Nutrient budgets, soil fertility management and livelihood analyses in Northeast Thailand: A basis for integrated rural development strategies in developing countries

J.D. Wijnhoud
Promotor: Prof. dr. ir. H. van Keulen  
Hoogleraar bij de leerstoelgroep Plantaardige Productiesystemen  
Wageningen Universiteit

Promotiecommissie:
Prof. dr. ir. R. Rabbinge  
Dr. P.G.M. Hebinck  
Dr. R.P. Roetter  
Dr. R.D.B. Lefroy  

(Wageningen Universiteit)
(Wageningen Universiteit)
(Wageningen Universiteit en Researchcentrum)
(CIAT, Columbia)

Dit onderzoek is uitgevoerd binnen de C.T. de Wit onderzoeksschool: Production Ecology and Resource Conservation.
Nutrient budgets, soil fertility management and livelihood analyses in Northeast Thailand: A basis for integrated rural development strategies in developing countries

J.D. Wijnhoud

Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
prof. dr. M.J. Kropff,
in het openbaar te verdedigen
op maandag 29 januari 2007
des namiddags te half twee in de Aula.
Wijnhoud, J.D. (2007)

Nutrient budgets, soil fertility management and livelihood analyses in Northeast Thailand: A basis for integrated rural development strategies in developing countries.

Wijnhoud, J.D. –[S.l.:s.n.]. Ill.

PhD thesis Wageningen University. –With ref.–

With summaries in English and Dutch
ISBN: 90-8504-594-0
Abstract


In Northeast Thailand, the sustainability of rainfed lowland rice-based systems, the dominant land-use system (LUS) in the region, is a concern for livelihood development in this relatively poor area of the country. Poor soil fertility and low inputs are considered major causes of the sustainability problems. Similar problems exist for a wide range of LUS in the developing world. Reversal of such developments requires integrated rural development strategies aimed at breaking the environment-poverty downward spiral.

The key hypothesis for this thesis is that, efficient and effective, rural-development strategies, aimed at the twin-objectives of sustainable natural resource management (SNRM) and improved and sustainable livelihood development, require ‘innovative’, i.e. more participatory, integrated and holistic approaches, while following a strict priority setting by combining holistic concepts and a small selected set of participatory, integrated and/or complementary analyses to keep efforts manageable and result-oriented. The challenge therefore is to find the appropriate balance between on one hand the demand for more comprehensive contextual and integrated analyses and on the other hand the requirement to keep such efforts manageable in terms of human, material and financial resources. The key hypothesis was partly tested in a collaborative research and development (R&D) programme in Northeast Thailand. Additional evidence was based on literature study and later experiences, including work in sub-Saharan Africa. The introductory chapter elaborates relevant concepts, principles and approaches, such as the multiple dimensions of SNRM, the sustainable livelihood concept and approach (SLC/A) and nutrient balance analyses, which are useful for the work in Northeast Thailand, but also – often even more essential – for development strategies in the least developed countries (LDCs) of the world.

The collaborative R&D programme in Northeast Thailand explicitly examined the relevance of integrated nutrient budget, soil fertility management and livelihood analyses within their broader – dynamic resource management domain (DRMD) – context. This entailed DRMD characterization, multi-scale partial nutrient balance analyses (PNBA) and integrated environmental and socio-economic analyses, including livelihood and correlation analyses, as well as integrated environmental and socio-economic accounting. Large variations in partial N, P, and K balances were found among and within farms, especially at land utilization type (LUT) level. Although the mean values were positive, many negative partial balances were observed, especially at the LUT level. These large variations are the result of the fact that farmers manage nutrients for similar parcels of land in very different ways, even for LUTs with identical cropping systems within the same farm. Results were assessed with specific emphasis on biophysical aspects, in line with a discussion on methodological aspects. Diversification of income sources, through off-farm employment, non-agricultural on-farm income, such as weaving, and diversification of the agricultural system beyond rice, had a large impact on household wealth. This, in turn, affected the capacity of the household to manage the natural resources of the farm. No significant
correlation was found between total income or non-rice income and nutrient inputs; however, this does not mean that they are unrelated. Based on fertilizer use and prices, mean elemental N, P and K retail prices were calculated and used for integrated environmental and economic accounting. Based on mean partial N, P and K balances, partial N, P and K balances were calculated in monetary terms. The results followed the average positive partial balances for rice-based systems established for a sample of 30 farms with large variability among farms and, even more so, among land utilization types, distinguished cropping system-management combinations, however, for each nutrient to a degree depending on its price. Partial nutrient balances were most extreme for N and K. In contrast, in monetary terms P balances were most extreme. These analyses revealed that, due to the common use of N-P or N-P-K compound fertilizers, investments in P that is generally non-limiting and rather expensive, are too high. Some alternative – prototype – cost benefit analyses (CBA) have been performed for rice cultivation in 1999 on one farm included in the main survey. Complementary and integrated biophysical and socio-economic analyses are relevant for decision support for SNRM and livelihood development, including the development of decision support tools for farmers and extension workers. The collaborative R&D programme served as an exemplary and paradigmatic case for innovative approaches and contributes to the advocacy for their broad adoption.

Other relevant aspects are briefly alluded to, including less tangible ones such as governance, decentralization, organizational and institutional development, and capacity development. Broader perspectives are also highlighted based on a summary overview of major challenges and opportunities for rural development in Ethiopia and Mozambique, respectively. This is followed by a general discussion that advocates that SNRM can only be achieved by following a livelihood approach, including a strong emphasis on socio-economic incentives. In addition, major challenges are identified for multi-scale sustainable institutional development, which requires efforts aimed at good governance.

Keywords: Rainfed lowland rice-based systems, Northeast Thailand, nutrient balance analyses, sustainability assessment, sustainable natural resource management, integrated rural development strategies, livelihood analyses, contextual analyses, multi-scale approach, interdisciplinary approaches, holistic approaches, decision support, Least Developed Countries, Ethiopia, Mozambique.
Contents

List of acronyms and abbreviations

Preface

Chapter 1  General introduction
  1.1. Background and rationale
  1.2. Multiple dimensions of sustainable natural resource management (SNRM)
  1.3. The sustainable livelihood concept and approach (SLC/A)
    1.3.1. The origin of the sustainable livelihood concept/approach
    1.3.2. Key elements and principles of SLA
  1.4. Nutrient budget studies: General use and perspectives
    1.4.1. Nutrient budgets and early developments in agriculture
    1.4.2. Increased interest in nutrient balance studies:
      The need for increased agricultural production
    1.4.3. Nutrient budget analyses: How and why?
    1.4.4. Examples of nutrient balance analyses
  1.5. Conclusions

Chapter 2  Case study in Northeast Thailand: Rationale and methodology
  2.1. Introduction
    2.1.1. Background and rationale
    2.1.2. Goal and objectives
  2.2. Methodology
    2.2.1. New approaches and concepts for SNRM and improved livelihoods
    2.2.2. General DRMD characterization
    2.2.3. General survey method and issues of scale
    2.2.4. Data collection, storage and management
    2.2.5. Data analyses
    2.2.6. Paradigmatic relevance, prototyping analyses and contributions to
dynamic and site-specific decision support
  2.3. Conclusions

Chapter 3  Case study in Northeast Thailand: Dynamic resource management
domain (DRMD) characterization, R&D bottlenecks and opportunities
  3.1. Introduction
  3.2. Land-use and agricultural change over two decades
3.3. Rainfed lowland rice-based farming systems 51
   3.3.1. General characteristics and developments 51
   3.3.2. Effects of the economic crisis 53
   3.3.3. Current nutrient management and soil fertility R&D 54
3.4. Research impacts, opportunities and trends 58
   3.4.1. The low impact of research 58
   3.4.2. Improving the use of existing data 60
   3.4.3. Participatory and interdisciplinary research methods 60
   3.4.4. Integrated agro-ecological research 61
   3.4.5. Specific research applications 63
3.5. Conclusions 66
3.6. Summary of bottlenecks and challenges for R&D in Northeast Thailand 66

Chapter 4  Case study in Northeast Thailand: Multi-scale nutrient balance analyses (NBA) 69
4.1. Introduction 69
4.2. Results 70
4.3. Discussion of results 78
   4.3.1. Biophysical characteristics of land and nutrient budgets 78
   4.3.2. Methodological aspects 80
4.4. Towards decision support for nutrient management and environmental protection 84
4.5. Conclusions 90

Chapter 5  Case study in Northeast Thailand: Integrated analyses 93
5.1. Introduction 93
5.2. Links between socio-economic factors, rice production, and natural resource management 94
5.3. Integrated environmental and socio-economic accounting 97
   5.3.1. Introduction 97
   5.3.2. Fertilizer survey and calculation of N, P and K retail prizes 97
   5.3.3. Monetary assessment of inputs and monetary partial balances 99
5.4. Analyses of economic viability 105
5.5. Conclusions and discussion 109

Chapter 6  Conclusions, broader considerations and general discussion 113
6.1. Conclusions 113
6.2. Missing links: Hiatus and issues that require additional attention 117
6.2.1. Organizational development 118
6.2.2. Institutional development and the politics of integrated rural development 120
6.2.3. Stakeholder collaboration and sustainable institutionalization of innovative R&D 120
6.2.4. Capacity development 123
6.2.5. Good governance and the relevance of decentralization 125
6.2.6. Local realities: Illiteracy, gender, socio-cultural inequalities, HIV-AIDS, political agendas 125
6.2.7. Rural and livelihood transitions 126
6.2.8. Rural-urban linkages 127
6.2.9. Gender equality and mainstreaming gender 128
6.2.10. Mainstreaming HIV-AIDS 129
6.2.11. Participatory approaches: Action learning and action research 131
6.2.12. Private sector development – farming as a business 131
6.2.13. Business associations and market access 132
6.2.14. Translation of international and national development policies into local strategies and action (PRSP and MDGs) 135
6.2.15. Learning, education and human capital 138

6.3. Elaborations on developments, challenges and opportunities in two sub-Saharan African countries 138
6.3.1. Ethiopia: Perpetuating environmental degradation, food insecurity and poverty? 138
6.3.2. Localization of the Millennium Development Goals (MDGs) in Mozambique based on capacity development for local economic development (LED) 143
6.3.3. Synthesis 153

6.4. Final discussion: Contemporary insights for SNRM and livelihood development 153
6.4.1. Introduction 153
6.4.2. Towards a sustainable livelihood approach to SNRM 155

