P_2O_5, 100 kg K_2O and 10 kg Calcium was found to alleviate the need to apply 3 t ha^{-1} coconut ash.

Split doses of lime and nitrogen. At the same level of total application, splitting the doses of both lime and nitrogen fertilizer resulted in pod yield increases of about 10% over a complete basal application (Table 4). Hence, higher profits could be realized from reallocation of a fixed level of input.

Effect of superphosphate application. In a trial in Duc Hoa district of Long An province, application of 25 kg ha^{-1} phosphorus as superphosphate increased pod yield by 15% over control (2.96 t ha^{-1}). Superphosphate application also increased shelling percentage from 69% (in the control) to 75%.

Rhizobium trials. Rhizobium inoculation gave 14% higher yield than that of farmers' practice. The pure *Rhizobium* strain (isolated from Ly variety) was compared with mixed exotic strains and no *Rhizobium* in two groundnut varieties Ly and Moket. The mixture of inoculum having Ly *Rhizobium* + 431/DMG+UPPNL6 (23%), or a mixture of Ly *Rhizobium* + 431/DMG (14%) gave significantly higher yields over control.

Table 4. Effect of different methods of lime and nitrogen fertilizer application on pod yield of groundnut in districts of Tay Ninh province, southren Vietnam, winter spring crop, 1991/92.

Treatment	Pod yield (t ha^{-1})			Yield increase over control (%)
	Duc Hoa	Cu Chi	Mean	
Lime				
Basal application (400 kg ha^{-1})	3.68	2.34	3.01	-
200 kg ha^{-1} as basal + 200 kg ha^{-1} at flowering	4.10	2.62	3.36	12
Nitrogen				
100% N as basal	3.59	2.34	-	-
50% N basal + 50% N as one spray at peg formation	-	2.62	-	12
50% N basal + 50% N as two sprays (at flowering and peg formation)	3.84	-	-	7

Control of foliar diseases. To study the efficacy of some fungicides in controlling the late leaf spot (LLS) and rust diseases, Daconil (1 or 3 sprays), Copper-zinc (3 sprays) and Hexaconazol (3 sprays) were compared with the control. Hexaconazol was found to be most effective in controlling LLS and rust and gave 20-25% higher yields in both summer and winter-spring seasons.

Control of defoliators. Five chemicals were compared to identify the appropriate pesticide to control defoliators (*Spodoptera* and *Helicoverpa*). Two sprays of Karate and Lannate were able to control defoliators, and resulted in higher yields compared to no spray and other chemical treatments (Table 5)

Weed control. Of the seven different herbicides tried along with the control (no herbicide), in Trang Bang district, Onicide and Dual were most efficient in reducing the density of weeds m^{-2} with no damage to the groundnut crop.

Table 5. Effect of Rhizobium inoculation on groundnut production, Trang Bang, South Vietnam, winter-spring season 1993/94.

Rhizobium (strains)	Pod yield ($t\ ha^{-1}$)	Nodules $plant^{-1}$	Nodules mass $plant^{-1}$	Shelling %
NC 92	4.06	208	185	78
NC 92 + ISL	3.59	202	178	78
ISL + IS 4 + ISU	3.61	212	175	77
CONTROL	3.58	172	153	77
SE	±0.20	±17	±29	-
CV%	5	9	17	-

Combined application of promising technologies, Northern Vietnam

Based on the results obtained from the single factor trials during 1991-1993, a set of improved production practices was formulated. The improved production practices were compared with the farmers' local practices in Dien Phong (185 ha) and Dien Thinh (472 ha) villages of Dien Chau district during spring 1995. The improved production practices produced a mean pod yield of 2.2 t ha^{-1} compared to farmers' practice yields of 1.5 t ha^{-1}. In Thanh Hoa province, the improved practices produced an average (over 3 locations) pod yield of 2.3 t ha^{-1} compared to 1.6 t ha^{-1} with farmers' practices.

The improved production practices were compared with farmers' practices using local cultivars (Gie Ngo Quan and Sen Nghe An) in one set and improved cultivars i.e. Sen Lai, No 4329, and V 79 in another set in Thach binh, Ngo Quan, and Ninh Binh villages during the spring of 1996. The improved production practices using local cultivars in the first set gave a mean pod yield of 1.5 t ha^{-1} compared to that of 1.37 t ha^{-1} pod yields recorded with farmers' practices. In the second set, the improved production practices with improved varieties recorded 1.8 t ha^{-1} compared to the yields of 1.6 t ha^{-1} obtained with farmers' practices. The economic efficiency has indicated that the improved production practices with improved variety gave 108.9% higher economic returns (533,667 Dong) compared to that of improved production practices with local cultivars (225,500 Dong) (1 US $ + 11000 Vietnamese Dong).

During 1997 the improved production technology [improved variety (Sen Lai), FYM (12-16 t ha^{-}), balanced fertilization (28 kg N, 64 kg P_2O_5, 34 kg K_2O), micro nutrient spray (two times at 6-7 leaf stage and flowering), and lime application(200 kg ha^{-1} as basal and 200 kg ha^{-1} at flowering) was compared with the farmers practice in Nghe An province. The pod yields were increased by 22-26 % in improved practices over the farmers' practice yields, while in Ha Bac, improved production practices [seed treatment (with Bavistin), lime application (basal and at flowering), single seed per hill, Rhizobium (nitrazin) inoculation, and improved variety (V 79)] tested in 5 ha area resulted in 13-16% increased pod yields over the traditional farmers' practices (Table 6).

Improved varieties were tested under improved and traditional practices in Thach Binh, Nho Quan, and Ninh Binh resulted in pod yield increases of 7-14% (Table 7) and monetary gains of 87,500 to 825,500 Dong (Table 8).

Combined application of promising technologies, Southern Vietnam

Based on the results obtained from single-factor diagnostic studies, improved production practices consisting of improved variety (purified Ly), alternate fertilizer to cocoash, seed treatment (Bavistin), weed control (Dual), foliar disease control (Anvil) were compared with farmers' practices in Cu Chi and Trang Bang districts. The improved production practices gave 25% higher yields compared to farmers' practice yields of 2.3 and the cost for production of 1 kg of pods was reduced by 29% in improved production practices compared to farmers' practice (Table 9).

Crop improvement, Southern Vietnam

The groundnut crop improvement program in Vietnam is centred around the objective of breeding for early- maturity to fit well in the existing cropping systems, and confectionery types with large seed size since groundnut is grown mostly for export. Ideally, the farmers of Vietnam would like to have a variety with a 90-day growing period. However, they are willing to grow a variety with a 100-day maturity provided it has large seed mass and good seed quality which can fetch a good market price. In the Advanced Short-duration Groundnut Varietal Trial (9 lines + 1 control), conducted at Cu Chi, Trang Bang, Hoa Thanh, and Duong Minh Chau, all the varieties evaluated were harvested around 90 days. Although the test entries gave similar yield to that of VD 1 (a newly released improved variety), the 100-seed mass (test weight) was significantly higher than the control (Table 10). This is a very important characteristic for export. Vietnamese farmers preferred VD 1, VD 3, VD 5, VD 9, and VD 10 due to their tolerance/resistance to bacterial wilt disease.

Table 6. Effect of new technologies on groundnut yield of V79 variety at Viet Yen, Ha Bac

Variety	Treatment	Germination %	Total pods/plant^{-1}	Mature pod (%)	Pod yield t ha^{-1}	Yield increase %
V79	Farmers' production practices	90	168	79	1.77	-
	Improved production practiccs	93	194	87	2.06	16
Su tuyen	Farmers' production practices	93	193	78	1.56	-
	Improved production practices	94	216	87	1.76	13

Table 7. Effect of combined technologies on the groundnut yield at Thach Binh-Nho Quan, Ninh Binh.

Variety	Treatment	Mature pods plant^{-1}	100 pod mass (g)	100 seed mass (g)	She-lling (%)	Pod yield t ha^{-1}	Yield increase	
							%	kg ha^{-1}
Gie nho quan	Farmers' production practices	11.2	98.5	46.2	74.2	1.20	-	-
	Improved production practices	13.2	103.2	47.2	78.3	1.33	11.6	139
Sen nghe an	Farmers' production practices	9.0	114.3	49.6	76.0	1.56	-	-
	Improved production practices	12.8	118.3	51.3	77.7	1.67	7.1	111
Sen lai 75/23	Farmers' production practices	5.5	147.5	58.6	72.0	1.26	-	-
	Improved production practices	10.4	153.5	61.0	72.1	1.33	6.6	83
4329	Farmers' production practices	5.0	152.0	58.7	72.6	1.72	-	-
	Improved production practices	6.3	160.5	62.0	70.0	1.96	13.7	236
V79	Farmers' production practices	7.8	144.7	64.4	74.0	1.84	-	-
	Improved production practices	14.2	153.9	66.2	74.5	2.10	14.6	267

Table 8. Economic effect of new agro-technieques on groundnut at Nho Quan - Ninh binh Province in 1991-1992.

Variety	Total income	Cost of cultivation (Dong)	Profit	Benifit-cost ratio
Gie Nho quan	556,000	244,500	311,500	2.28
Sen Nghe an	444,000	244,500	199,500	1.82
Sen lai 75/23	332,000	244,500	87,500	1.36
4329	944,000	244,500	699,500	3.86
V79	1.068,000	244,500	825,500	4.37

Table 9. Improved package versus farmers' practice of roundnut production, Cu Chi and Trang Bang districts, Vietnam, 1994/95. (1 US$ = 11,000 Dong)

Production practices	Location	Pod yield ($t\ ha^{-1}$)	Input cost (Dong)	Cost of production per kg of groundnut (Dong)
Improved practices	Cu Chi 1	2.94	5,582,100	1895
	Cu Chi 2	2.76	6,210,800	2087
	Cu Chi 3	2.91	6,013,300	1866
	Tr. Bang	2.95	5,905,450	2006
Mean		2.90	5,927,913	1963
Farmers' practices	Cu Chi 1	2.41	6,352,800	2637
	Cu Chi 2	2.38	7,103,500	2828
	Cu Chi 3	2.45	6,644,000	2457
	Tr. Bang	1.98	6,296,950	3180
Mean		2.30	6,599,313	2776

Crop improvement, Northern Vietnam

A promising bacterial wilt resistance groundnut cultivar, ICG8666, was evaluated in Ha Tay (three locations) and Ha Bac (two locations) provinces during the spring 1996. ICG 8666 produced an average pod yield of 2.48 t

ha^{-1} compared to the yield of 2.15 t ha^{-1} by the local cultivar. The wilt incidence of ICG 8666 in hot spot locations, Xuan mai (Ha Tay province), Thach Binch (Ninh Binh province), Thanh Liem (Ha Nam province), and Thai Nguyen (Bac Thai province) varied between 0 and 6.5% compared to 30-82.5% of the susceptible local cultivar.