References 159
Summary 177
Samenvatting 183
List of selected papers of the author 191
PE&RC PhD Education Statement Form 195
Curriculum vitae 197
**List of acronyms and abbreviations**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABCD</td>
<td>Asset Based Development Approach</td>
</tr>
<tr>
<td>ACIAR</td>
<td>Australian Centre for International Agricultural Research</td>
</tr>
<tr>
<td>ADB</td>
<td>Asian Development Bank</td>
</tr>
<tr>
<td>AfDB</td>
<td>African Development Bank</td>
</tr>
<tr>
<td>ADLI</td>
<td>Agriculture-Development Led Industrialization (Ethiopia)</td>
</tr>
<tr>
<td>ADP</td>
<td>Area Development Programme</td>
</tr>
<tr>
<td>AIDS</td>
<td>Acquired Immune Deficiency Syndrome</td>
</tr>
<tr>
<td>ALS</td>
<td>Alternative Livelihood Strategies</td>
</tr>
<tr>
<td>ARV</td>
<td>Antiretroviral</td>
</tr>
<tr>
<td>ASEAN</td>
<td>Association of Southeast Asian Nations</td>
</tr>
<tr>
<td>AU</td>
<td>African Union</td>
</tr>
<tr>
<td>B/C ratio</td>
<td>Benefit/Cost ratio</td>
</tr>
<tr>
<td>BNF</td>
<td>Biological Nitrogen Fixation</td>
</tr>
<tr>
<td>BS</td>
<td>Base Saturation</td>
</tr>
<tr>
<td>BSWM</td>
<td>Bureau of Soils and Water Management (Philippines)</td>
</tr>
<tr>
<td>BuZa</td>
<td>Ministry of Foreign Affairs (The Netherlands)</td>
</tr>
<tr>
<td>CA</td>
<td>Christian Aid (United Kingdom)</td>
</tr>
<tr>
<td>CBA</td>
<td>Cost-Benefit Analysis</td>
</tr>
<tr>
<td>CDS</td>
<td>Capacity Development Services</td>
</tr>
<tr>
<td>CEA</td>
<td>Conventional Economic Accounting</td>
</tr>
<tr>
<td>CIAT</td>
<td>International Centre for Tropical Agriculture</td>
</tr>
<tr>
<td>CPR</td>
<td>Common Property Resources</td>
</tr>
<tr>
<td>CRDA</td>
<td>Christian Relief and Development Association (Ethiopia)</td>
</tr>
<tr>
<td>CSE</td>
<td>Conservation Strategy of Ethiopia</td>
</tr>
<tr>
<td>DFID</td>
<td>Department for International Development (United Kingdom)</td>
</tr>
<tr>
<td>DGIS</td>
<td>Directorate-General for International Cooperation (BuZa, The Netherlands)</td>
</tr>
<tr>
<td>DOA</td>
<td>Department of Agriculture (Thailand)</td>
</tr>
<tr>
<td>DRC</td>
<td>Democratic Republic of Congo</td>
</tr>
<tr>
<td>DRMD</td>
<td>Dynamic Resource Management Domain</td>
</tr>
<tr>
<td>DST</td>
<td>Decision Support Tool</td>
</tr>
<tr>
<td>DSS</td>
<td>Decision Support System</td>
</tr>
<tr>
<td>ECA</td>
<td>Economic Commission for Africa, United Nations</td>
</tr>
<tr>
<td>ECDPM</td>
<td>European Centre for Development Policy Management (Maastricht, The Netherlands)</td>
</tr>
<tr>
<td>ECEC</td>
<td>Effective Cation Exchange Capacity</td>
</tr>
<tr>
<td>EEA</td>
<td>Ethiopian Economic Association</td>
</tr>
<tr>
<td>EEPRI</td>
<td>Ethiopian Economic Policy Research Institute</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment / Analysis</td>
</tr>
<tr>
<td>EPDRF</td>
<td>Ethiopian Peoples' Democratic Revolutionary Front</td>
</tr>
<tr>
<td>FADINAP</td>
<td>Fertilizer Advisory, Development and Information Network for Asia and the Pacific (UN)</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization (UN)</td>
</tr>
<tr>
<td>FAOSTAT</td>
<td>Food and Agriculture Organization Statistical Database</td>
</tr>
<tr>
<td>FESLM</td>
<td>Framework for Evaluating Sustainable Land Management</td>
</tr>
<tr>
<td>FIF</td>
<td>Farm Inventory Form (NBS-NET)</td>
</tr>
<tr>
<td>FS</td>
<td>Farming Systems</td>
</tr>
<tr>
<td>FFW</td>
<td>Food for Work</td>
</tr>
<tr>
<td>FNBA</td>
<td>Full Nutrient Budget / Balance Analyses</td>
</tr>
<tr>
<td>FPE</td>
<td>Farmer Participatory Extension</td>
</tr>
<tr>
<td>FPR</td>
<td>Farmer Participatory Research</td>
</tr>
</tbody>
</table>
Preface

I was not aware I was on my way to start a PhD trajectory when crossing the Indian Ocean from Mozambique to a new job with the International Board for Soil Research and Management (IBSRAM) in Thailand, in November 1998. At IBSRAM, I got directly involved in starting up of Nutrient Balance Studies in Northeast Thailand (NBS-NET), a collaborative R&D programme between Ubon Ratchathani Rice Research Centre (URRC), under the Rice Research Institute (RRI) of the Thai Department of Agriculture (DOA), and the International Board for Soil Research and Management (IBSRAM). About eight years have passed during which it has not always been certain that a PhD thesis would be the final outcome at the end of a long and bumpy road. This trajectory went counter clockwise around the Indian Ocean, interrupted by a short year back in The Netherlands. With the centre of gravity of the thesis work in Northeast Thailand, the whole ‘circle’ has been essential in shaping and enriching my thoughts, insights and this PhD thesis, in a way that would have been impossible without such a wide ‘circle’, full of experiences and learning in a wide range of settings and countries. The road and impressions have been beautiful but, due to poverty and injustice, also gloomy and full of despair, particularly in sub-Saharan Africa. Both, professionally and privately, Thailand was a great experience. Isan (Northeast Thailand) culture and hospitality have been impressive and I got and still am addicted to Thai food, which is nowhere prepared with the original taste and quality as in Thailand itself. I am glad that some work in and experiences from Africa, the continent where I have been living altogether for over eight years now, also found their way into this thesis. I feel strongly attracted to and at the same time challenged by the African Continent in all its diversity, beauty, happiness, despair and suffering, but also with some hope. Privately, my life went through major changes concurrently as our family doubled in size after our first daughter was born in Bangkok, Thailand (1999) and our second daughter in Zwolle, The Netherlands (2005), the latter in between a move from Ethiopia back to Mozambique again.

I am extremely grateful to four persons that have been most essential in the realization of this thesis. First and foremost, I would like to thank my promotor, Herman van Keulen. In advance, I never could have imagined that somebody could have so much energy, dedication and commitment to the supervision of a PhD thesis. I got to know you as a “no-nonsense”, honest, passionate, friendly professor, very much down-to-earth and, above all, very knowledgeable. Therefore, I am very happy that I exactly found you on my way for supervision of my PhD work and as promotor. I am very
grateful to you for all the efforts and work you have put into my supervision that already started in 1999, when Frits Penning de Vries established the first contacts and we established our initial relationship. The relationship intensified from my period at the Plant Production Systems (PPS) Group in Wageningen (2001) onwards. Thank you for having offered the position of ‘visiting scientist’ to me. When having to go abroad again, we maintained our communication by e-mail and we had our face-to-face encounters on an annual basis during my annual leaves, sometimes with limited progress. Too busy in moving to, settling-in and working in a new country (Ethiopia) and in finding my way in new positions, years passed by with ‘drafts’ of the core chapters remaining locked up in drawers for most of the time. From 2005 onwards, when having returned to Mozambique again, the momentum was there again and the last six months of 2006 have been very intensive and tough for both of us, knowing that I am not the only one you have been supervising. I really admire your patience and am grateful that you never lost belief that, in addition to my regular jobs and with the years passing by, I would end up with this thesis. I owe you a lot. My appreciation also goes to Clara for the sacrifices she obviously made and has to make for your work and passion, but also for her hospitality when we visited your home together with other PhD students, early 2005.

Secondly, I would like to thank Rod Lefroy (CIAT), who has been my direct supervisor, colleague and friend during the 2.5 years that I spent at IBSRAM (1998-2001). As for Herman, I really admire your energy, dedication and commitment far beyond ‘official’ working hours and days. I learned an incredible lot from you and I very much acknowledge the opportunities you created for me. I have never had a supervisor working so closely and intensively as you did those years. It was exactly what an ambitious young professional needed to get motivated, learn and grow. You have been critical in the persuasion to do a PhD and have established critical contacts and brought me into networks that have been invaluable for NBS-NET and the realization of this thesis. I gratefully acknowledge your contributions to and supervision of a number of our joint papers, many of them with involvement of Yothin Konboon as well, which have formed the basis for this thesis.

Third, I would like to thank Yothin Konboon, our main counterpart at the Ubon Ratchathani Rice Research Centre (URRC) of the Thai Department of Agriculture (DOA). Your contributions, guidance, hospitality and above all friendship have been of immeasurable value for the realization of this thesis. It covers, to a large extent, our collaborative research & development efforts within the framework of NBS-NET. The work was part of the URRC agenda for improving rice cultivation and the livelihoods of the people of Ubon Ratchathani Province and Isan (Northeast Thailand). I would have liked to stay longer in Thailand to continue the collaborative efforts as there was
more work that we could have done together. Unfortunately, my contract expired ‘too early’ and at a critical stage for the generation of output and results. More than anybody else you introduced me deeply into Thai and Isan culture. Your collaboration and support were invaluable from strategic and scientific perspectives, including the direct interaction and collaboration with local farmers and extension workers, but also to get a URRC team involved and to establish linkages with local partners. Your contributions to most of the chapters are gratefully acknowledged. I also would like to express my great appreciation to your wife, Toey, and your two sons, for the hospitality and the social sessions we and our families joined together. I never forget the ‘hottest’ and most delicious Tom Yum (spicy Thai soup) I could ever imagine, and how in your garden I washed down a fried fly (Isan delicacy), caught in the same garden, with some ice cold Singah beer (with ice!), but also our get-togethers at the floating restaurant on Moon River.

Fourth, I would like to thank and I am grateful to Frits Penning de Vries, former Director of Research of IBSRAM. You have been critical in establishing the contact with Herman and to let my work on NBS-NET be supervised as a PhD research trajectory. Without those critical steps, the whole PhD trajectory and this thesis most likely would never have been realized. I also would like to express my gratitude for your supervision and overall support to NBS-NET and the initial efforts for working on this PhD thesis.

I would like to express my gratitude to the Netherlands Directorate-General for International Cooperation (DGIS) of The Netherlands Ministry of Foreign Affairs (BuZa). I was seconded to IBSRAM on a DGIS contract. DGIS also funded my participation in an international conference, a training course and my study leave that I spent as a ‘Visiting Scientist’ at the Plant Production Systems group and the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) at Wageningen University and Research centre (WUR).

I would like to thank the International Rice Research Institute (IRRI) for the NBS-NET grant they provided to IBSRAM. I would like to thank the Thai Department of Agriculture (DOA) and the Ubon Ratchathani Rice Research Centre (URRC). I am very grateful to the URRC director, Nopporn Supapoj, for all his support to NBS-NET and all hospitality. I also would like to thank Suda Sripodok and Prasert Chaiwatr for their support to NBS-NET. I am extremely grateful to the extension workers, college students and all the Ubon Ratchathani farmers involved.

I would like to thank the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) and the Plant Production Systems (PPS) group at WUR. Your hospitality and support have been of great value. In particular, I would
like to thank Ken Giller, Claudius van de Vijver, Peter Leffelaar and Gon van Laar. Gon, I admire and appreciate all support you gave to editing, preparing and formatting the final manuscripts, contacting the print shop, and all other assistance you provided, while I was at a long distance from Wageningen myself. I would like to thank Maja Slingerland for guidance provided to get the thesis published in the Tropical Resource Management Papers (TRMP) series and Myriam Adam for having translated the TRMP abstract into French. I would like to thank all students and internees with whom I had useful interactions in the ‘large’ ‘attick’ at the Haarweg in Wageningen in 2001, as well as other students and staff at the Haarweg with whom I have been interacting or that have supported me in one way or another.

I am thankful to IBRAM and its staff, even though IBSRAM as such does not exist anymore and some of its programmes have been taken over by the International Water Management Institute (IWMI) in 2001. I acknowledge the relevant discussions, contributions and support offered by many of my colleagues. I would like to thank the IBSRAM director at that time, Eric Craswell, for all his support. Robin Lesley, thank you for having turned my ‘Double Dutch’ into ‘English’. I owe you and Rod for having improved my English writing skills a lot. Rung, thank you for your support in developing the NBS-NET relational database system (RDBS). Hans-Dieter, Jean-Louis, Amado, Vipavee, Wiroj, Pay, Lucy, Thomas, Jean-Pierre, Djoko, Jens, Suraporn, Tony, Tanadol, Naiyana, Par, Pinsiri, Pornchai and other colleagues that I may have forgotten, thank you for your discussions, contributions and /or support.

I would like to thank SNV (The Netherlands Development Organization) for having provided me with an even broader exposure and broad experiences in the development arena. SNV enabled me to work with a wide range of different ‘types’ of organizations at different levels and with very different mandates. It provided me with a broader, but also evermore complex vision and ‘reality check’ about complex development realities. I am grateful to the SNV managers that authorized and supported me to finalize this job. The number of SNV colleagues and staff of partner organizations with whom I have been involved in relevant experiences, had relevant discussions or that contributed to this thesis, is too high to mention them all by name. I am grateful to all of you.

I am also thankful to a range of other persons that, at times unknowingly, have inspired my thesis work. With some of them, interactions may have been short but extremely useful. Jaime Duzenta, in Mozambique before moving to Thailand, my collaboration with you has been essential in learning to appraise poverty, food insecurity and related local realities in a participatory way. Toon Defoer, we never met in person, but our interactions by E-mail and your work with farmers has been of inspiration to me. Shaun Ferris and Robert Delve of the CIAT Africa programme, you
and your colleagues certainly contributed to shaping some insights that have been relevant for sections within the final chapter.

I would like to thank my family and friends that have supported and inspired me in good and bad times. A number of them I would like to thank in particular. Granddad, Jan Derk Stegeman, I thank you for your wisdom, interest and support. My brother Bert and Jose, thank you for your hospitality, having been allowed to use your PC, Internet connections and home, as well as all other and frequent support during our stay of one year and additional ‘leaves’ in The Netherlands. My sister Erna and Joost-Pieter, my sister Paola and Jan, thank you for all the support, inspiration and ‘breaks’ you gave us. Erna and Paola, thank you very much for willing to serve as my paranymphs. I would like to thank my mother-in-law, Leia Tovela, for all her support and care when visiting and working in Maxaquene, Maputo. I am extremely grateful to my parents, Kornelis Wijnhoud and Johanna Wijnhoud-Stegeman, for all the support they have given me from the day I came to earth. You always have been there for me and the family, in easy and more difficult times. You taught me to stay down-to-earth and about the relevance of education. I am grateful and indebted to our two lovely daughters, Leianne and Ella-Marit, for all the time I was not there for you, while being asked for. I cannot count the number of occasions that I have been refusing to play games or go out with you, even after regular work, during the weekends or ‘holidays’. Most grateful of all I am to my beloved wife, Julieta. I don’t have words for the patience, understanding and support you have given me over the years. I sincerely hope that our family can somehow compensate for the lost moments together and anything else in the months and years to come.

I am very grateful to all persons (farmers and those having moved out of farming), households, communities and their organizations that are working towards their own development and with whom I had the honour to interact or work with. You are the ultimate target groups of and have participated in and contributed intensively to the work covered by this thesis.

Last, I would like to thank the members of the promotion commission and everybody else that I have been interacting with, provided support or contributed to this thesis, but has not been mentioned by name.

I would like to emphasize that there may be statements in this thesis that do not necessarily reflect the opinion(s) of those that have contributed to the research & development activities at its basis, or, of those who have been supportive to the efforts that led to this thesis. Neither do they necessarily represent the opinion of organizations that I have been working for or with over the last ten years. I take the full responsibility for them in person.

I am dedicating this thesis to my wife, our two daughters, my parents, and last but
not least, to those living in extreme poverty and/or having been marginalized and disempowered for unjust reasons. I sincerely hope that this thesis will make some contributions to the ongoing fight against poverty and injustice.

J.D. (Danny) Wijnhoud
Beira, Mozambique, December 2006
CHAPTER 1

General introduction*

Abstract
This chapter starts off with the background and rationale of this thesis (Section 1.1). This is followed by the key hypothesis that efficient and effective rural-development strategies, aimed at the twin-objectives of sustainable natural resource management (SNRM) and improved and sustainable livelihood development, require ‘innovative’, i.e. more participatory, integrated and holistic approaches, while following a strict priority setting by combining holistic concepts and a small selected set of participatory, integrated and/or complementary analyses to keep efforts manageable and result-oriented. The challenge therefore is to find the appropriate balance between on one hand the demand for more comprehensive contextual and integrated analyses and on the other hand the requirement to keep such efforts manageable in terms of human, material and financial resources. The key hypothesis was partly tested on the basis of a collaborative research and development (R&D) activity in Northeast Thailand (Chapter 2–5), shortly introduced in this chapter. The R&D activity explicitly examines the relevance of integrated nutrient budget, soil fertility management and livelihood analyses. It serves as an exemplary and paradigmatic case for innovative approaches and contributes to the advocacy for their broad adoption. As a back-up, based on literature study and later experiences, including work in sub-Saharan Africa, this introductory chapter elaborates on relevant concepts, principles and approaches, such as the multiple dimensions of SNRM (Section 1.2), the sustainable livelihood concept and approach (Section 1.3) and nutrient balance studies (Section 1.4), which are useful for the work in Northeast Thailand, but also – often even more essential – for development strategies in the least developed countries (LDCs) in the world.

There is briefly referred to other relevant aspects, including less tangible ones such as governance, decentralization, organizational and institutional development, and capacity development. They partly surface in this introductory and the following four chapters on the collaborative R&D activity in Northeast Thailand and are further discussed in the final chapter (Chapter 6).

1.1. Background and rationale
In Northeast Thailand, questions about the sustainability of rainfed lowland rice-based systems, the dominant land-use system (LUS) in the region, is a concern for livelihood development in this relatively poor area of the country. Poor soil fertility and low inputs are considered major causes of the sustainability problems. Similar problems exist for a wide range of LUS in the developing world. Reversal of such developments requires integrated rural development strategies aimed at breaking the environment-poverty downward spiral. Appropriate decision support and incentives are required to bring about sustainable natural resource management and agricultural production to improve livelihoods and stimulate agricultural and non-agricultural based economic development, whereas in turn improved livelihoods and pro-poor economic development will catalyse sustainable natural resource management and agricultural production. However, such developments are challenged by the complexity of these

* Parts of this chapter were derived or adapted from: Lefroy and Wijnhoud (2001), Wijnhoud et al. (2001), Wijnhoud and Lefroy (2001) and Wijnhoud and Solomon Abate (2004).
systems and their dynamics, within the dynamic context of continued agricultural commercialization, de-agrarianization, occupational change, economic diversification and urbanization in an evermore ‘globalizing’ world.

This thesis starts from the key hypothesis that efficient and effective rural-development strategies, aimed at the twin-objectives of sustainable natural resource management (SNRM) and improved and sustainable livelihood development, require ‘innovative’, *i.e.* participatory, integrated and holistic approaches, while following a strict priority setting by combining holistic concepts and a small selected set of participatory, integrated and/or complementary analyses to keep efforts manageable and result-oriented. The challenge therefore is to find the appropriate balance between on one hand the demand for more comprehensive contextual and integrated analyses and on the other hand the requirement to keep such efforts manageable in terms of human, financial and material resources. As part of the objectives and focus of the central research and development (R&D) trajectory for this thesis, the relevance of integrated nutrient budget, soil fertility management and livelihood analyses is explicitly examined.

The main goal of this thesis is to provide evidence for the usefulness of ‘integrated’ rural development strategies, based on both practical experiences and results of a collaborative R&D programme in Northeast Thailand during 1998–2001 and some broader theoretical considerations as largely inspired by work and experiences in sub-Saharan Africa. As part of the advocated strategies, ‘integration’ is taken beyond the level of ‘integrated’ area development programmes (ADPs), as implemented in the developing world in the 1980s and 1990s (Farrington *et al.*, 2002). Such ADPs followed locally driven multi-sector, *i.e.* multi-disciplinary, approaches and dealt with different disciplines simultaneously, but more or less in isolation. They generally overlooked the key aspects of the innovative approaches, referred to earlier, that explicitly advocate increased emphasis on participatory and interdisciplinary or ‘trans-disciplinary’ dimensions (Chapter 3; Fink, 2002), as well as contextual analyses, taking into account spatio-temporal dimensions at multi-scales. Moreover, ADPs did not pay much attention to less tangible, but often critical, aspects related to decentralization, good governance (Shackleton *et al.*, 2002; Ribot, 2004; Wijnhoud, 2005), organizational and institutional development (SNV, 2002a), capacity development requirements (Fukuda-Parr *et al.*, 2002; SNV, 2002a) and the sustainable institutionalization of integrated research and development (R&D) efforts (Lundy *et al.*, 2005; Kaganzi *et al.*, 2005; Hassam and Wijnhoud, 2005).

The central part of this thesis (Chapters 2–5) describes the methodology for and provides the results of a collaborative R&D programme in Ubon Ratchathani Province of Northeast Thailand (Figure 1.1). The collaborative R&D programme started in 1998
under the name ‘Nutrient Balance Studies in Northeast Thailand’ (NBS-NET) and was later continued as: “Nutrient budgets: accounting for environmental and socio-economic sustainability in Northeast Thailand” (Wijnhoud et al., 2001, 2003). The work in Northeast Thailand serves as an exemplary and paradigmatic case advocating innovative approaches, while including prototyping elements for scaling up efforts following similar or somewhat deviating R&D approaches.

Chapter 2 provides a full overview of the rationale and methodology of the collaborative R&D programme aimed at addressing the daunting twin challenges of SNRM and improved and sustainable livelihoods. The programme started from a
predominantly biophysical angle, pivoting around multi-scale nutrient balance analyses (NBA), but from the planning and inception phases onwards, also studying socio-economic, and, although to a smaller degree, policy, governance and institutional dimensions within the broader spatio-temporal context. Its emphasis gradually shifted from biophysical to more socio-economic and integrated analyses and considerations. Synergy was not only derived from the integration of disciplines, but also from a focus at multi-scales, *i.e.* integrated or complementary analyses of relevant aspects and factors at different spatial scales (Andriesse *et al.*, 1994). It could be argued that, ideally, the central case for this thesis should have started from a perspective of disciplinary neutrality. However, due to contemporary institutional arrangements, development efforts are predominantly approached from specific disciplinary angles, even if under ‘interdisciplinary’ headings and/or as part of multi-disciplinary programmes. Therefore, also this case study started with a dominant emphasis on one disciplinary angle, *i.e.* biophysical aspects of SNRM within their broader interdisciplinary context (Chapters 3–4), with key emphasis on soil fertility management (Chapter 3) and multi-scale nutrient balance analyses for the assessment of SNRM and to generate decision support to achieve SNRM (Chapter 4). Gradually the emphasis shifted towards socio-economic analyses, such as livelihood analyses and integrated environmental and socio-economic analyses (mainly Chapter 5) with the relevance of additional aspects, such as governance, political, organizational and institutional dimensions and capacity development requirements, being heeded, in particular in the closing chapter (Chapters 6).