Another promising groundnut variety, ICGV 87391 produced a mean pod yield (3 locations) of 4.03 t ha^{-1} compared to that of 3.17 t ha^{-1} produced by the control Ly under optimum conditions. However, ICGV 87391 performed equally well with higher pod yields in both high input (5.2 t ha^{-1}) and low input and unfavourable conditions (1.3 t ha^{-1}) compared to that of 4.7 t ha^{-1} yields of Ly in high input and 1.0 t ha^{-1} under low input and unfavourable conditions.

Varietal trials were conducted to identify genetic material with good agronomic traits, resistance to major abiotic and biotic stresses and high yield potential. In the international short-duration groundnut trials conducted during the spring season of 1996, ICGVs 91112 (2.53 t ha^{-1}), 91151 (2.29 t ha^{-1}), 91109 (2.2 t ha^{-1}), and 91132 (2.19 t ha^{-1}) performed well and produced higher pod yields than the local controls (Table 11).

In the international medium-duration groundnut varietal trial (Spanish bunch), ICGV 91026 (2.19 t ha^{-1}), SB 11 x 95 (1.83 t ha^{-1}), and ICGV 90017 (1.73 t ha^{-1}) produced higher pod yields over the control yields of 1.4 t ha^{-1} (Table 12). However, in the international medium-duration groundnut varietal trial (Virginia bunch), ICGV 90057 (2.42 t ha^{-1}) alone produced significantly higher pod yields over the control's pod yield of 1.82 t ha^{-1} (Table 13). ICGV 87846 (2.94 t ha^{-1}) alone recorded significantly higher pod yield over the control (2.3 t ha^{-1}) in the international foliar diseases resistant groundnut varietal trial (Table 14).

Achievements

Until now, progress has been made in identifying appropriate groundnut varieties, appropriate application of lime and rhizobial inoculation, important pest and disease control methods, planting methods and rational use of inorganic fertilizers. There is an evidence of impact of improved production technologies in terms of increased yields of groundnut over large areas of farmers' fields. Although by 1996, the increase in area under groundnut was marginal (265,000 ha) but production (360,000 t) and productivity (1360 kg ha^{-1}) have increased dramatically.

Table 10. Pod yields of advanced short-duration groundnut varieties, southern Vietnam, winter, 1996/97.

Variety	Origin	Pod yield ($t\ ha^{-1}$)				
		Cu Chi	Trang Bang	Hoa Thanh	Duong Minh Chau	Mean
VD 1	Improved (control)	3.65	2.98	3.25	3.41	3.32
VD 2	Ly due hoa x (ICGV 88396 x USA 54)	3.69	3.26	3.04	3.40	3.35
VD 3	ICGV 87005 x (Tram Xuyen x Sen Nghean)	3.10	2.71	2.93	3.05	2.95
VD 4	Ly DBI x UPLPN4	3.39	3.37	2.61	3.26	3.16
VD 5	Ly x (ICGV 88396 x USA)	2.89	2.56	2.75	2.93	2.78
VD 6	Ly 8	3.34	2.67	2.71	3.11	2.96
VD 7	TM4 x ICGV 87302	3.28	2.98	3.40	2.96	3.15
VD 8	Ly x ICGV 86259	3.55	3.12	3.04	3.44	3.29
VD 9	BW 8666	2.65	2.60	2.38	3.01	2.66

Table 11. Performance of groundnut lines in International Short-Duration Groundnut Varietal Trial, northern Vietnam, spring, 1996

Genotype	Pod yield ($t\ ha^{-1}$)	100 seed mass (g)	Shelling (%)
ICGV 89023	1.92	3.86	80.8
ICGV 91109	2.20	38.0	73.9
ICGV 91112	2.53	41.7	74.2
ICGV 91114	1.96	43.1	75.0
ICGV 91116	2.04	41.7	78.9
ICGV 91117	1.92	42.9	73.0
ICGV 91123	2.19	38.4	78.5
ICGV 91124	2.02	39.0	80.4
ICGV 91146	1.63	41.3	79.7
ICGV 91151	2.29	34.2	77.4
ICGV 92209	1.55	40.3	79.4
ICGV 92242	1.75	41.7	76.1
ICGV 92268	1.65	40.3	76.2
ICGV 92269	1.56	47.1	76.2
Chico	1.86	27.8	79.2
Control (Ly Cam Ranh)	1.82	41.3	80.3

Table 12. Performance of groundnut lines in the International Medium-duration Groundnut varietal Trial (SB), northern Vietnam, spring 1996.

Genotype	Pod Yield ($t\ ha^{-1}$)	100-seed mass (g)	Shelling (%)
ICGV 86994	0.75	46.1	76.2
ICGV 86934	0.40	46.1	72.4
ICGV 86953	1.40	59.0	72.2
ICGV 86935	0.49	46.0	73.0
ICGV 88132	1.20	47.5	68.6
ICGV 89355	0.77	47.0	70.8
ICGV 89359	1.44	49.5	71.0
ICGV 90011	1.11	47.8	77.2
ICGV 90017	1.73	61.7	72.4
ICGV 91015	0.61	43.2	67.4
ICGV 91026	2.19	58.2	75.4
ICGV 91061	1.54	48.8	74.0
ICGV 91040	1.15	48.6	71.4
ICGV 91058	0.49	49.8	62.8
SB 11 X 95	1.83	46.0	76.8
Control (V 79)	1.40	50.4	74.5

Table 13. Performance of groundnut lines in the International Medium-duration Groundnut varietal Trial (VB), northern Vietnam, spring 1996.

Genotype	Pod Yield ($t\ ha^{-1}$)	100-seed mass (g)	Shelling (%)
ICGV 86201	1.25	46.1	74.4
ICGV 89379	1.50	55.8	74.1
ICGV 90039	-•	-	-
ICGV 90043	1.55	69.0	72.2
ICGV 90045	1.63	82.5	67.5
ICGV 90046	1.07	81.1	67.0
ICGV 90057	2.42	57.0	76.2
ICGV 91001	1.74	46.0	75.5
ICGV 91003	1.69	48.4	79.4
ICGV 91004	-1.54	34.0	72.2
ICGV 91060	1.66	53.2	74.6
ICGV 91061	1.90	43.8	74.9
ICGV 91067	1.35	43.7	69.2
ICGV 91074	1.00	58.3	72.1
ICGV 91077	1.99	41.9	73.5
Control (V79)	1.82	56.6	73.6

• Genotype had poor plant stands

Table 14. Performance of groundnut lines in International Foliar Diseases Groundnut Varietal Trial, northern Vietnam, spring 1996.

					Disease Score*
Genotype	Pod yield (t ha^{-1})	100-seed mass (g)	Shelling (%)	Rust	Late leaf spot
ICGV 87846	2.94	60.8	75.7	3.7	4.7
ICGV 87860	2.09	50.6	75.4	5.0	5.0
ICGV 87866	1.38	44.3	77.8	6.3	6.3
ICGV 88256	1.83	41.5	75.8	3.3	3.7
ICGV 89402	1.49	58.4	75.6	3.7	4.0
ICGV 90074	1.51	59.8	78.0	6.7	6.7
ICGV 81223	1.27	58.0	77.0	3.0	2.7
ICGV 91227	1.70	56.3	71.8	3.0	4.0
ICGV 91228	1.00	56.1	62.6	4.0	4.7
ICGV 91230	1063	51.4	72.0	5.3	4.7
ICGV 91234	2.16	59.8	73.6	4.0	4.0
ICGV 91246	2.00	60.0	76.6	3.3	3.3
ICGV 91040	1.37	62.0	76.8	5.3	5.3
ICGV 91247	1.66	61.4	72.0	5.3	5.3
ICGV 87160	2.26	44.3	73.6	7.0	7.0
Control (SB 11x94F2H82-5x87157	2.30	45.1	78.4	7.0	7.0

*On 1-9 scale

Per annum compounded rate of growth in production has been about 7% and productivity 4% since 1991. The exports of groundnut have gone up by over 450%. Groundnut area in Vietnam is spread throughout the country. However, much of the change in productivity has occurred in the Red river delta and the eastern zone of southern Vietnam and Mekong delta agro-ecological zones.

At the test locations the farmers are willing and enthusiastic to adopt the improved production technologies since the improved technologies were simple, low-input, and easily understood by farmers. The district and provincial agricultural departments have expressed their desire to extend and conduct of such on-farm trials to improve the access of available technologies to farmers. Farmers consider on-farm research to be a good way of technology exchange in which interaction between scientists, extension workers, and farmers can be greatly enhanced and farmers have an opportunity to evaluate advanced technologies and select appropriate ones for themselves.

Future research needs

Research needs to be aimed at enhancing and sustaining the productivity of groundnut based production systems in Vietnam through conservation and efficient utilization of the natural resources while controlling degradation of the natural resource base. This can be best achieved by (*i*) introduction of management practices for sustained increases in groundnut productivity and (*ii*) minimizing environmental degradation and increasing farmers' incomes through increased system productivity and conservation of water and nutrients.

Delineation of groundnut based production systems across various ecological zones based on a detailed natural resource characterization and analysis of agro-ecological potential is required to identify suitable agro-ecological zones for intensification of groundnut production. The yield gap analysis between the current and potential groundnut yields in different regions needs to be estimated.