Chapter 6 provides a summary overview of key conclusions and a final discussion that also elaborates on the results of the collaborative R&D programme and its relevance and paradigmatic value for R&D in Thailand, but also for other developing countries, including the least developed countries (LDCs) in the world. In this perspective, in Chapter 6, there are identified some relevant hiatus or issues that require further attention in the framework of integrated rural development strategies, including less tangible dimensions such as governance, decentralization, organizational and institutional development, and capacity development. Their (partial) omission is the result of a combination of factors, in particular the inherent limitations and boundary conditions of the R&D case in Northeast Thailand. Moreover, at the start of the NBS-NET activities in 1998, some of the issues, in current development efforts identified as gaps or hiatus, at that time were not widely recognized as relevant to integrated rural development strategies. They may also have been perceived as less critical in a relatively better-off country, an Asian ‘Tiger’ in full transition like Thailand – although developments were temporary disturbed due to the economic crisis in the late 1990s (Chapter 3) – than in the LDCs in the world. Whereas
awareness about their relevance has partly been created by the contextual analysis (Chapter 3) and synthesized results of the case itself (Chapters 3–5), within the additional trajectory that led to this thesis, they were further shaped by additional literature study and insights obtained during later – practical and partly also policy and research focused – work in sub-Saharan Africa (Wijnhoud and Solomon Abate, 2004; Hassam and Wijnhoud, 2005; Wijnhoud, 2005). Linking these later experiences to the R&D programme in Northeast Thailand certainly adds more innovative dimensions to the latter, largely included as additional attention points and recommendations in the final discussion (Chapter 6). In turn, the lessons learned from the work in Northeast Thailand, including observations of livelihood, economic and rural transitions, not only have inspired later work in sub-Saharan Africa, but serve as useful inputs for rural development strategies for the LDCs in general (Chapter 6).

As for the larger part based on literature study, this introductory Chapter 1 is proceeding with elaborations on relevant concepts, principles and approaches, respectively dealing with the multiple dimensions of SNRM (Section 1.2), the sustainable livelihood concept and approach (Section 1.3) and the nutrient balance approach (Section 1.4), which are relevant to the work in Northeast Thailand, but also often even more essential, for integrated rural-development strategies in the least developed countries (LDCs) in the world.

1.2. Multiple dimensions of sustainable natural resource management (SNRM)

The resource degradation versus poverty nexus in Northeast Thailand is of major concern and has resulted in extreme soil erosion, deforestation, loss of biodiversity and other forms of natural resource degradation, all affecting the livelihoods of large numbers of people in this relatively poor part of the country. This is a common tendency in major parts of the developing world, even more so in many of the LDCs (Wijnhoud and Solomon Abate, 2004). Often merely ascribed to erratic rainfall and periods of relative ‘drought’ or inappropriate land husbandry from a technical point of view, the human, economic and socio-political, including poverty, dimensions of low agricultural productivity and land degradation have often been overlooked or ignored. Degradation of natural resources may have passed the threshold of socio-economically feasible regeneration at many places both in Northeast Thailand and elsewhere. This means that large groups of smallholders, and other land-users, gradually have lost and continue to lose out on their biophysical capital assets. Despite the many efforts aimed at halting the process of degradation, the results have often been far below expectations. One reason for uncoordinated and failed efforts aimed at SNRM in Northeast Thailand and elsewhere, is that SNRM too often is perceived in too narrow a sense, with a mere focus on
Chapter 1

biophysical and technical aspects (see also Chapter 6). There is a lack of common understanding about the concept and its multiple dimensions, particularly with respect to its socio-cultural, economic, political, policy and institutional dimensions (Chapter 6). Therefore, further insights into – what is meant by – SNRM in its broadest sense, are appropriate.

‘Natural resources’ in their broadest sense, refer to the complete set of simple and complex elements of nature, that could be made useful to human purposes and, as such, have a direct or indirect value, the higher as they are or may become scarce. In this perspective, SNRM interventions should aim at breaching the environment-poverty downward spiral that is perpetuated by interrelated unfavourable biophysical and socio-economic conditions. SNRM should specifically aim at attaining both sustainable use and/or management of natural resources and improved and sustainable livelihoods, beyond the mere reliance on degrading/reduced natural (livelihood) capital assets (see Section 1.3). The latter may only be possibly through provision or existence of favourable policies or income incentives for SNRM (Wijnhoud and Solomon Abate, 2004).

Narrowly defined, from a biophysical point of view, SNRM refers to the proper utilization of natural resources without jeopardizing their overall functions and value in the long term, (although in the case of mining and the exploitation of non-renewable resources, different standards may apply and full exploitation might be a deliberate choice). SNRM links ‘natural resources’ to ‘imposed human action on them’. This adds to the multiple dimensions of SNRM. The SNRM-sector is linked to a wide range of (sub-)sectors, such as the agricultural, forestry, wildlife, water, mining and (rural) energy sectors. Equally important, through its human dimensions, it is related to a much wider range of socio-cultural (including indigenous knowledge systems), economic, political/policy and institutional factors. These also include the education, health, social welfare and labour sectors and issues of gender and social equality/inclusion and peace and conflict, as related to access to and control over resources. Spatio-temporal variability in the various dimensions provides a context of dynamic resource management domains (DRMD) at different spatio-temporal scales (Chapters 2, 3 and 6; Syers and Bouma, 1998), including the global scale as affected by globalization. One can distinguish the interdisciplinary and holistic aspects of SNRM, or its multiple dimensions. Therefore, more broadly and correctly defined, sustainable SNRM refers to both the protection and proper utilization of natural resources for long-term sustainability in socio-economic welfare for women and men, based on their interaction with natural resources available to them in a sustainable way. The latter does not imply that SNRM requires reliance of the total rural population on sustainable natural resource-based livelihoods. On the contrary, within
the context of economic diversification and growth, efforts should be aimed at rural transitions, that lead to a situation where due to livelihood and economic diversification, a growing part of the population no longer depends directly on natural resources (alone) for their livelihoods. Such a process on one hand would reduce the pressure on natural resources and on the other may allow investments in technological innovations in sustainable natural resource-based production practices by a smaller proportion of the population, as part of agrarian reform and rural transformation (Section 2.2.1; Chapters 5 and 6).

Smyth and Dumanski (1993) distinguish five pillars of sustainability that need to be satisfied simultaneously to achieve sustainable land management in its broadest sense (synonymous to SNRM): (1) productivity, (2) stability or risk avoidance, (3) economic viability, (4) socio-cultural acceptability, and (5) maintenance of the resource base (including biodiversity), or protection. It is appropriate to add social and gender equality as a sixth pillar of sustainability. Social and gender inequality, expressed in terms of voicelessness, exclusion or unequal participation, are at the heart of SNRM-poverty issues in Northeast Thailand and elsewhere (Wijnhoud and Solomon Abate, 2004).

1.3. The sustainable livelihood concept and approach (SLC/A)

1.3.1. The origin of the sustainable livelihood concept/approach
In the 1990s, UK-based institutions initiated the development of the sustainable livelihood concept (SLC) that became central to the new ‘sustainable livelihood approach’ (SLA) to development (DFID, 1997). Initially used as a people-centered grass-root concept and approach, the ‘SLC/SLA’ further developed into a more holistic and full-fledged development concept/approach that may serve as an objective, principle and framework at the same time. This evolution was influenced by the interactions with sector wide approaches (SWAPS) that were adopted in many developing countries, based on long-term partnerships with the international donor community and embedded in national poverty reduction strategies (PRS), the emergence of the rights-based approach (RBA), predominantly advocated by a number of international non-governmental organizations (NGOs) and new insights in the relevance of policy research and development, organizational and institutional development and the harmonization of development efforts, including micro-macro linkages (Ubels et al., 2005; Chapter 6). Where in the remainder of this thesis reference is made to SLA, SLC is intrinsically part of it.

A livelihood comprises the capabilities, assets (including material, social and mental resources) and activities required as a means of living. A livelihood is
Chapter 1

sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base (Chambers and Conway, 1992; DFID, 1999).

Chambers and Conway (1992) emphasized the need for truly participatory and empowering approaches. They were implicitly advocating SLA, as explicitly formulated some years later. Catchwords, such as ‘sustainable livelihoods’, ‘human development’ and ‘environmental sustainability’, gradually gained ground. When in the UK a new labour government took over from the Tories in 1996, it adopted one year later, the ‘White Paper on International Development’, explicitly putting key emphasis on the SLA (DFID, 1997). The policy was partly a result of the institutional necessity to deviate from the neo-liberal policies of the preceding government that focused on economic growth, and the belief that results would trickle down to all social layers of society. On the other hand, it was based on the labour ideology of the need for a people-centered and pro-poor approach that relies on the possibilities and assets of people themselves, instead of on the trickling down effect of economic growth. During the years that followed, the SLA gained popularity and was gradually adopted in one way or another, by a wide range of international institutions, including some of the organizations under the wings of the UN, but also by some of the World Bank (WB) departments and the International Monetary Fund (IMF). The latter could be considered as partial correction to the structural adjustment policies (SAPs) and neo-liberal approaches imposed by WB and IMF during the 1980s and 1990s. These corrections were a reaction to and in line with growing criticism voiced for most of the 1990s. The introduction of the human development index (HDI; UNDP, 2004) and the Millennium Development Goals (MDGs; United Nations, 2000) is evidence of this international policy shift, even though a weakness may be that they are based on averages, thresholds and percentages, with the depth of poverty for those below the poverty line and social dis-aggregation (diversity) often not being addressed, unlike done by ‘Save the Children UK’ in collaboration with the Institute for Development Studies (IDS) when making use of the SLA in South Wollo, Ethiopia, in order to come up with appropriate development interventions (Sharp et al., 2003). HDI and MDGs have been launched without clear-cut strategies for their realization and they do not explicitly account for the sustainability of ‘poverty alleviation’ and development interventions (Chapter 6).

Due to different and gradually shifting interpretations of SLA, it may be relevant to explain its general meaning, either following a conventional and simple SLA, only incorporating five types of capital assets (see Section 1.3.2) to be assessed and to be build up at grass-roots level, or a more complex SLA within a broader perspective. The latter would at least touch on policies, institutions and processes (PIPs) at different
scales, as affecting livelihood capital assets at the grass-roots level (see Section 1.3.2; IDS, undated) and often some other aspects, not incorporated in the initial phase of its development, like governance, in- or exclusion, human, political and democratic rights as capital assets, as well as organizational and institutional capital assets.

The local and international NGOs, and other international organizations that incorporated the SLA in their development interventions, often referred to the SLA more explicitly in the LDCs than in emerging economies like Thailand; however, it also is relevant there, to counteract human and environmental vulnerability and to contribute to the twin objectives of SNRM and improved and sustainable livelihoods.

By touching on the multiple dimensions of SNRM (Section 1.2; Wijnhoud and Solomon Abate, 2004), the SLA appears a powerful instrument for thorough poverty analysis, including SNRM analysis. The same holds for the development and implementation of well thought-out intervention strategies aimed at the twin-objectives of SNRM and poverty alleviation, i.e. livelihood development (Bebbington, 1999). The broader adoption of the SLA into development efforts in Thailand and elsewhere could result in improved stakeholder coordination in concerted multi-stakeholder, multi-scale efforts and partnerships in order to reverse the environment-poverty downward spiral.

1.3.2. Key elements and principles of SLA

Initially, the SLA pivoted around the measurement of the following five different types of capital assets of communities, households and/or its individual members:

1. **Financial.** Financial capital assets usually include savings, but also livestock and other assets may be included, if they are directly convertible into cash or can easily be used for barter.

2. **Physical.** Physical capital assets cover the house and farm equipment, such as a motor pump, (hand) tractor, but also non-farm equipment, such as a sewing-machine.

3. **Natural.** Natural capital assets cover land and water as production factors, as well as wild flora and fauna that can be accessed by communities, households or individuals for their livelihoods. Biodiversity may also be included in this category, although its relevance may vary among ‘beneficiaries’, the different groups and individuals at community level.

4. **Social.** Social capital assets cover essential social and institutional relationships, the latter if institutional capital assets are not included as a separate category (see 8), safety nets, level of gender and ethno-cultural (or intercultural) equity. More recent interpretations, following a broader definition, also include the level of representation by rights-based and political organizations at different levels, if not...
accounted for in a separate category of political capital assets (see 6).

5. Human. Human capital assets include the level of education, (self) employment/income-relevant competencies, but also health, including the HIV-AIDS situation. According to a broad definition, also the human rights status can be included in human capital assets.

In more recent applications, additional types of capital assets are being distinguished:

6. Political. Political capital assets refer to the level of inclusion and potential for participation and sharing of development benefits, as partly defined by the level of democracy and responsive and accountable governance. Consideration of this category of livelihood assets gained ground with the emergence of rights-based approaches (RBA) in development and their integration into the SLA. This also touches on the political economics of development, anticipating societal disaggregation and how it influences participation in decision-making processes (Eponou, 1996). Such capital assets may be partly overlapping or intertwined with the social and institutional capital assets (see 4 and 8).

7. Cultural. Cultural capital assets refer to culturally based values and knowledge systems, including indigenous technical knowledge (ITK) and may contribute to locally driven innovations. Certain cultural dimensions may be perceived and categorized as less positive or ‘negative’ for (constraints to) livelihood development, for example when cultural influences contribute to health risks, conflicts, passiveness, prejudices, discrimination, superstition, anti-entrepreneurship or exclusion of certain people or groups of people, work against (the positive dimensions of) innovation, modernization and development and may therefore be considered as constraints to livelihood development rather than as livelihood assets.

8. Organizational and institutional. Organizational and institutional capital assets refer to the additional values or benefits (synergism) that arise when individuals with specific interests, farmers and other business people, women, groups of resource-poor individuals, etc. join hands in more or less official organizations, such as local community-based organizations, local NGOs, farmer and other business associations. Organizational assets refer to the benefits derived from being a member of an organization, whereas institutional assets refer to benefits (constraints if unfavourable) of certain institutional arrangements or ‘rules-of-the-game’; i.e. formal and informal structures, patterns and relationships among different types of organizations and interest groups (SNV, 2002a; Lundy et al., 2005; Hassam and Wijnhoud, 2005).

The last three categories are not part of every SLA application and may be (partly)
overlapping or intertwined with the first five. A range of alternative, often more or less related categorizations may be encountered, including categories that are overlapping with or difficult to disentangle from the categories described above. One example is ‘spiritual and emotional capital assets’, such as ‘instrumental freedoms’ or ‘deprivation of capabilities’, as positive and negative assets, respectively (Sen, 1999).

There are no clear conventions, as yet, how to deal with certain less tangible capital assets and how to differentiate between or disentangle certain assets and allocate them to different categories. For example, human rights may be partly accounted for in human capital, if considered from a personal, household or community perspective, but other aspects could be accounted for in social, political, institutional or even cultural capital assets. Moreover, complications may arise because categories of capital assets comprise different elements with distinctly different relevance for livelihood status and development, which makes integrated assessment of an overall value as capital asset or qualitative comparisons rather challenging and quantitative comparisons impossible. Cultural capital assets may even comprise negative and positive elements within one single category that cannot be quantified, let alone accounted for in budgetary form.

Experience learns that not only the magnitudes of and balances among the capital assets, which can be depicted in a so-called radar or spider diagram, are relevant as measures for livelihood development. In fact, the substitutability (exchangeability) among different types of capital assets may be equally important and essential for the capacity of the system to overcome shocks and show resilience to stresses, characteristics that are also indispensable from the perspective of sustainability (Wijnhoud and Solomon Abate, 2004).

When dealing with the assessment of capital assets based on the SLA, as well as with strategies for the generation of sustainable capital assets, the following aspects should be taken into account:

i. ‘Assets vs. vulnerability/risks’ is a relevant dimension of the SLA, both in theory and practice. Accumulation of assets is primarily relevant to provide resilience against shocks/stresses. In this perspective, it may relevant to distinguish between uncontrollable and variable assets on one hand and controllable and exchangeable assets on the other hand, the latter being more relevant for the development of sustainable livelihoods.

ii. The SLA can be used as a principle, fighting deprivation, an objective, normative, a framework, e.g. for poverty analysis and monitoring and evaluation of livelihood development and poverty alleviation, and an approach, strategy without providing a set of tools, which however could be build around the capital assets and PIPs (IDS, undated; see also iv). Enhancement (or accumulation) of controllable and
mutually exchangeable capital assets can be a goal. Based on the actual livelihood status and opportunities, considering the local and broader context/environment, strategies for livelihood development and reduced vulnerability can be developed, either based on local assets, like based on the so-called asset based development approach (ABCD) or catalysed by external support, but in general through a combination of both.

iii. Depending on the objectives, capital assets can be assessed and developed at the individual, household or community level, but it should be emphasized that households and communities are no homogenous entities, and diversity and inequalities may be overlooked if not dis-aggregating along e.g. gender, age, ethno-cultural, religious, and HIV-AIDS infection/affection lines.

iv. The SLA should not only focus on grass root level assessments and interventions. The holistic and multi-scale dimensions are very important with many factors beyond direct sight and control of community members, influencing the development or decline of their capital assets and their mutual exchangeability. Therefore, the SLA requires multi-level analysis and interventions. In this perspective, the UK Department for International Development (DFID) introduced the term PIPs (policies, institutions and processes). PIPs may be inhibiting, but should be enabling at different levels (IDS, undated).

v. Exclusionary processes and power relations among different actors at the same and different levels should be taken into account, as partly operationalized in the RBA. The RBA first and foremost emphasizes the right of women and men to enjoy the freedom to pursue their own sustainable development. In addition, besides democratic rights it heeds the right for basic livelihood (development) requirements, such as potable water, food, shelter, and basic education and health services for all.

vi. Goals (assets), opportunities (assets/vulnerability), strategies (income intensification /diversification/ migration), implementation (locally driven and local assets and/or externally driven or supported by and based on external inputs).

vii. Different opportunities and therefore different strategies and pathways for livelihood development may exist within a certain context for different individuals, households and communities (Ellis, 1999). Often, there may be substantial scope for livelihood development within the margins of the actual PIPs (see under iv), but for other pathways, interventions aimed at changing PIPs may be needed, which will require concerted multi-stakeholder and multi-scale interventions and partnerships. However, grass root realities will always be essential as ground-truth for policy dialogue and policy advocacy initiatives at local, (sub-)regional, national and international levels.
Principles of the SLA (for policy and practice) can be summarized as follows:
1. People-centered; but with a holistic understanding (see 3, 6 and 7 below);
2. Empowering; genuinely participatory and responsive to people’s needs;
3. Based on integrated approaches/interventions;
4. Aimed at sustainability in its broadest sense; social, economic, environmental and institutional;
5. Strength-based; taking the people’s strengths, community/local assets and existing opportunities as first entry points;
6. Multi-level and multi-stakeholder; emphasizing issues of scale, multi-level partnerships and the holistic perspective;
7. Disaggregated; effective development interventions require dis-aggregation along gender, age, socio-ethnic and HIV-AIDS infection/affection lines and need to address exclusionary processes;
8. Long-term and flexible; difficult in view of donor requirements/commitments.

This section highlights some of the strengths and weaknesses of the SLA. A major weakness is that it is very difficult to compare the different types of capital assets and to assess their relative importance, especially for the less tangible capital assets that have been introduced in recent years. Any kind of comparative assessment may require time-, site- and case-specific qualitative methods. Depending on the context and target group, anticipated pathways for livelihood development and the associated priorities for targeting specific capital assets may vary within and among development strategies. Moreover, subjective considerations may play a role and priorities for building up specific capital assets may be based on disciplinary bias, whether justified or not. There exists a risk that the interdisciplinary dimensions and linkages among the different assets may be ignored too much. Disciplinary bias may be justified when having very specific objectives and/or when dealing with a dominant or overriding asset. In this context, it is often disputed whether human rights (human capital) in their broadest sense take precedence over other capital assets, as advocated in the RBA, i.e. whether they form a necessary condition for sustainable generation of (some) other capital assets. Disciplinary bias may be based on deliberate and rational choices, if capital assets are considered in a hierarchical way, but also may be disputed, if a number of non-substitutable capital assets (factors) are all essential for improvement and sustainability. Another weakness of the SLA – in particular if not including the PIPs perspective – is its rather static character, focusing on the state of the capital assets and less, at least not explicitly, on how to change these states. In addition to the challenge of comparing different types of capital assets, assessing their mutual substitutability may be even more challenging. It may be possible to make some
reasonable assessments of the potential substitutability between financial and physical capital assets. A more general assessment of substitutability of different capital assets may be limited to some rough qualitative statements, if possible at all. During its initial stages, a major point of criticism about the SLA was its too local character, ignoring holistic and multi-scale dimensions; this has been remedied at later stages.

The main strength of the SLA undoubtedly is the powerful reality check that it could generate. The SLA supports comprehensive (pre-) assessments for development interventions, based on the actual reality of people. This results in a rather complete check-list of issues of relevance for general development assessments and interventions. An explorative analysis of interrelated livelihood capital assets, factors that influence them and the relations among them, already may be an extremely useful, but often ignored, entry point for innovative R&D efforts. Such efforts may either start from an objective or neutral disciplinary basis or from a certain disciplinary angle, as long as the relevance of other disciplinary angles for results, viability and sustainability is taken into consideration, either by the SLA or related approaches.

Key to the SLA, in its broadest sense, is the need for a people-centered holistic perspective, and with the understanding that policies and institutions condition the environment within which people operate. The holistic approach is required since these different aspects cannot be treated in isolation, but need to be dealt with simultaneously as part of multi-scale development interventions (Goldman et al., 2000).