The Vietnam Agricultural Research Institute (VASI) has emphasized in its current natural resource management research, soil and water management to counter drought and short-term flooding, and the tailoring of fertilizer doses and soil amendments for different soil types.

Land degradation is one of the most urgent agricultural and environmental problems in Vietnam. Conservation effective, sustainable systems of farming need to be developed and introduced urgently to stop further degradation of soils. But resource poor farmers will adopt soil conservation measures when these are synchronized with economically viable crop production systems. Groundnut is a cash-export-oriented crop and farmers are interested to adopt natural resource conservation systems for the groundnut based farming systems in order to sustain its productivity. Identification of important constraints for increasing groundnut yields will enable presentation of options to farmers for sustaining groundnut production and for efficiently managing the land resources so as to minimize land degradation. Identification of integrated soil, water, nutrient management strategies for conservation and efficient utilization of soil and water resources is required to minimize the degradation of sloping midlands in northern Vietnam.

In cooperation with ICRISAT, some work on the yield gap analysis by crop modeling to identify high priority research and development needs of different groundnut growing agr-ecologies have been done, so that sustainable and high crop yields are harvested by the resource poor farmers. However, the Vietnamese scientists need to be trained in the use of high technology tools such as geographical information systems (GIS), and simulation modeling of the groundnut crop to assess growth and yield of elite groundnut germplasm which can tolerate most of the biotic (foliar diseases, bacterial wilt, and insect pests) and abiotic stresses (drought).

The initial studies in natural resources management research have strongly indicated a need to follow a watershed approach on landscape topo-sequences, particularly for mid- and sloping lands which are prone to severe land degradation resulting in low and unsustainable crop yields. To minimize land degradation and to increase groundnut productivity, land and water resources must be conserved. The watershed approach is a time tested approach for conserving natural resources, particularly in rainfed agriculture. The evaluation of agricultural watersheds and the demarcation of the hydrological units in Vietnam is urgently needed for natural resource conservation.

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An analysis of Natural Resource Management issues in the Red River Delta

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Introduction

In Vietnam, as in other developing countries, the major natural resource management issues are all related to pressure of population on natural resources. The human population is rapidly increasing, creating greater demands on natural resources. Proper management of these resources is thus the key factor to the future of South-East Asia and the survival of its population. The ongoing transition from a central planned economy into a market oriented economy, the rapid industrialization and modernization process in Vietnam from one side are accelerating the socio-economic development of the country, upgrading the living conditions of the people, but on the other side are creating new complex issues of natural resource degradation. Effective management of rural resources, however, faces a series of complex issues and the associated problems are not-easily-solved, for example, rapid population growth, poverty, current patterns of resource use, environmental degradation, increased demands and competition for resources. These issues are interrelated and in fact, are issues in agro-ecosystem management, as nowadays man has become an environmental manager, assuming responsibility for designing, contracting, and maintaining the ecosystem on which he depends for his continued survival.

The Red River Delta of Vietnam is one of the areas characterized by high population density and intensive land use, and may be a good example for an analyses of natural resource management issues.

Physical environment

The Red River Delta of North Vietnam is encompasses a total area of 17,321 km^2. The area resembles a triangle with Viet Tri at the top and the coastline of the Gulf of Tonkin stretching from Hai Phong to Ninh Binh at the bottom. The area is inhabited by more than 13 million people and is one of the most densely settled rural areas in Asia with an average of about 900 persons per km^2. Topographically, the Red River Delta can be divided into three sections:

- The hill and mountain section is slightly elevated area with maximum altitude not exceeding 10 m above sea level and average inclination of 18° to 22°. The hill soils are fertile but concretion occurs in some places. The hill surface areas, however, are now seriously eroded and barren.

- The flat alluvial plain occupies the largest area, with elevation ranging from 3 to 5 m above sea level. It is an ancient and stable part of the delta. This part formerly experienced alluvial deposition, but the large low-lying area is now interrupted by dike systems, and natural alluvial deposition no longer takes place.

- The coastal part has the youngest alluvial soils in the Red River Delta. The area is very flat and currently experiences alluvial deposit and sea encroachment.

The climate of the Red River Delta is tropical monsoon, influenced by the ocean climate. There are two distinct seasons: dry and rainy. The rainy season is from April to October with 80-100 rainy days providing 80-85 percent of the annual rainfall of 1,600-1,800 mm. The dry season is from November to March with 40 rainy days providing less than 150 mm of rainfall.

The hydrology of the Red River Delta is dominated by the Red River system and Thai Binh River system. The Red River's flow is 120 billion m^3 of water per year on the average, with a peak volume of 158 billion m^3 of water per year. Its alluvial content averages 1.31 kg m^{-3}, 3-3.5 kg m^{-3} in the flood season, and 0.5 kg m^{-3} in the flood season, and 0.5 kg m^{-3} in the dry season.

Flooding is the most dramatic hazard in the Red River system. During reclamation and protection of the land, the people of the Red River Delta constructed an extensive dike system to control flood water. These systems culminated in maximum control against the threat of flooding. However, since construction of the closed dike system, the delta has been isolated from the natural deposition and extension of the Red River system.

Land use in the Red River Delta

Because the soils in the Red River Delta are renowned for their suitability for paddy rice, almost all cultivated land is used to grow rice. Only a small proportion remains for cash crops or other crops. There are two distinct crops: the winter-spring crop from November and December to May and June, and the summer-autumn crop from May and June to October and November. The current improved irrigation system helps the local people control the cultivation factors. Beside the two traditional crops, local people now grow early spring-summer crops and very early summer crops, and favor cold-tolerant winter crops. Various crop varieties and crops that can grow in winter-deficit conditions have been introduced. There are two groups of winter crops: early winter tropical-derived crops and late winter temperate zone-derived crops. Crops in the first group are maize, soybean, sweet potato, onion, and garlic, which can be planted between 20 September to 20 October. The second group includes potato, cabbage, kohlrabi, and wheat, which can be planted from 20 October to 20 November. Rice varieties with different maturity duration have also been identified, making possible the arrangement of cropping schedules to fit the alternative cropping systems.

The demographic dilemma (Nguyen Xa village as a study site)

In 1992 and 1993, CRES in cooperation with the Southeast Asian Universities Agroecosystem Network (SUAN), East-West Center, University of Hawaii, and Hanoi Agriculture University No. 1, conducted research in the Red River Delta, using Nguyen Xa village as a study site (Le Trong Cuc & Rambo, 1992; Patanothai, 1996).

We chose Nguyen Xa Village as our study site because it represented an extreme case from the standpoint of human ecology – the most density populated village in the most densely polluted province in the Red River Delta, which is itself one of the most densely populated rural regions in Asia, indeed anywhere in the tropics. The extreme population pressure on limited natural resources, more than any other factor, constraints the development prospects of the delta. Before World War II, 295 villages, mainly in the maritime provinces of Nam Dinh and Thai Binh, had densities in excess of 1,500 persons km^{-2} (Gourou, 1936). Today, Nguyen Xa is the only village in the delta having a population density at that level. Calculated on the cultivated-area basis, the village population density is 2,030 persons km^{-2} of cultivated land. Each hectare must support 20.3 persons, i.e. only 490 m^2 of cultivated land area for each inhabitant of the village. The need to provide food for its vast peasant population under hyperdensity conditions already necessitates that every potentially arable plot of land be intensively cultivated to meet current grain production needs. Yet population continues to grow despite family planning programs and government sponsored resettlement of excess people into frontiers. The rate of increase is slowing but, even under the most optimistic projection (1.3%), there may be as many as one-third more stomachs to fill before growth is stopped 20 years from now. Although rice production is currently sufficient to meet minimum nutritional requirements of the population, productivity will have to be increased considerably in the next several years to keep pace with the demands of a growing population; otherwise, nutritional standards will undergo serious decline. Such a population increase places heavy demands on limited land, both for rice fields and sites for houses.

Prospects for boosting agricultural productivity

Over the centuries, the farmers of the delta have brought the environment under ever more complete control. The productivity of the system has been greatly increased by improved water control and through introduction of new technology. High-yielding varieties and chemical input, along with better managed irrigation, have resulted in much higher yields. In the paddy fields of Nguyen Xa village, Thai Binh province, the average yield of two crops exceeds 11 t ha^{-1} in favorable years, while the best fields under optimal conditions already reportedly exceed the estimated maximum yield potential for Red River Delta of 15 t ha^{-1}. Not many places in the world have achieved this level of yield. Results from our crop simulation indicate that the current rice yield in Nguyen Xa village has already reached 80% of its potential. However, the estimated potential yield is based on the assumption that there is no limiting factor except weather conditions. In reality, everything is unlikely to be perfect, even under the best management possible. Thus, the maximum yield that could actually be realized would certainly be lower than that simulated. Apparently, the opportunity to increase production through adoption of modern technologies has nearly been exhausted. Significant yield increases will depend on genetic breakthroughs in improving rice crop varieties, which is unforeseen in the near future.

Currently all lands have already been used. Essentially all paddy fields have been planted to two crops of rice. The third crop currently covers about 40% of the paddy land. Therefore, the potential for further increase in cropping intensity is virtually very low.

The possibility for increasing animal production is also limited. Buffalo and cattle numbers are decreasing due to lack of grazing area and fodder. Pig raising, although unprofitable, is being maintained because of the need for manure. There appears to be a considerable potential for increasing fish production in the ponds, but their multiple sharing makes it difficult in practice. Some possibilities exist for increasing fish production in the irrigation canals where fish raising can be accommodated.

Although agriculture is the main occupation, many households are also engaged in subsidiary enterprises ranging from making sweets, liquor, pressed ham, and tofu; dealing junk and scraps; working in construction, carpentry, rice mills, and glass manufacturing; transporting goods by motorized vehicles. Income from subsidiary activities has become the major part of family income for many households. These subsidiary activities, however, affect agriculture more positively than negatively. Positive effect are more investment in pig raising and in input for crop production, while negative effects are less time spent on crop production and a declining interest in growing the third crop. Subsidiary activities have actually helped to maintain or even increase the inflow of nutrients to the fields, which consequently sustains productivity of the land resource. With little room left for improvement in agriculture, subsidiary activities may be the only alternative for coping with increasing population in the long run.