In this perspective, pathways and strategies for livelihood development may be based on alternative sustainable livelihood strategies (ALS), which may mean diversification (on- and off-farm, i.e. taking up new specializations), but for others also intensification and/or commercialization within the same sector (e.g. farming) (Wijnhoud et al., 2003). Diversification and specialization may occur subsequently or simultaneously at different levels. Diversification at household level, when non-farming activities are taken up in addition to farming, may take place simultaneously with diversification at community level, followed by specialization at household and community levels. The latter may be common transitions in developing societies, often performing as emerging economies, where economic diversification and occupational specialization are common phenomena. After income diversification through non-farming activities, some households may move fully out of farming and take up other occupations, either locally or after migration to urban areas. Others may specialize and after innovating their farming activities, may develop their farms into remunerative business enterprises. One development, particularly when educational opportunities increase, could be, an even stronger occupational change within households, based on rather specialized jobs, which may result in the disintegration of originally ‘extended’ farm households and in a reduced number of larger farms being run by smaller
households or less people often when all of the children of farmers take on non-farming jobs (Rigg, 1997).

Structural adjustment programmes (SAPs) in the 1980s and 1990s have had negative effects on the farm sector and the income of smallholders. Making a livelihood from peasant farming became increasingly difficult under the influence of market liberalization in developing countries, while market protection and financial agricultural support (subsidies) in OECD countries continued. In many developing countries it forced individuals and households to diversify income and resulted in occupational change (Bryceson, 2000). The rural population became squeezed between SAPs and bottlenecks hampering their efforts at income diversification and occupational change. Such bottlenecks relate to lack of viable opportunities for farmers to leave their land behind in a viable way – in many developing countries, remarkably many of them among the LDCs, land cannot be owned and sold –, lack of incentives to invest in farm and income diversification and lack of enabling policies and an enabling institutional environment for business and economic development. In Thailand, due to a relatively enabling environment and considerable public investment in quality education (human capital) (Rigg, 1997), opportunities were much more favourable than in many other developing countries in and outside the region. Therefore, development has been much more progressive and, not withstanding existent challenges, may set several development paradigms for the LDCs (Chapter 6).

One of the key recommendations brought forward by this thesis is that for the achievement of SNRM the minimum requirement will be to take on a sustainable livelihood approach for it (Chapter 6)

1.4. Nutrient budget studies: General use and perspectives

1.4.1. Nutrient budgets and early developments in agriculture

Principles of assessing nutrient balances or nutrient budgets, i.e. the comparison of inputs and outputs, have been at the heart of the development of plant nutrition and of agricultural science more broadly. Many examples of the early use of such analyses are outlined in the introductory section in ‘Soil Conditions and Plant Growth’, the authoritative soil science text by Russell (1961). One of the earliest studies into plant growth was the experiment of Woodward in 1699, in which he grew spearmint in water of different quality (Table 1.1). He concluded that the plants were “not formed of water, but of a certain peculiar terrestrial matter” and that the plants were “more or less augmented in proportion as the water contains a greater or lesser quantity of that matter”. Hence, although not appreciating the exact nature of the ‘terrestrial matter’, Woodward did appreciate the relationship between plant growth and inputs.
Table 1.1: Comparison of relative growth rates (RGR) of spearmint grown in water of different quality from the experiment of John Woodward in 1699.

<table>
<thead>
<tr>
<th>Water source</th>
<th>RGR relative to control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainwater (control)</td>
<td>1.0</td>
</tr>
<tr>
<td>River Thames</td>
<td>1.5</td>
</tr>
<tr>
<td>Hyde Park conduit</td>
<td>2.0</td>
</tr>
<tr>
<td>Hyde Park conduit + garden mould</td>
<td>5.0</td>
</tr>
</tbody>
</table>

The first real agricultural field experiments were done by Jean Baptiste Boussingault in the 1830s. They meant another major advance in the development of agricultural science as touching on nutrient balance principles. In these experiments, balance sheets were drawn up for different nutrients and plant constituents for a range of crops grown in different rotations. Uptake by the crops was compared to inputs in manure and those derived from other sources, with the recognition that the relative balance affected the enrichment or depletion of the soil. These studies led to those of Liebig in the 1840s and to his conclusion that “The crops on a field diminish or increase in exact proportion to the diminution or increase of the mineral substances conveyed to it in nature.” and, subsequently, to his “Law of the minimum” that “by the deficiency or absence of one necessary constituent, all the others being present, the soil is rendered barren for all those crops to the life of which that one constituent is indispensable”.

1.4.2. Increased interest in nutrient balance studies: The need for increased agricultural production

Direct or indirect assessment of nutrient budgets continued at the heart of expansion in agricultural production.

By far most nutrient balance studies include one or more of the so-called macro-nutrients: Nitrogen (N), Phosphorus (P) and Potassium (K). N is essential for the production of plant proteins. It is very mobile, both in soluble and gaseous forms. P is also essential for plant proteins, but is far less mobile and not susceptible to leaching or gaseous losses. On the contrary, P is for the larger part present in chemical components that are not directly accessible to plants. K is essential for formation, transformation and transport of carbohydrates and also for protein synthesis. Crop residues often contain considerable quantities of K, making recycling important. Although less mobile than N, and not present in gaseous forms, part of the K in the soil is mobile in solution and is therefore susceptible to leaching (Tisdale *et al*., 1995).

Application of early P fertilizers, based on basic slag, a by-product from the steel
General introduction

industry, enabled intensification and expansion of agriculture. Subsequently, artificial N fertilizers were developed and broadly adopted. In the late 20th century, intensification and expansion of food and fiber production, particularly in the developing world, were driven by the use of nitrogen fertilizers (‘Green Revolution’), often associated with mining of other nutrients, particularly K and P. In parallel, increasing understanding of the biological processes underlying plant production led to identification of ever more essential plant nutrients, allowing agricultural production on previously unused or under-utilized areas for which micronutrients, such as copper, zinc, and molybdenum, were recognized as the primary limitations.

The rapid increase in agricultural production associated with the green revolution in the last four decades of the 20th century outpaced the increase in population, so that average per capita consumption of food increased. These gains resulted from a combination of factors, i.e. an increase in the area of land cultivated, development and adoption of higher yielding varieties of the major staple crops, particularly wheat, rice, and maize, and increased use of irrigation, fertilizers, pesticides, and herbicides, which enabled realization of the yield potential of these improved varieties.

Despite improvements, in Asia per capita production has increased but with production risks in more marginal areas, including semi-arid, sloping and flood-prone lands or those characterized by ‘acid soils’, and with accessibility to food being highly unequal, resulting in food insecurity and malnutrition for still a considerable percentage of people, in particular the poorest and most vulnerable in South and Southeast Asia. With global average figures being positive, the green revolution largely bypassed sub-Saharan Africa and, due to considerable population growth per capita, food production declined, resulting in widespread food insecurity, in particular in vast areas of rainfed production under erratic rainfed conditions, but with conflicts, corruption, political turmoil and the HIV-AIDS pandemic being major barriers to address vulnerability and food insecurity through sustainable development efforts (Chapter 6). To present, the current numbers of poor, and malnourished people continue to pose a significant challenge for agricultural production in the early 21st century, admitted that part of the problem can only be addressed by acknowledgement of multi-scale socio-economic and political barriers, including factors contributing to inequalities in a globalizing world.

Population pressure

For the 10 ASEAN countries, the pressure of population growth on the demand for agricultural production is clearly demonstrated. Total population approximately doubled, from 240 million to 500 million from 1965 to 2000, and is expected to increase to approximately 720 million in 2035 (Figure 1.2).
Available land

The reserves of potentially arable land are not evenly distributed throughout the world (Alexandratos, 1995). The major part of unused land is in just 10 countries, with the largest reserves in Brazil and the Democratic Republic of Congo (DRC). In Asia, reserves are limited, with Indonesia having the largest reserves in SE Asia. Even where expansion of agricultural land is feasible, in general, the quality of that land is much lower than that of the land already under cultivation. Moreover, substantial areas of agricultural land are being lost to degradation (Penning de Vries, 2001).

It is possible to estimate current production (current average yield × current land area) and current potential production (estimated maximum yield × estimated potential arable land) and compare these to projected production and potential production estimates (Penning de Vries, 2001). Average yields may be expected to increase with time, but land degradation is likely to cause a reduction in both potential yields and potential area of land for agriculture. Although such analyses must be interpreted cautiously, results for East Asia and the Pacific, for 2000 and 2025, suggest significant potential for expansion of agricultural production until 2025, but very limited potential after that (Figure 1.3). Results of such analyses differ for different regions of the world, with wide variations in land reserves and/or yield gaps.
Global fertilizer use

The recent increases in agricultural production have been associated, almost proportionally with increases in the use of fertilizers. In fact, the differential increase in agricultural production in different regions is related directly to the expansion in fertilizer use, which has been greatest in parts of Asia, especially China, and least in sub-Saharan Africa. By far the greatest contribution to the increase in fertilizer use is largely accounted for by N fertilizer, with much lower growth figures, and even a recent decline in absolute terms for K and P fertilizers (Figure 1.4).

To meet the challenge of providing adequate food to all regions of the world, agricultural production must increase substantially and land degradation must be reduced and eventually reversed. This will require appreciable increases in resource utilization efficiency and the development of more sustainable production systems. While many aspects of production systems need to be addressed, the efficient use of nutrients is critical, which explains the recent high interest in nutrient balance analyses.

1.4.3. Nutrient budget analyses: How and why?

Issues of scale and system boundaries

Nutrient balance analyses or nutrient budgeting can be performed at very different
Figure 1.4: Global trends in the use of N, K, and P fertilizers (Tg y\(^{-1}\)) from 1965 to 1995 (Source: FAOSTAT, undated).

scales, with different aims, and using different methods. The scales of analysis can vary enormously, depending on their objective(s). Scale categories are not fixed, but schematically, analyses can be classified in field or farm level, district, province or country level, and regional, \textit{i.e.} (sub)-continental, or global level. Analyses at different scales often have different objectives for input management and general sustainability management, \textit{i.e.}:

<table>
<thead>
<tr>
<th>Scale:</th>
<th>field/farm</th>
<th>district/country</th>
<th>region/globe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizers/inputs:</td>
<td>recommendations</td>
<td>distribution</td>
<td>production/trade</td>
</tr>
<tr>
<td>Management tool:</td>
<td>farm sustainability</td>
<td>infrastructure/policy</td>
<td>trade/aid / policy</td>
</tr>
</tbody>
</table>

A major application for nutrient balance analyses is in management of fertilizers and other nutrient input sources. At field and farm level, such analyses can be part of the process of developing recommendations or decision support systems for inorganic and organic inputs. At higher levels, they can be used in planning the geographic distribution of inputs, such as fertilizers, to match supply and demand. At still higher levels, such information is valuable for developing strategies for the production and/or import of fertilizers. In a slightly different way, nutrient balance analyses feed into management tools at different scales. At field and farm level, they can be utilized to develop land use plans, including annual and multi-annual/perennial cropping patterns, management of cultivation, irrigation, and fertilizer application, and as part of economic analyses. At higher levels, they are a management tool for developing
infrastructure (roads, storage, etc.), government policies and strategy development for the private sector as often being interrelated by regulations or based on partnerships. At supra-national level, they can be used for planning trade and aid policies and for (sub-)continental and global environmental management, including inherent agendas for policy research.