Conclusions and recommendations

A strategy for sustainable natural resource management in the Red River Delta will have to combine the effort to control population growth and reduce human pressure on resources with attempts to improve agro-ecosystem performance through fine tuning, while diversifying non-farm sources of development and income for the rural population.

Population control deserves a very high priority: The government already supports a strong effort to reduce fertility that has enjoyed considerable success. More could be done, however, particularly by improving the quality of birth control materials and offering adopters a greater range of choices with regard to techniques. Moving people into a more familiar environment might also decrease environmental damage. Expansion of employment opportunities in urban centres may offer a more viable alternative to further resettlement in marginal areas.

Improvement of agroecosystem performance: A major question in developing agriculture in the Red River Delta is that of how to increase biological diversity in the system. 'Diversity' is a property of agro-ecosystem structure. At the field level, diversity is measured in terms of genetic and species variability within the crop species (rice varieties, azolla, ducks, fishes, crabs). At the landscape level, diversity is measured in terms of number of different types of communities constituting the agro-ecosystem.

There are a number of reasons that increasing biological diversity is urgent. One is to increase the range of foods available to people – more fruits, more meat, more fish – but it is especially critical to preserve the genetic diversity of rice. Over the centuries, hundreds of traditional land races have evolved as adaptations to the multitude of micro-habitats in the delta. These traditional varieties represent an irreplaceable storehouse of genetic information on which plant breeders must draw on. If this viability is lost, the risk of precipitous failure of wet rice agriculture in the delta is greatly increased.

Diversifying sources of employment and income: Since adoption of the market mechanism, small-scale non-farm activities have enjoyed a renaissance in the delta. In the delta today many households derive more cash income from small-scale craft production, (embroidery in Vu Thu, Thai Binh province employs 12,000 people, export to Europe and Asia. Sedge mats in Ninh Binh employs 2,000 people, export to Korea, Hong Kong, and Japan), especially food processing (making of sausage and candy, distilling of alcohol) than they do from their farming. Indeed, purchase of chemical inputs needed to maintain rice production is actually subsidized from these sideline activities. People also engage in off-farm occupations to earn cash. People even engage in seasonal migration to Hanoi to work as scavengers in the waste dumps during agricultural off-seasons. They do this in order to reduce pressure on household resources and to earn cash to purchase consumer goods for their families.

Active promotion of small-scale rural industry may offer the best hope of alleviating the pressure of people on delta land. Particular attention should be given to the development of local processing of agricultural products. Such industries will raise rural income by increasing the value-added component of normally low-value crops. They could also stimulate crop diversification, thus reducing the current overwhelming dependency on rice cultivation.

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Section C

Towards a common vision of NRM in the Red River Basin

Basin-wide water resources planning for the Red River

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Introduction

Vietnam has 330,000 km^2 of land area and more than 1 million km^2 of water surface with thousands of islands. It has a coastline of about 3260 km. The potential agricultural land accounts for approximately 10 million to 11 million ha, of which more than 7 million ha are cultivated. Ricefields occupy about 4.11 million ha, but cultivated land per capita is less than 0.1 ha.

The Red River is the largest river system in Vietnam, with a total catchment area of 169,000 km^2, of which 86,507 km^2 (including the Delta area from Son Tay and Pha Lai downward) are located in Vietnamese territory. The Red River has 3 main tributaries: Da River on the left, Thao River between Lo-Gam River on the right with catchment areas of 52,900 km^2; 51,700 km^2 and 39,000 km^2 respectively and the sub-basin of the Thai Binh River (including Cau River 6030 km^2 , Thuong River 6650 km^2, Luc Nam River 3070 km^2). The Red River has a total runoff volume of surface water of about 137 billion m^3, of which 41% are from China.

The catchment distribution along different elevations of the Da, and Thao Lo Rivers is as follows:

Elevation (m)	Total area at Viet Tri		Area located in China		Internal area	
	km^2	%	km^2	%	km^2	%
>3000	115	0.08	90	0.1	25	0.04
3000-2500	1,105	0.80	990	1.2	115	0.80
2500-2000	9,470	6.62	8,280	10.2	1,190	1.95
2000-1500	24,440	17.10	20,930	25.8	3,510	5.76
1500-1000	43,948	30.60	30,860	38.0	11,990	19.70
1000-500	35,750	24.90	15,180	18.7	20,570	33.00
>500	28,460	19.90	4,910	6.0	23,550	38.60
Total	143,300	100	81,240	100	61,260	100

In general, the Red River has two main components. The mountain and midland areas in the upstream and the Delta. Son Tay and Pha Lai may be considered as the distinguishing points.

Located in the tropical monsoon region, Vietnam in general and the Red River in particular has access to abundant water resources. However, annual rainfall is not evenly distributed in space and time. Rainfall is concentrated in 6 months of the wet season, amounting to 80 to 85% of total rainfall in a year. The annual rainfall is about 1900 mm. There are some rain-cells: Muong Te on the Da River and Bac Quang on the Lo River with annual rainfalls of 2800 to 3000 mm and 4000 to 5000 mm, respectively. The maximum daily rainfall reportedly caused by typhoon is 573 mm at Muong Te in 1967, 462 mm at Bac Quang in 1972, and 730 mm at Phu Tho in 1980.

The Red River is located in a humid tropical region with an annual average temperature of about 22-23°C and evaporation of 900 to 1050mm/year. The relative humidity is rather high in comparison with surrounding countries. The average annual humidity is about 80% while in the Mekong Delta it is only 60 to 70%.

River slope -- some of the tributaries of the Red River have very high slope -- such as Lo River 19.7%, Gam River 22.7%, Nam Bum River 48.5%, Nam Ma 28.3%, Nam Mu 37.5% -- which provides favorable conditions for hydropower development.

Natural resources in the Red River Basin (RRB)

Land resources

The total catchment area of the Red River in Viet Nam is 86,507 km^2, of which, the mountainous area is about 60,000 km^2, midland is 9,007 km^2 and the Delta is about 17,500 km^2. The total agricultural land for the basin amounts to 1,826,000 ha or 24.5% of the agricultural land for the whole country, of which annual cropland is 1,500,000 ha, and perennial land is 120,229 ha. Average agricultural land per capita is about 0.07 ha, but this is decreasing due to increasing perennial crop land and urbanization.

Forestry plays an important role in the environmental and ecological conditions in the Basin. In a region of tropical monsoon climate and abundant rainfall, forest is more important. Under these conditions, forestry should have a high rate at about 50 to 60% of the natural area, but in the Red

River Basin, it is only 1,611,400 ha, accounting for 28% of forest area, or 17% of the natural area of the Red River Basin within Vietnamese territory.

The condition of the forest stand depends generally on its accessibility to people. In the more populated areas, the forests are degraded because of excessive cutting and shifting cultivation to create farmland from the forest.

Water resources

The Red River is the largest river system of Vietnam, each year on the average more than 137.2 billion m^3 of water flows into the East sea. An average amount of water per capita is 6178m^3 per year accounting for 77% and 51% of that in the world and the whole country, in which 3589 m^3 per capita per year is the rate of internal flow within Vietnam. The average annual discharge at Son Tay is 3710 $m^3 s^{-1}$. The sources of this surface flow within the basin are quite disparate, the discharge reflects the pattern of rainfall distribution during the year. In the dry season, under natural conditions without any upstream reservoir, the average low flow at Son Tay is only 837$m^3 s^{-1}$; the water resources at probability of 75% for the whole basin is 112.6 billion m^3 of which 48.8 billion are generated from neighboring countries, 67.7 billion m^3 are local flow; and 6.09 billion m^3 are groundwater. Based on estimates of water balance, it is expected that by the year 2000, the total demand in Vietnamese territory will be 25.04 billion m^3. The difference would mean 87.56 billion m^3 of excess water. In contrast, during the dry season, say 5 months from January to May, at the same flow probability of 75%, the total water resource is 31.9 billion m^3 (with regulated flow from the reservoirs) and total demand in the same period is 16.29 billion m^3; the difference would be only 15.61 billion m^3. By the year 2010, these figures will be: 30.3 billion m^3 and the demand (5 months in dry season) 21.9 billion m^3 and there will be a 8.4 billion m^3 difference.

Human resources

The Red River Basin has considerable human resources. The population of Vietnam in 1995 is about 74 million, of which 24.5 million live in the RRB. The growth rate averages 2.2% a year. Of the 24.5 million in 1994, nearly 20-21 million were rural and 3.5-4 million or 14-17% urban. By the year 2000, the basin's population is expected to be 27 million and it will be 30 to 32 by the year 2010. There are about 27 ethnic minorities living within the basin. They are mostly practitioners of shifting cultivation and tree cutting for farmland.

Hydropower resources

The RRB has the greatest hydropower potential of Vietnam. The basin has the theoretical potential of about 100 billion Kwh per year. This reflects the runoff from the entire Red River, and its technical potential is about 45 bill. Kwh (45%) and its economic potential about one third (30%) of the theoretical. The two existing reservoirs at Hoa Binh and Thac Ba with installed capacity of about 1920MW and 108MW respectively provide 8.6 billion Kwh, and these are considered essential power resources for the whole country.

Water resources development and constraints

Like all other developing countries, Vietnam is intent upon the expansion and diversification of industrial and agricultural production and the improvement of services in order to raise the people's living standards as well as environmental improvement based on sustainable resource development policy. The development of water resources, therefore, is given attention for the production of hydropower, water supply for irrigation, industry and domestic use, fish production by the provision of protection against flood and salinity intrusion and eco-environmental improvement. The objectives for water resource development of the Red River Basin are discussed in the following sections.

Upper basin

The upper basin plan is concerned with the contribution of water and related resources to the overall economic and social development of the Basin, especially, the lower basin -- the Delta. The development of water resources and related resources of the basin is to provide essential infrastructure relating to flood control, hydropower generation, water supply for irrigation, industry, navigation, etc. The development of resources envisaged in the plan will encourage and support development and growth in other sectors.

The upper Basin of the Red River including upstream of the mainstream of the Red River and upstream of the Thai Binh River is considered to be from Son Tay and beyond Pha Lai.