Another important application for nutrient balance analyses is increasing insight in processes, *i.e.* in nutrient, carbon, and hydrological cycles, again for different objectives and at different scales with different levels of accuracy. As space has three dimensions, in addition to the horizontal dimension (geographical scale), depending on the system and objectives a decision about the vertical dimension (scale) has to be taken. The latter may be critical for the outcome of nutrient balance analyses. It may not always be easy to choose the vertical spatial unit as defined by lower and upper boundaries, and apart from based on expert knowledge this may be partly done in an arbitrary way. Often only the most relevant layer for crop growth, the topsoil, is considered. However, it may depend on the crop variety involved what would be an appropriate definition (dimension), as referring to the depth of the topsoil. Such decisions get even more complex when multiple cropping systems are studied. Nutrients are flowing from the topsoil into the sub-soil by the process of leaching. In turn, they may be subtracted from the sub-soil and brought in the system again by deep rooting crops, but also through capillary rise, meaning not all leached nutrients will be automatically lost in the long term (Wijnhoud and Lefroy, 2001).

For nutrient balance analysis involving land-use systems with perennials, like *e.g.* rubber trees, one could argue that the most appropriate upper boundary of the vertical reference unit for nutrient balance analysis will be the top of the biomass layer. Nutrients taken from the soil are retained within (largely) perennial biomass. This means there is a (in upward direction) shifting upper system boundary and increasing spatial vertical unit as crop growth proceeds (Wijnhoud and Lefroy, 2001).

For annuals and perennials the choice of the lower boundary will depend on crop and system and arbitrarily defined. The maximum rooting depth of a full-grown crop could be chosen as lower boundary, or the depth were *e.g.* 75 or 90% of the roots of mature crops are encountered. The choice on the lower system boundary gets more complex in case of multiple cropping (rotational and mixed) systems. This includes very complex situation of mixtures between relatively shallow rooting annuals and deep rooting perennials (Wijnhoud and Lefroy, 2001).

For realistic analysis, *e.g.* in case of modelling plant-nutrient interactions, one single and/or static lower boundary may result in incorrect or insufficient accurate results, more specifically for complex systems or those characterized by large temporal variations. Therefore, assessment of nutrient balances for more than one vertical
spatial unit, having more than one lower boundary, and/or for vertically varying spatial units having (downwards) shifting lower boundaries would be appropriate, however difficult to implement (Wijnhoud and Lefroy, 2001).

**The mechanics of nutrient balance analyses**

Depending on scale, interest, and opportunities for measurements or estimates, different analyses cover different parts of the nutrient cycles. The main input and output flows that are included are given in Tables 1.2 and 1.3, with a qualitative indication of the ease with which these characteristics can be monitored in nutrient

<table>
<thead>
<tr>
<th>Input</th>
<th>Characteristic</th>
<th>Monitor</th>
<th>Manage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer</td>
<td>rate/source</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Organics</td>
<td>residues/rate/quality</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>BNF</td>
<td>cropping system</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Irrigation</td>
<td>quantity/concentration</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Rainfall</td>
<td>quantity/concentration</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>quantity/concentration</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
</tbody>
</table>

| Sum of inputs  | ✓ ✓                      |

= can be monitored/managed easily; ✓ = can be monitored/managed;
* = limited capacity to monitor/manage; - = cannot be monitored/managed.

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Characteristic</th>
<th>Monitor</th>
<th>Manage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>harvest</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Residues</td>
<td>residue recycling</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Run-off</td>
<td>cropping system/tillage</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Erosion</td>
<td>mulch/groundcover</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Leaching</td>
<td>irrigation</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Gaseous</td>
<td>fertilizer/water management</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
</tbody>
</table>

| Sum of outputs | ✓ ✓                      |

= can be monitored/managed easily; ✓ = can be monitored/managed;
* = limited capacity to monitor/manage.
balance studies and managed within farming systems. For instance, nutrient application in fertilizer can be, both, monitored accurately and managed easily; application of organics can be managed fairly easily, but accurately estimating application rate and nutrient content is more difficult. Other input and output flows, such as irrigation, erosion, and sedimentation can be affected by management, but are very difficult to monitor. Rainfall can be measured easily, but its nutrient content is measured less frequently, and there is no practical way to manage either of these characteristics.

Types of nutrient balance analyses
In addition to, and within the variations in the scale (field to global) of the analyses and the objectives of the studies (from management to policy, and to understand the process), a number of further variations in the types of analyses can be distinguished.

Complete or partial: The analyses can vary in completeness, both in terms of the number of nutrients included and, more importantly, in the number of input and output factors considered. An even broader set of input and output factors than included in the Tables 1.2 and 1.3 can be distinguished in order to get closer to the assessment of full nutrient balances. Examples of additional inputs are tree leaves blown in from outside the system, recovery by deep rooting weeds / trees, weathering /sub-surface gains, input of seeds / seedlings, run-on / subsurface inflow / capillary raise, inflow of soil fauna / purchase of livestock and human excreta and waste material. Examples of additional outputs are grazing / forage collection, deep ploughing of nutrients, deep roots that are not harvested or ploughed back, weeding, tree leaves and organics blown out, fixation into non-accessible compounds, removal of fauna / sale of livestock products, sewage and waste products leaving the system, energy maintenance of humans and livestock (Wijnhoud and Lefroy, 2001).

Many of such factors may only be relevant either for precision assessment or if of relevant magnitude in a specific system. Precision assessment may only be feasible up to a certain limit and depends on investments in measurements and accuracy at small spatial scales.

Taking into account the difficulties involved in accurately monitoring certain flows (Tables 1.2 and 1.3), instead of a full nutrient balance analysis it may be considered more useful to perform a more accurate partial analysis, including only the input and output factors that can be measured with reasonable accuracy. Such partial budgets have to be interpreted cautiously, acknowledging the flows that have been excluded, whereas in complete budgets the differences in accuracy of the different factors have to be taken into account. A more accurate partial budget may be easier to interpret than a complete budget that suggests unwarranted accuracy.
Temporal aspects: Nutrient balance analyses can be performed as a one-time effort that provides a ‘snapshot’ of the situation. A one-time instantaneous or snapshot measurement determines merely the state (of a system parameter; e.g. nutrient pool) at a certain moment, whilst through continuous monitoring the gradual change in state is studied. Periodical measurement may fall in between continuous screening and a one-time measurement over a defined period (time unit). The latter could be done for equal time intervals, i.e. periods (daily, weekly, growing season, annually, etc.) or unequal time intervals tailored towards the ‘system’ under research, such as crop development stages (of unequal duration). Rate and state of nutrients may also be linked to certain (management) interventions or natural occasions (e.g. fertilizer application, rainfall, flooding etc.) with the state to be measured just before and after such processes (Wijnhoud and Lefroy, 2001).

In most cases, all that is required is assessment of inputs and outputs over a given period, often on an annual basis or for one growing season. However, where the aim is to increase understanding of the underlying processes, a more continuous monitoring is required, to capture the dynamic nature of nutrient cycles.

Data sources: The information required for nutrient balance analyses can originate from a mixture of sources. The most accurate estimates are derived from direct measurements of the quantities of nutrients transferred in each flow. Many of the flows can be estimated with reasonable accuracy by using a combination of observations, interviews, and secondary data. The accuracy of such estimates is closely related to the rankings in Tables 1.2 and 1.3. For instance, interviews can provide satisfactory estimates of the amounts of fertilizer applied and secondary data provide the quantities of nutrient(s) applied in the fertilizer. Nutrients applied in organic matter are less easily quantified. While the quantity, usually the volume, applied can be determined with reasonable accuracy, dry matter and nutrient content are less easily estimated. Many farmers can provide reasonable estimates of crop yield, and local secondary data can be used with reasonable accuracy for estimating nutrient contents. This does not hold for nutrient removal in residues, as farmers generally can not provide accurate estimates of the quantities of crop residues removed, let alone their nutrient content, and although they are related to crop yield, the relationship is not unique. Some of the other flows, such as inputs through biological nitrogen fixation, irrigation, rainfall, and sedimentation, and outputs in run-off, erosion, leaching, and gaseous losses are more difficult to measure and to estimate.

Nutrient availability: Complexities are related to the availability of nutrients to crops and plants, like for example how to account for less available nutrients in certain
resistant soil minerals where in turn availability may depend on variety/crop/plant characteristics e.g. with certain varieties of certain crops being better able to get access to certain P-pools than other varieties/crops. Another example related to complexities how to go about NBA, is for example how to account for nutrients in systems where the majority of certain nutrients are ‘stored’ for short (leaves) and longer (stems, roots) terms in large amounts of biomass, like for tropical forests. It could be decided instead of soil nutrient balance assessment alone to include the biomass as part of the system (Wijnhoud and Lefroy, 2001).

1.4.4. Examples of nutrient balance analyses

Biogeochemical cycles
Detailed analyses of global nutrient cycles have been used frequently to study environmental and ecological impacts of human activities. Examples are studies of natural and anthropogenic cycles of nitrogen and sulphur at different scales, i.e. the atmospheric, the continental, and the local, and for different ecosystems and agro-ecosystems (Galloway et al., 1985; Howarth et al., 1992).

Early applications in sub-Saharan Africa
In the last three decades, both agricultural and environmental scientists have worked on methods to assess deficits and surpluses of nutrients through NBA. These were largely driven by biophysical research interests and aimed at improvement and biophysical sustainability of agricultural production systems (Penning de Vries and Djitèye, 1982; Pieri, 1985, 1989; Proctor, 1987).

The NUTMON model developed in Wageningen (Smaling and Fresco, 1993) formed the basis for one of the better known series of nutrient balance studies. In an initial study, N, P and K balances were estimated for roughly defined Land-Use Systems at the national and sub-continental levels in sub-Saharan Africa using secondary data sources (Stoorvogel and Smaling, 1990). For this continental study they used the following conceptual nutrient balance model, which includes five nutrient input components and five output components:

\[
\text{NB} = (\text{IN1} + \text{IN2} + \text{IN3} + \text{IN4} + \text{IN5}) - (\text{OUT1} + \text{OUT2} + \text{OUT3} + \text{OUT4} + \text{OUT5})
\]

Inputs:
1: Mineral fertilizers
2: Manure and other organic inputs
3: Deposition by rain and dust
4: N-fixation
5: Sedimentation

Outputs:
1: Harvested product
2: Removed crop residues
3: Leaching
4: Gaseous losses
5: Erosion
These are the most relevant in- and output factors, in particular for reconnaissance studies at large spatial scales (Wijnhoud and Lefroy, 2001). Even if some of the above input or output components will be omitted from the ‘black box’ model, partial nutrient balance analyses (PNBA) based on the relatively accurate, rapid, and simple assessment of partial nutrient budgets, can be of great value if due consideration is given to the possible magnitude of the (full) balance factors that are not included (Wijnhoud and Lefroy, 2001), which may be possible at smaller spatial scales. A more complete set of input and output flows than used by Stoorvogel and Smaling (1990) may be required to more closely approach full nutrient balances as relevant for accurate precision assessment (Wijnhoud and Lefroy, 2001). This is only feasible to a certain extent and at small spatial scales, depending on investments in measurements and accuracy (Wijnhoud and Lefroy, 2001). Moreover, the ‘black box’ complete nutrient balance model merely accounts for the net nutrient in- or outflow for a certain system although efforts to look inside the box, such as studies about nutrient pools and availability may have much additional value for practical applications (Wijnhoud and Lefroy, 2001).

The analysis by Stoorvogel and Smaling (1998) divided the 38 countries analysed, into four main categories of annual nutrient depletion rates (Table 1.4).