There are 1,377,000 ha of agricultural land. In the basin plan is a sectoral plan for the development of the water and related resources to provide the infrastructure and services (such as flood control, irrigation; power development) as well as some improvement of water supply for irrigation (by increasing water level) and navigation downstream. Recently, environmental protection such as soil erosion, wildlife conservation, etc, have also been included.

In the mountain areas of Ha Giang, Tuyen Quang and Moc Chau provinces located in the upstream of the basin, there is potential for planting industrial and fruit crops. The potential of the tea crop is about 12435 ha at present, 15,795 ha by 2000 and 17,100 ha by 2010 but to get higher yield, it will be necessary to change plant varieties.

The most important problem in the upstream basin is to save the watershed from soil erosion due to non-sustainable logging and land clearing for shifting cultivation. This has caused severe erosion and sedimentation; forest cover for the basin which was nearly 46% of total land area in 1945 had become 10.3% by 1993. Soil erosion creates many problems : increased sediment loads with the rate of 804 tons km^{-2} greater than that of the Mekong at 285 tons km^{-2}. Before the Hoa Binh reservoir was constructed, the sediment load across the Hoa Binh site was only 70 million tons per year. When the river was closed in 1988, the sediment load was significantly reduced; it was only 6.62 million tons per year in 1992 accounting for 90% of total sediment load before, i.e., approximately 60 million tons per year was kept in the reservoir. Due to changes in sediment balance, there is deep erosion in the riverbed, total soil erosion in the river bed amounts to 26 million tons per year in 1991-1992. In the downstream area of the dam, it causes the water level to decrease. At a discharge of 3000 $m^3 s^{-1}$, water level is reduced to 1.43 m and it is 0.3 m when the discharge is 7500 $m^3 s^{-1}$. It is estimated that soil degradation would expand to the Trung Ha site by 1995.

For the upper basin, constructing the reservoirs is extremely close to the objectives for flood control and hydropower development. In 1962, the Master Plan of the Red River Basin was prepared and this indicated the importance of the reservoirs of Hoa Binh and Ta Bu (presently Son La), nowadays. Some other reservoirs have been proposed for development on the cascades of the Da and Lo Rivers, while on the Thao River, there is no favorable topographical condition to build a reservoir.

In the master plan, the total scheme will:

- Ensure flood water levels at Hanoi to be less than 12.0 m when floods are as severe as the flood that occurred in August 1971;

- Ensure the discharge at Son Tay at any time in the year equals to or is greater than 2200 $m^3 s^{-1}$; and

- Produce electrical energy with probability of 95% not less than 27000 GWh per year.

However the scheme will cause the inundation of 124000ha of forest and rice fields, as shown below in the following:

Stage	Development scheme	FSL (m)	Full operation	Active storage capacity (10^6 m^3)	Scheme benefit			
					Average low flow at Son Tay ($m^3 s^{-1}$)	Hmax at Hanoi (m)	Firm energy (Gwh)	inundation areas (1000 ha)
0	Natural condition		1971		837	14.8	0	0
1	with Thac Ba res	58	1972	1600	1005	14.5	290	22.0
2	Add Hoa Binh res	115	1991	5650	1434	12.9	5370	43.8
3	Add Son La res	265	2010	16217	1800	12.6	21095	67.7
4	Add Dai Thi res	115	2010	1914	1914	12.2	21813	79.4
5	Add Huoi Quang res	480	2015	2215	1015	12.2	25155	89.8
6	Add Bac me res	235	2020	3048	2174	12.2	26451	1015
7	Add Bac Muc res	75	2025	1525	2260	11.9	27055	124.2

Note:

- Discharge at Son Tay is average discharge for 5 months in stage 1; for 6 months in stage 2; for 7 months in stage 3 and so on (from November to next May), all with the probability of 75%;

- Flood water level at Hanoi, for each stage was computed using values for the flood of 1971 in all rivers; and

- Firm energy is energy corresponding to the firm power with probability of 95%.

Some small reservoirs constructed in the midland areas of the Red River can serv 119,000 ha of agricultural land, of which 85,800 ha are rice, and 47,000 ha are industrial and subsidiary crops.

For the upper basin of the Thai Binh River, it is expected that from Thac Buoi in the Cau River, Cau Son in the Thuong River and Chu in the Luc Nam

River upward, it will be possible to build some medium reservoirs for only irrigation purpose to the downstream. Their storages are not big enough for flood control downstream. The existing Cam Son reservoir with active storage of 227 million m^3 can irrigate 24,100 ha. Some proposed projects such as Van Lang, Ban Luong, Cam Dan and Na Lanh have not yet been built because of inundation problems and a low efficiency to serve local requirements.

The proposed scheme for the upper basin of Thai Binh River is as follows:

Stage	Development Scheme	FSL (m)	Full operation	Scheme benefit		
				Low flow (m^3 s^{-1})	Irrigated areas (ha)	Annual energy (Gwh)
0	Natural condition		1960	79.0		
1	With Cam Son res.		1968	95.6	24100	14.0
2	Add Khuoi Than res		1970	97.8	25300	
3	Add Suoi Nua res		2000	98.8	26100	
4	Add Dong But dam		2000	102.8	30100	
5	Add Van Lang res	82	2005	123.8		
6	Add Ban Luong res	147	2005	132.8		75.33
7	Add Cam Dan		2010		38900	
8	Add Na Lanh		2010		41800	48.33

In the Red River Delta

Agricultural development in the Red River Delta The constraints in the Red River Delta are the differences in topographical condition resulting from differences in irrigation as well as drainage. The elevations are distinguished as follows:

Elevation (m)	Areas (ha)	Accumulated areas (ha)	%
1-2	279,300	572,320	58.4
2-3	134,260	706,580	72.1
3-4	115,420	822,000	83.9
4-5	41,300	863,300	88.1
5-6	19,680	882,980	90.1
6-7	41,160	924,140	94.3
7-8	14,700	938,840	95.8
8-9	15,680	954,520	97.4
>9	25,480	980,000	100.0

The socio-economic development of the Basin is based upon many points of view on national industrialization and modernization. The development of the Red River Delta has to be integrated and holistic, focused on development of industry and service parallel with agricultural and infrastructure development to promote cash crops for a market economy. The main targets of the Red River Delta are

- Quick development of the "economic triangle" of Hanoi-Hai Phong-Quang Ninh

- Formulating industrial economic routine along the highway No. 5, highway No. 18, highway No. 21, industrial zones of Hanoi, Hai Phong, Son Tay, Pha Lai and Ninh Binh

- Completing and upgrading infrastructure: transportation (upgrading the highway No. 1, highway No. 5., highway No. 18, highway No. 10), rural electrification;

- Integrated agricultural development based on the policies of product diversification and food security, Rural industrialization and modernization;

- Quick and strong development of services and tourism;

- Soil, water and biological resources conservation in accordance with development;

- Urbanization;

- Maintaining the cultural and historical tradition; and

- Environmental protection.

To achieve these targets, several development alternatives of the Basin have been proposed. The need is to expand the output of food in order to meet the requirements of a growing population and to provide a surplus for export. Recently, the Red River basin has produced surplus rice for export of not more than 300,000 tons. However, the monetary value is not high because of the quality of rice. The yield of rice in the Red River Delta could be doubled or tripled with the use of irrigation water, fertilizer as well as cash crops. Further increase and diversification of agricultural production has to be based upon irrigation, modern cultivation methods and crop diversification. To meet the food requirements of 27 million people in year 2000 and 32 million people with rice consumption per capita of 170 kg a year by 2010 respectively, it is estimated that rice grain production will have to be 6.6 tons and 8.0 tons per ha, respectively. In the Red River Delta, presently, there are 29 irrigation schemes, of which 8 schemes are inter-province, 8 schemes are inter-district and only 13 schemes are located in one district's territory. The development of water resource infrastructure includes 500 irrigation and drainage sluices; 1700 pumping stations along the rivers, 2713 km river dikes to protect the Delta against high floods and 60,000 km of canals to supply water from headworks to the fields. The total capacity of these structures can irrigate 680,782 ha, catching the rate of 79.7% of designed areas or 70.8% of command areas and a drainage of 820,199 ha, meeting 84% of drainage command areas.

The main problem of the Delta is unfavorable topographical conditions. For instance, some areas which are located in higher elevations and some in the lower need to be irrigated either by gravity or pumping. The irrigation duty is very high and investment unit per ha is also high due to power consumption for pumping. The low-lying land suffer from both water-logging and drought. Therefore, over 50% of the drainage areas have to be drained by pumping because the water level in the river is higher than the fields. This area can only have low cropping intensity, low rate of doubled crops, and less fertilizer; all these especially in the areas to the left of the Red River. It is urgent to trap alluvium for improvement of soil and to change the cropping patterns. On the other hand, the Delta is affected by tidal movement and salinity intrusion, especially in the coastal areas, and this leads to low productivity and yield. The augmentation of low flow that will result from mainstream storage projects will push back salinity intrusion.

Flood protection and control. The need for flood control in the Red River Basin is strongly needed when compared with many other South East Asia countries where flood plain population density is higher and economic activities are more intensive. For the Red River Delta, mitigation of flood and water logging is most essential but requires a long time to achieve. Except for the coastal and upper Delta areas, which may be gravity drained, the remaining areas have to be drained by pump. Although upstream of the Red River, two existing reservoirs (Hoa Binh and Thac Ba) with flood storage of 4.7 billion m^3 and 450 million m^3 respectively, and more than 2300 km of dike, can protect the Delta from floods. However, Hanoi is not considered completely safe when currently the global climate change has been highly variable.

In addition, it is necessary to expand floodwater drainage routes and consolidate existing dike systems. Three main waterways need to be maintained as follows: mainstream of Red River; Thai Binh River and Day water diversion.

In the mountain and midland areas of the Red River Basin, there is potential land for industrial, fruit and subsidiary crops such as tea, coffee, orange, plume, maize. In Vietnam, sugarcane planting still provides benefits and is attractive for foreign investment because of the climate and ecological conditions. The midland area is quite suitable for sugar cane, however, its yield presently is still very low. The yield is about 45.3 tons ha^{-1} but could be 80 tons ha^{-1} if water irrigation and fertilizer are available. By the year 2000, 200,000 ha of sugar cane will be planted for the whole country, of which 20,000 ha will be planted in the midland and 20,000ha in the Delta of the Basin. Where short-time crops give low benefit, they will be changed to either sugar cane or cash crops.

Salinity intrusion along the coast during dry seasons is the main water quality problem. In the Red River Delta, the intrusion is not too serious because the Hoa Binh reservoir helps regulate water flow. The saline boundary line with the salt rate of 2% during dry season causes intrusion up to 15 km when ebb tides appear and it is 18 km when high tide occurs, but this lasts only for 6-8 hours.

Water quality: Good water quality is necessary for many of the users in the Red River Basin. All natural water contains waste substances from industrial and agricultural production. Water with sediment in the Red River Basin has pH values from 7 to 8. After completion of the Hoa Binh reservoir, the pH was found not to have changed much from 7-8, to 7.1-7.5 presently. The content of nitroge, 1.72-4.9 mg l^{-1} , has changed to 1.4-5.6 mg l^{-1}. The content of phosphate is slightly reduced, from 1.5-3.1 mg l^{-1} to 0.2-0.6 mg l^{-1}. The chemical components of water before and after construction of the Hoa Binh reservoir are shown below:

Constituents	Unit	1980-1981	1991-1992
pH	-	7.1	7.44
Fe	mg l^{-1}	0.34	0.38
SiO2	mg l^{-1}	20.2	8.09
Ca	meg l^{-1}	1.29	1.16
Mg	meg l^{-1}	0.63	0.34
Na+K	meg l^{-1}	0.5	0.45
HCO3-	meg l^{-1}	2.29	1.88

The value of COD and fecal coliform are shown below.

	COD ($mg\ l^{-1}$)		Fecal coliform (colonies $100ml^{-1}$)	
	7/1992	7/1993	8/1992	7/1993
Hanoi	17.5	13.8	130	340
Thuong Cat	11.2	12.08	310	290
Trung Ha	18.0	12.95	60	110
Son Tay	13.2	13.2	100	340
Hoa Binh	16.6	14.2	48	140

With respect to the adequacy of water quality in the Red River for irrigation use, the present indications are that the water is good enough. So far, the water quality of Nhue and some places in the Cau River, are poor due to industrial plant waste. People should be made aware of the problem of poor water quality caused by fertilizer and pesticides. Presently, the content of Cu, Pb, As, Hg is less than allowable standards for drinking water. However, the content of Mg is a little bit high in some locations. Water to be used for domestic and municipal purposes should satisfy physical, chemical and bacteriological criteria and be treated before use. In the big cities in the Delta -- Hanoi, and Hai Phong -- water is mostly supplied from groundwater sources, and the quality can be considered generally good. However, groundwater exploitation can result in the ground sinking, and it has been found that, after three years (1988-1991), the ground sank 1.88 mm at Thuong Cat. 77.77 mm at Thanh Cong and 175.99mm at Phap Van. Because of such situations, the water supply capacity for Hanoi should not be higher than 700,000 $m^3\ d^{-1}$.

Water balance

Land available for agricultural production does not change much. It is around 1,826.000 ha to 1,900,000 ha, with perennial cropland of about 120000 ha to 130000 ha by the year 2000 and 2010. Most of this is for intensive farming, with possibilities for cropping pattern changes and crop diversification. Irrigated areas amount to 4,728 ha; 52,585 ha; 113,720 ha; 438743ha for the midland of the Red River, upper Basin of Thai Binh River, midland of Thai Binh River and the Red River Delta respectively. In total, the irrigated area of the Delta is about 609,826 ha. According to water balance computations, the water requirement for agricultural development in Vietnam by the 1990, 2000 and 2010 are 17291 million m^3, 21063.9 million m^3 and 22386.4 million m^3, respectively. Water requirements for industrial and domestic uses in the same periods are estimated at 1168.6 million m^3, 3069 million m^3 and 10051 million m^3 respectively. This is based on the results of water balance calculations for the whole country produced by the Scientific Research Program KC-12.

The total water balance with the runoff probability of 75% for the sub-region within the Basin is as follows:

By the year 2000

Annual average — Unit: (billion m^3)

Basin	Water resources	Water demand	Balance	Percentage of resources (%)
Upper Red Basin	99.9	4.5	95.4	4.5
Upper Thai Binh Basin	4.4	1.2	3.18	27.7
Midland and Red River Delta	112.6	19.32	93.28	17.2

Average low flow for 5 months — Unit: (billion m^3)

Basin	Water resources	Water demand	Balance	Percentage of resources (%)
Upper Red Basin	22.9	2.94	19.98	12
Upper Thai Binh Basin	0.75	0.79	-0.04	105.3
Midland and Red River Delta	31.9	12.56	10.04	39.0

By the year 2010

Annual average — Unit: (billion m^3)

Basin	Water resources	Water demand	Balance	Percentage of resources (%)
Upper Red Basin	99.9	6.43	93.47	6.4
Upper Thai Binh Basin	4.4	1.23	3.17	27.9
Midland and Red River Delta	110.62	26.34	84.28	23.8

Average low flow for 5 months Unit: (billion m^3)

Basin	Water resources	Water demand	Balance	Percentage of resources (%)
Upper Red Basin	22.92	4.11	18.81	17.9
Upper Thai Binh Basin	0.75	0.83	-0.08	110.1
Midland and Red River Delta	30.3	16.94	4.41	55.0

The table shows that by the year 2010, water resources developed will not be more than 6.4%, 27.7%, and 17.2% of the annual potential with probability of 75% for the Upper Red River, Upper Thai Binh River Basins and Midland and Red River Delta respectively. However, in dry seasons, say 5 months, in the midland and Red River Delta it will reach 55% of the potential, and in the upper Basin of Thai Binh River is 110.1% over the water potential. Therefore, in the future, it is necessary to build some more upstream reservoirs in order to not only regulate the flow in the dry season but also for flood control and hydropower development.

Conclusions

The water resources development of the Red River Basin are based on sustainable development policy and should consider the following issues:

- Institutional issues: Development in the Basin must be planned and managed on hydrologic boundaries; so it is necessary to coordinate water resources development and ongoing development. In the near future, water resource development and management will have to follow the Water Law, presently in the 17th draft. This points out the need for two types of Basin bodies: River Basin Committees and River Basin Authorities;

- Water resource development and management will have to follow the principles of integrated water resource development and management as well as decentralization of water management. It is urgent to pay more attention on

- Watershed management including soil erosion, resettlement for the ethnic minorities and afforestation, wildlife protection, etc.;

- Building new reservoirs for flood control, hydropower generation, and water supply in accordance with eco-environmental protection;

- Crop diversification in the Red River Delta, Ecological conservation for the coastal areas;

- International cooperation in water resource management and flood forecasting, information exchange; and

- Capacity building and management of technical standards, norms and quality.

Agrarian systems and future scenarios for the Red River Delta

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Introduction

In the 1930s, a French geographer Pierre Gourou (1936) wrote a book, named 'Peasants of the Tonkin delta'. This is a work on human geography of 666 pages. The author described the physical environment of the Red River Delta (RRD), its peasants, the peasant society with its production systems and institutions, and the problems of development. Although at that time there was no notion of 'agrarian systems', this work is a model study on agrarian systems, which has not become out of date yet because the problems raised by the author still exist.

However, after 60 years, agrarian systems in the RRD have changed. In the beginning of the thirtie, the delta was inhabited by 6.5 million people with a density of 430 persons per km^2. From demographic studies, the author predicted that the population of the delta would reach 13 million in 1984 - 2001. But now we have more than 14 million of rural people. The growth rate that the author predicted was between 1.0 and 1.3% per year, while the real rate is 1.2%. The current population density is more than 900 persons per km^2.

Gourou wrote: 'It seems impossible that the Delta, which feeds insufficiently at the present time 430 persons per km^2, will satisfy the need of a population of two times more' (p. 197). But the peasants of the Delta, after different trials have solved difficulties in development. They can feed not only a more than doubled population, but feed them better with a grain production increase from 277 to 390 kg per capita during that period.

Gourou predicted: 'In general the most useful measure for the peasant will be to stop the development of the big property, and even the suppression of the existing ones, with the need of agrarian laws, in order to avoid the meagre resources that the cultivators draw out from the two narrow earth to be reduced by a land rent' (p. 577). Reality has confirmed the rightness of this prophecy.

A conclusion of this book is still valid: 'However, people do not only have material requirement: the traditional civilization can provide a moral and social equilibrium to the peasant which cannot achieve in many more advanced societies where the progress, exclusively in material production, dips them in trouble' (p. 578).

• The evolution of the agrarian system of the Red River Delta

During the last 60 years, the population of the RRD has increased by no more than 2 times because a part of the population migrated to the mountainous regions and the Mekong river delta. During this period, about one third of agricultural land has been lost, so the available land per capita decreased more than 3 times. However, due to intensification the yield of food crops (cereal and tuber) has increased 4.5 times, and food per capita has increased by 1.4 times (Table 1).

Table 1. The evolution of agrarian systems in the two largest deltas in Vietnam.

		Rural population (million)	Agricultural land (1000 ha)	Land density (m^2 per cap)	Food crops production (1000 ton)	Food yield ($t\ ha^{-1}$)	Food per capita (kg)
Red River	1930	6.5	1.2	1846	1.8	1.5	277
Delta	1996	13.9	0.8	573	5.4	6.8	391
Growth rate	(%)	1.1	–0.6	–1.8	1.7	2.3	0.5
Mekong	1930	3.2	2.0	6250	2.6	1.3	812
Delta	1996	13.6	2.7	1991	14.0	6.6	1028
Growth rate	(%)	2.2	0.45	-1.7	2.6	2.5	0.35

During the same period in the Mekong delta, the population increased faster and the area of agricultural land also increased. Although the land per capita has been reduced, it is still higher by 5.3 times that in the RRD, and the food production per capita is 2.6 times that of the RRD.

In the Red River Delta, the average net income per capita has improved by more than 1.5 times during this period. Although with a higher level, it is only equal to 80% that of the Mekong delta. However, income equity in the RRD is improving faster than in the Mekong delta (Table 2).

Table 2. The evolution of peasant living standard and income equity in the two deltas.

		Average net income (kg paddy per cap.)	Gini coefficient	Sources
Red River	1930	584	0.43[a]	Gourou. (1936)
delta	1945	370	0.59*	Gen. Stat. Office (1980)
	1954	501	0.35	Estimated from
	1957	568	0.07	General Statistical Office
	1965	596	0.15	(1971, 1979, 1982)
	1970	570	0.26	and data of Provincial
	1978	680	0.25	Statistical Offices
	1990	692	0.25	Gen. Stat. Office (1992)
	1993	895	0.26	World Bank (1995)
Mekong	1930	782	0.87*	Gourou (1940)
Delta	1955	600	0.84*	Callison. (1983)
	1966	866	0.80*	U.S. Dept. of Agric. (1973)
	1972	863	0.55	Nishimura (1975)
	1981	1009	0.30	Gen. Stat. Office (1982)
	1990	1259	0.35	Gen. Stat. Office (1992)
	1993	1128	0.30	World Bank (1995)

a Gini coefficient of land ownership.

Characterization and zoning of the Red River Delta

The Red River Delta considered in this study comprises two deltas, those of the Red river and the Thai Binh river. In 1995, this Delta is composed of 72 districts while the administrative RRD region is only composed of 56 districts. The results of characterization show that the RRD can be divided into nine sub-ecoregions (Table 3). The characteristics used for this zoning are:

Table 3. Characteristics of sub-ecoregions in the Red River Delta.

Region	Type	District number	Food/ arable land (kg ha^{-1})	Arable land/ total land (%)	Upland/ arable land (%)	Reed/ arable land (%)	Summer rice stability (%)
1	Intensive with rice	8	5936	63	6	0	74
2	Coastal less saline	9	5347	53	8	2	70
3	Coastal high saline	5	4947	47	12	6	81
4	Medium lowland	10	4188	66	12	0	55
5	Low lowland	13	3474	53	15	0	44
6	Upland	9	3907	55	33	0	69
7	Intensive with less upland	6	4883	63	22	0	76
8	Intensive with more upland	6	6007	59	24	0	58
9	Degraded soil	7	3144	31	35	0	78

The districts of each sub-ecoregion are following:

Intensive with rice: My van, Cam binh, Tu loc, Nam thanh, Kim mon, Dong hung, Kien xuong, Nam ninh.

Coastal less saline: Thuy nguyen, An hai, Kien an, Kien thuy, Tien lang, Vinh bao, Quynh phu, Hai hau, Nghia hung.

Coastal high saline: Yen hung, Thai thuy, Tien hai, Xuan thuy, Kim son.

Medium lowland: Tien son, Yen phong, Than oai, Ung hoa, Phu xuyen, Phu tien, Ninh thanh, Duy tien, Binh luc, Y yen.

Low lowland: Yen dung, Gia luong, Que vo, My duc, Kim bang, Thanh liem, Vu ban, Gia vien, Hoa lu, Yen mo, Yen khanh, Thanh tri.

Upland: Tan yen, Viet yen, Hiep hoa, Me linh, Gia lam, Dong anh, Chau giang, Chuong my, Ly nhan.

Intensive with less upland: Vinh lac, Thuan thanh, Quoc oai, Kim thi, Hung ha, Vu thu.

Intensive with more upland: Thach that, Phuc tho, Dan phuong, Hoai duc, Thuong tin, Tu liem.

Degraded soil: Chi linh, Ba vi, Hoang long (Nho quan), Soc son, Lap thach, Tam dao, Dong trieu.

- The degree of intensification, represented by the food yield on arable land;

- The flatness of the region represented by the percentage of the arable land on the total land;

- The percentage of upland crops grown on non flooded fields on the total cropping area;

- The degree of salinity represented by the area of reed (crop resistant to salinity); and

- The degree of flooding represented by the stability of summer rice yield.

These nine sub-ecoregions comprise three intensive subregions with different percentages of upland, two lowland subregions with two different degrees of flooding, two coastal subregions with different percentage of saline soil, two upland subregions with different percentage of non agricultural land (hills).

Classification of peasant households in the Red River Delta

At the present time, the agrarian system is also identified by household activities. Each household participates in different production activities according to their resource availability. If we don't understand the structure of households, we cannot predict the development of the system.

Many studies on the household economy of the RRD have been publised (Dao The Tuan, 1995). In this paper, the results of analysis from the Vietnam living standards survey, 1992-1993 (State Planning Committee, 1994) are introduced. The method of hierarchical ascendant classification followed by the grouping around the moving centres (Bouroche & Saporta, 1980) was applied. After many trials, the following criteria were selected for classification:

- Area of arable land;
- Gross income per capita;
- Income from crop production; and
- Income from non-agricultural activities.

The results in Table 4 show that in the RRD the richest group of farmers is composed of households with less land and high income from non-agricultural activities, while in the Mekong delta the richness of farmers depends on their land availability. It implies that in the RRD, due to the scarcity of land, it is more difficult to develop commercial agriculture than in the Mekong delta.

Table 4. Classification of peasant households in the two deltas
(Data of the VLSS, 1992-1993).

Region	Index	Household types			
		I	II	III	IV
Red	Percent	26	51	17	6
River	Gross income	1280	1367	2108	4509
Delta	Crop income	308	675	1172	557
	N-agr income	483	222	219	2669
	Arable land	309	614	1022	475
Mekong	Percent	54	34	11	1
River	Gross income	1550	2852	5684	13621
Delta	Crop income	409	1480	3366	9158
	N-agr income	744	756	1096	2891
	Arable land	610	1881	4398	10370

Agricultural diversification in the Red River Delta

The RRD is a region where the agricultural diversification has decreased during the last decade. The purpose of analysis is to understand the situation of this region. Statistical data of districts in the RRD provided by the General Statistical Department were grouped into 9 sub-ecoregions. Prices in 1994 are applied.

In order to determine the degree of diversification, a criterion, namely 'index of diversification,' was proposed. This index is a modification of the index of diversity used in ecology proposed by Simpson (Odum, 1986).

$$D = \Sigma (X_{ij} / X_j)$$

Xij : value of product j in sub-ecoregion i

- Xj : average value of product j in the whole delta.

The index is the sum of the value per capita of each product divided by the average value per capita of that product of the delta. The higher the number of products in a sub-ecoregion and the higher the production of a product in a sub-ecoregion compared to the delta average, the more it contributes to the index of diversification of the sub-ecoregion. The diversification index also reflects the growth of production in the sub-ecoregion.

Table 5. Annual growth rate of different products in the Red River Delta.

Products	87	88	89	90	91	92	93	94	95	Av.
Rice	1.32	17.46	7.55	-5.16	-13.69	37.16	16.42	-12.75	15.43	7.08
Maize	25.69	107.48	5.71	-25.00	-25.75	43.31	13.19	10.06	3.55	17.58
Sweet potato	26.92	-27.69	9.38	11.03	28.98	49.22	-20.48	-19.39	-17.61	4.48
Potato	52.03	-28.41	-5.46	9.19	-21.49	-7.17	0.33	-10.09	8.08	-0.33
Cassava	-2.15	9.27	-4.47	-4.69	-2.48	12.09	-9.52	1.01	-8.54	-1.05
Soybean	105.65	-39.34	22.92	54.38	-5.97	-4.09	66.13	36.86	-6.29	25.58
Groundnut	25.97	-3.09	-18.97	3.74	-9.84	-12.18	33.12	8.73	151.25	19.86
Vegetables	-4.29	-5.68	15.81	0.34	-3.43	4.98	3.62	5.40	5.47	2.47
Beans	0.81	-0.57	26.10	-8.11	1.61	-11.87	37.45	3.10	65.02	12.62
Pork	6.79	0.81	4.38	3.78	-4.74	12.19	15.46	11.05	6.63	6.26
Cattle	4.72	9.44	9.96	4.14	6.75	0.81	4.85	2.84	4.22	5.30
Poultry	1.17	5.18	9.04	8.83	2.92	8.49	8.86	5.09	5.16	6.08
Sea fishery	-13.53	-1.02	0.30	13.09	9.34	1.98	7.13	12.64	5.25	3.91
Aquaculture	11.06	5.45	0.90	2.22	-0.21	32.30	-5.52	9.72	5.95	6.88
Wood	0.18	-16.50	-13.75	4.46	8.08	-45.18	39.25	-8.67	11.51	-2.29
Bamboo	18.50	13.06	-4.76	-5.63	21.85	1.20	3.33	2.39	4.26	6.02

Table 5 shows that the average annual growth rate for rice is 7.08 % per year in the whole RRD. It also shows that only few products have a growth rate higher than rice: peanuts - 19.86%, soybean - 25.58%, maize - 17.58%, legumes - 12.62% while the other products have a lower growth rate than rice: aquaculture - 6.88%, pork - 6.26%, bamboo - 6.02%, poultry - 6.08%, cattle - 5:30%, sweet potato - 4.48%, sea products - 3.91%, vegetables - 2.47%, potato - -0.65%, cassava - -1.05%, and wood - -2.29%. In 1988, maize production increased 140% due to the expansion of this crop in the wetlands, but after this year it decreased in 1990 and 1991. In 1992, there was a small increase of maize and sweet potato production caused by the loss of harvested rice in 1991. Also in 1992, aquaculture had a significant increase. In 1993, there was an increase of soybean, pork and poultry production.

Agricultural production increased faster in the intensive and the lowland sub-ecoregions than in other areas (Tables 7 and 8). The upland and the degraded sub-ecoregions had negative growth rates.

The diversification index (Table 9) shows that the upland, the degraded and the intensive-with-less-upland sub-ecoregions are more diversified. The coastal-high-saline, the coastal-less-saline and the intensive-with-rice sub-ecoregions have lowest diversification indexes. The diversification index decreased in the intensive-with-more-upland , the upland, the degraded and the coastal-high-saline sub-ecoregions while the intensive-with-rice , the coastal-less-saline and the intensive-with-less-upland sub-ecoregions have an increase in diversification index.

Table 6. Evolution of different products in the Red River Delta.

Products	86	87	88	89	90	91	92	93	94	95
Rice (ton)	3276761	3320001	3899531	4194035	3977442	3432964	4708642	5481766	4782688	5520738
Maize (ton)	95188	119641	248234	262405	196808	146137	209434	237050	260894	270164
Sweet potato (ton)	556011	705685	510293	558146	619692	799280	1192716	948401	764467	629859
Potato (ton)	295857	449801	322026	304451	332424	260992	242289	243077	218556	236209
Cassava (ton)	88945	87033	95097	90842	86578	84431	94639	85629	86497	79109
Soybean (ton)	7903	16253	9859	12118	18708	17590	16870	28026	38356	35944
Groundnut (ton)	26380	33230	32204	26096	27072	24409	21436	28537	31026	77955
Vegetables (ton)	1108284	1060762	1000480	1158641	1162544	1122660	1178533	1221213	1287114	1357464
Beans (ton)	5339	5383	5352	6749	6202	6302	5554	7633	7870	12987
Pork (ton)	161972	172974	174374	182019	188899	179948	201877	233094	258847	276019
Cattle (ton)	9773	10234	11220	12315	12825	13691	13802	14471	14883	15510
Poultry (ton)	24419	24706	25984	28332	30835	31735	34428	37478	39386	41417
Sea fishery (ton)	16258	14059	13916	13958	15785	17260	17601	18856	21239	22354
Aquaculture (ton)	21462	23836	25135	25363	25926	25872	34230	32339	35482	37592
Wood (m3)	35449	35513	29654	25577	26718	28877	15831	22044	20132	22450
Bamboo (1000 pieces)	627	743	840	800	755	920	931	962	985	1027

Table 7. Value of agricultural production in sub-ecoregions of the Red River Delta (10^9 dong 1994).

Sub-ecoregions	86	87	88	89	90	91	92	93	94	95
Intensive with rice	1701	1933	2036	2172	2113	1856	2409	2726	2589	2824
Coastal less saline	1379	1365	1474	1569	1574	1589	1898	2105	2075	2108
Coastal high saline	752	793	852	888	892	919	1115	1209	1108	1219
Medium lowland	1425	1562	1624	1748	1696	1488	1921	2205	1927	2293
Low lowland	1074	1135	1250	1331	1315	1179	1524	1725	1453	1757
Upland	1212	1302	1353	1470	1424	1275	1485	1681	1566	1298
Intensive with less upland	945	1087	1187	1259	1252	1038	1356	1508	1471	1630
Intensive with more upland	718	697	773	789	786	628	767	839	753	1127
Degraded soil	738	748	769	837	786	739	970	1041	1132	1104

The analysis of correlation coefficients and of principal components shows that there is no single factor but many factors determining the diversification index. The multiple regression shows that the diversification index is determined in the following equation:

Diversification index = 31.31 upland crops + 6.59 agricultural/total land + 36.68 agricultural land per capita - 0.003 population density + 0.004 agricultural production per capita - 0.172 growth rate of diversification index - 0.35; with a square of correlation coefficient of $R^2 = 0.590$

Table 8. Annual growth rate of agricultural production value in sub-ecoregion of the Red River Delta.

Sub-ecoregions	87	88	89	90	91	92	93	94	95	Av.
Intensive with rice	13.96	5.08	7.51	-3.44	-13.09	31.65	13.44	-6.08	9.44	6.50
Coastal less saline	-1.01	7.97	6.46	0.28	0.97	19.43	10.88	-1.43	1.60	5.02
Coastal high saline	5.52	7.42	4.25	0.43	3.03	21.24	8.43	-8.33	9.96	5.77
Medium lowland	9.61	3.93	7.64	-2.96	-12.24	29.07	14.79	-12.63	18.97	6.24
Low lowland	5.72	10.05	6.48	-1.17	-10.35	29.25	13.19	-15.79	20.95	6.48
Upland	7.45	3.92	8.63	-3.12	-10.48	16.51	13.14	-6.85	-43.20	-1.56
Intensive with less upland	15.05	9.13	6.11	-0.59	-17.12	30.64	11.25	-2.49	10.82	6.98
Intensive with more upland	-2.90	10.96	2.10	-0.45	-20.12	22.19	9.39	-10.34	49.77	6.63
Degraded soil	1.42	2.81	8.78	-0.63	-6.06	31.29	7.33	8.72	-2.46	-0.35

Table 9. Annual growth rate of the diversification index of sub-ecoregions of the Red River Delta.

Zones	87	88	89	90	91	92	93	94	95	Av.
Intensive with rice	11.24	-2.76	1.45	8.01	-9.42	1.69	1.42	6.39	-0.41	1.96
Coastal less saline	1.93	2.41	-0.61	-1.58	5.13	1.34	-1.65	6.55	-0.08	1.50
Coastal high saline	-2.05	6.12	-1.34	-5.39	6.17	-6.26	-4.90	-0.16	-2.35	-1.13
Medium lowland	9.47	-6.96	0.99	0.21	-3.82	4.73	0.38	-2.16	-1.31	0.17
Low lowland	2.51	2.53	0.54	2.84	5.40	2.32	-1.02	-10.21	-9.29	-0.49
Upland	2.10	-1.99	1.48	-5.78	-0.87	-4.04	0.34	0.63	-16.25	-2.71
Intensive with less upland	5.32	3.64	1.57	4.12	-2.77	-4.15	1.61	5.34	-5.07	1.07
Intensive with more upland	-12.52	4.11	-6.73	-7.40	2.20	-3.97	-5.68	0.11	-9.40	-4.36
Degraded soil	-3.08	-6.13	-0.02	3.01	-2.09	5.98	5.08	4.74	-19.10	-1.29

So the diversification index is higher in the sub-ecoregion with higher ratio of agricultural land to the total area , more upland crops and less population pressure.

The variations in diversification index is determined in the following equation:

Growth rate of the diversification index = +26.14 agricultural land per capita + 8.08· agricultural/total land - 0.002 population density - 0.064 percent of upland crops + 0.001 agricultural production per capita - 0.216 diversification index - 1.048 with a square of correlation coefficient of R^2 = 0.186

The increase of the diversification index is determined firstly by the availability of land per capita and also by the availability of upland crops. However, this relationship is valid mostly in areas where diversification is still low and the production per capita is high.

A model for the simulation of the food security and the agricultural diversification of the Red River Delta

After economic reform in the 1980's, Vietnamese agriculture has developed with a rapid growth rate. Food production is not only enough for the domestic consumption but also for export. The RRD became self-sufficient in food production. In the near future, the development will happen in a context of rapid industrialization and urbanization. In agriculture, food security and diversification seem to be contradictory, because only with higher diversified production can farmers create more employment and achieve higher income.

In order to understand the relation between different development processes, a model was built for for simulation of different industrialization scenarios and their impact on agricultural development and on the peasant economy.

The following issues were taken into consideration in the model:

- Rapid growth will be achieved by rapid industrialization that increases the rate of urbanization, the rural exodus and the reduction of agricultural land, and subsequently leads to changes in the agricultural structure; and

- Rapid growth will also reduce the population growth rate and increase the income that affects food consumption. These changes will affect food security and agricultural diversification.

Basic input data for the model were taken from statistical data of Vietnam from 1990 to 1995, and the trend of development is extrapolated from growth during this period.

The model was run for the years of 2000, 2005 and 2010 under three scenarios:

- Scenario 1: the growth trend will continue without any structural change.

- Scenario 2: the GDP growth and the industrialization will increase with time, with 90% of the industry concentrated in urban areas.

- Scenario 3: the growth trend will be same in Scenario 2, but industrialization will be more decentralized with only 70% of the industry in urban areas.

The results of simulation lead to the following conclusions:

Rapid industrialization will create a higher rural exodus and will raise the farmers' income faster, but reduce greatly the area of agricultural land. The development of rural industry will lower the rural exodus and increase more rural income.

Higher income will change food composition: reducing the demand of grain for direct consumption but increasing the demand for meat, which in turn causes higher need of grain for feed. The total grain demand will increase with industrialization and rural development. This increased demand can be covered if the growth rate in agriculture is about 4% per year. However, according to the model, rice yield should be higher than 7 ton/ha. This target is difficult to be realized in the near future. So food security could be assured easier in the context of the whole country rather than only for the RRD.

The simulation results also show that there is no real contradiction between food security and agricultural diversification. Even when high grain production has to be achieved for food security, diversification growth can still be higher than the growth rate of grain production.

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Towards an Ecoregional Approach for Natural Resource Managament in the Red River Basin of Vietnam

Selected papers from a planning workshop held in the Ministry of Agriculture and Rural Development, Hanoi, Vietnam

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The ecoregional approach has been proposed as a new approach to address natural resource management (NRM) issues within defined geographic areas, using the tools from many disciplines to diagnose problems and to introduce changes, to generate new knowledge, and to introduce solutions that are socially, ecologically and economically acceptable to the communities in the ecoregion. The Red River Basin as an ecoregion comprising the delta, sloping lands, uplands and highlands of northern Vietnam, is a suitable area to use this approach. In implementing the approach, it is generally recommended that a situation analysis first be conducted in which major stakeholders are assembled to review the status of the knowledge on NRM, to arrive at a common understanding of key NRM issues, and to participate in a research planning process using a common vision for NRM in the ecoregion.

The planning workshop from which papers were selected for this book, therefore represented a first step in the process of applying the ecoregional approach for NRM in the Red River Basin. To the extent feasible, resourse persons and scientists from International organizations and advanced research organizations were invited to join participants from the key Vietnamese government and non-government organizations in developing this future research agenda.

The papers have been divided into three sections: an introductory section, a section on current and proposed research, and a section on aspects of a future vision of NRM. The way in which the book is organized makes it of specific value to scientists and policy makers in the Red River Basin to determine sound action for a sustainable future based on rational technologies for NRM.

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