Clearly, such national level assessments have little value for developing site-specific fertilizer recommendations and even run the risk of being misinterpreted for inappropriate blanket recommendations (Eyasu Elias, 2002; Wijnhoud et al., 2003; Chapter 4), but they remain relevant for agronomic and environmental management, including awareness creation and (lobby for) policy development / revisions at national level.

NUTMON analyses have been extended to other regions, particularly Central America, and for different scales with variations of nutrient balances within regions being assessed and comparisons between regions being made (Stoorvogel and Smaling, 1998).

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>22</td>
<td>2.5</td>
<td>15</td>
</tr>
<tr>
<td>Low</td>
<td>&lt; 10</td>
<td>&lt; 1.7</td>
<td>&lt; 8.3</td>
</tr>
<tr>
<td>Moderate</td>
<td>10–20</td>
<td>1.7–3.5</td>
<td>8.3–16.6</td>
</tr>
<tr>
<td>High</td>
<td>20–40</td>
<td>3.5–6.6</td>
<td>16.6–33.2</td>
</tr>
<tr>
<td>Very high</td>
<td>&gt; 40</td>
<td>&gt; 6.6</td>
<td>&gt; 33.2</td>
</tr>
</tbody>
</table>

Table 1.4: Categories of annual nutrient depletions (kg ha⁻¹) in sub-Saharan Africa (Stoorvogel and Smaling, 1990).
In the footsteps of Stoorvogel and Smaling (1990), nutrient balances for the whole of Africa were assessed by Henao and Banaante (1999). The fertilizer niche of Henao and Banaante (1999) directly becomes clear by their interpretation of negative balances as indicators for nutrient replenishment requirements, and like Buresh et al. (1997), they are advocating for soil fertility replenishment in Africa.

Nutrient balances in integrated analyses
Drechsel and Gyiele (1999) re-analysed the country-level N, P and K balances for sub-Saharan Africa (Stoorvogel and Smaling, 1990) in economic terms and calculated an average cost in nutrient losses of 7% of agricultural GDP across the 38 countries covered by the study.

Some interesting work has been published on the relation between land pressure and soil nutrient depletion. Tiffen et al. (1994) suggest that increased population pressure often leads to better soil husbandry because agricultural intensification related to population growth makes people more inventive in managing their resources. Their work was highly criticized by Simpson et al. (1996) for neglecting the higher outflow of nutrients as a result of higher yields under intensification. Based on the broad country-level data provided by Stoorvogel and Smaling (1990) a moderate to strong correlation was found between rural population density and negative N-balances for SSA (Drechsel et al., 2001), data not supporting the conclusions of Tiffen et al. (1994). Based on a study in Northern Nigeria by Harris (1998) the conclusion drawn by Tiffen et al. (1994) should not be put aside completely. Likely the specific context regarding livelihood standards, agricultural innovation and overall economic performance are essential factors (Boyd and Slaymaker, 2000).

Within the actual global agricultural situation there exists further evidence of highly intensive, but sustainable agriculture in many of the OECD countries, which is certainly strongly linked to high socio-economic standards. This supports the theory that enabling environments and real socio-economic developments provide the key towards intensified sustainable agriculture. It supports the case of the need for integrated approaches that address issues within dynamic resource management domains (Chapter 2), dealing at the same time with biophysical, socio-economic, cultural and political factors involved (Syers and Bouma, 1998; Konboon et al., 2001). An enabling environment, with better access to resources, often is a key factor for better and more intensified agricultural practices.

In combination with socio-economic data and analyses, nutrient balance analyses may assist in identifying and investigating socio-economic factors that are relevant for land management and farm performance, and in examining how land management and farm performance may affect socio-economic well-being, and vice versa (Chapter 5).
Chapter 1

Applications in Asia
Even though nutrient balance work in Asia is increasing, R&D based on nutrient balances is not as widespread as in sub-Saharan Africa and mainly related to minor activities in larger programmes. Examples of case studies in Asia include watershed-level modeling of soil nutrient budgets (N and Ca) for a catchments in the Nepal Middle Mountains (Brown et al., 1999), the assessment of sulphur balances at the country level (Blair and Lefroy, 1987), and assessment of broad-scale nutrient balances (N, P and K) for Northeast Thailand, based on agricultural statistics and secondary data (Lefroy and Konboon, 1998).

Nutrient budget assessments have been compared for sloping land practices at experimental sites in China, the Philippines, Vietnam, Indonesia, and Malaysia (Santoso et al., 1995) and for different agro-ecosystems in Vietnam, Thailand, and the Philippines (Patanothai, 1998). These activities reveal some interesting results, but also point at the existence of major information gaps.

Decision support systems based on partial and complete nutrient balances
Partial sulphur (S) balance studies in Indonesia, Malaysia and Thailand have demonstrated the benefits for fertility management through improved fertilizer recommendations of improved understanding of specific parts of nutrient cycles, such as fertilizer applications, S in rainfall, etc., without attempting to measure or estimate the whole nutrient balance (Blair and Lefroy, 1987, 1990). In other cases, studies of specific components have been combined into complete balances as a basis for nutrient management decision support systems. An example is the study of Dobermann and White (1999), in which N, P and K inputs and losses have been estimated for a lowland rice system that yields between 4 and 6 t ha⁻¹ of grain. This type of complete (or more complete) nutrient balances is the forerunner of decision support systems that are being developed to enable more site-specific nutrient management recommendations using available knowledge, transfer functions and expert systems, rather than extensive on-site experimentation (Dobermann et al., 2004; Chapter 4).

Using nutrient budget analysis for integrated environmental and socio-economic accounting, based on the valuation or costing of nutrients and (partial) nutrient balances, makes NBA powerful for decision support from both a biophysical and (socio-) economic perspective (Chapter 5).

1.5. Conclusions
The principles of nutrient budgeting have increasingly been used for a range of purposes and scales, from ecological to agricultural, from policy to research on underlying mechanisms, and from global to field level.
In the agricultural realm, nutrient balances, even partial balances, can provide useful insights and information on productivity and sustainability at different scales. Perhaps the two main areas of interest will remain the field and farm level, for improved nutrient use, economic return and sustainability, and at the country level, for developing and monitoring agricultural and environmental policies, such as fertilizers, principally imports, production, distribution and subsidies.

While precise and accurate measurement of all nutrient inputs and outputs can be undertaken and justified in studies on the mechanisms of nutrient dynamics, in general, the critical issue in the budgeting process is to achieve an appropriate level of accuracy with minimal complexity and effort in measurement or data collection. Herein lies the greatest weaknesses of nutrient balance studies: either the inaccuracies in measurements or estimates in the component inputs or outputs, especially in complete balance studies, or accurate partial balances are invalidated because of the exclusion of critical parts of the nutrient cycles. The key lies in the interpretation of the nutrient budgets. In some situations, a more accurate partial balance that is interpreted with appropriate caveats is more useful than a far less accurate complete balance that relies on poor estimates of certain components. In other cases, loss of overall accuracy in the balance, but with inclusion of all parts of the cycle, may be more useful. In the former situation, the risk is that caveats may be ignored, in the latter that unwarranted accuracy will be ascribed to the total balance data.

Like also concluded by Scoones and Toulmin (1998), it is important that nutrient balances, whether partial or complete, should not be used in isolation, neither for policy nor for farm-level fertility management recommendations, and may rely on additional expert knowledge not always and alone of scientist but also of extension workers or the farmers themselves.

In general, it can be stated that soil fertility management recommendations should aim to reinforce input factors that are correlated with positive nutrient balances and eliminate or reduce output factors that are correlated with negative nutrient balances. For most of the direct input and output factors, their influence on nutrient budgets are clear, however for other indirect factors their influence possibly could be quantified better, if possible in their site and case-specific context, which particularly holds for a number of socio-economic factors (Chapter 5), but mostly appropriately in their site- and case-specific context. Nutrient budget analyses present great potential for use in integrated environmental and socio-economic (rural) analyses and for integrated rural development strategies as demonstrated and described in this thesis.
CHAPTER 2

Case study in Northeast Thailand: Rationale and methodology*

Abstract
This chapter provides the background, rationale and methodology of NBS-NET (nutrient balance studies in Northeast Thailand), a collaborative research and development (R&D) activity in Northeast Thailand. The R&D activity explicitly examines the relevance of integrated nutrient budget, soil fertility management and livelihood analyses. One direct aim of NBS-NET was sustainability assessment of rainfed lowland rice-based systems.

A first objective was the characterization of the dynamic resource management domain (DRMD), both with respect to general aspects and developments and with respect to bottlenecks and challenges for R&D aimed at sustainable natural resource management (SNRM), emphasizing soil fertility management, and improved livelihoods (Chapter 3). A second set of core objectives relates to assessment of some biophysical aspects of SNRM through multi-scale assessment and interpretation of partial nutrient balances (Chapter 4). A third set of objectives dealt with the relation between farm performance, livelihood development and SNRM, which was investigated by studying the relationships between agricultural production, biophysical and socio-economic factors (Chapter 5). A fourth objective was to investigate the possibilities for integrated environmental and socio-economic accounting, starting from nutrient management, partial nutrient balances and the valuation or costing of nutrients and partial nutrient balances (Chapter 5). By drawing on aforementioned objectives and methods, a fifth objective was to identify and develop some of the basic elements of a decision support tool (DST) aimed at dynamic and site-specific decision support for improved soil fertility management, SNRM and improved and sustainable livelihoods (Chapters 4 and 5).

The chapter elaborates further on the NBS-NET methodology. NBS-NET serves as an exemplary and paradigmatic case, including prototyping elements, for innovative approaches to integrated rural development strategies and advocates for their broad adoption in Northeast Thailand and developing countries in general.

2.1. Introduction

2.1.1. Background and rationale
Northeast Thailand is an important area for rice production and a major source of high quality rice for export. Average rice yields in Thailand are low (2.2 Mg ha⁻¹), and those of the low input systems in Northeast Thailand are the lowest in the country (1.8 Mg ha⁻¹). The prevailing sandy soils are infertile and declining soil fertility is widespread in many agro-ecosystems in the region, including the dominant rainfed lowland rice-based systems. Agricultural management and planning is further complicated by a combination of erratic rainfall and significant micro-topographic variability. The region has a Tropical Savannah climate (Köppen ‘Aw’) with two distinct seasons, a dry season from November to April and a rainy season from May to October, with average annual rainfall between 1300 and 1500 mm with a slightly

* Major parts of this chapter were derived or adapted from: Wijnhoud et al. (2000); Wijnhoud et al. (2001), Konboon et al. (2001) and Wijnhoud et al. (2003).
bimodal character (peaks in May–June and August–September). Increased demand for agricultural produce has led to continuing deforestation and expansion of agriculture, including rainfed rice systems, into more marginal areas. Inappropriate management of these areas has resulted in their rapid degradation. Some of the lower parts of the areas under rainfed lowland rice-based systems are affected by salinization, partly caused by human-induced hydrological changes (Yuvaniyama, 2001).

The socio-economic structure of the small, but steadily growing non-farming sector in the region is relatively weak, as evidenced by the lowest socio-economic development indicators in the country, including lowest average income (OAE, 1999). It is likely that the Southeast Asian economic crisis of the 1990s has increased the rate of interrelated social and environmental decline (Miyagawa et al., 1998; ADB, 1999).

Within the context of intertwined socio-economic and biophysical constraints, current practices in rainfed lowland rice-based systems have raised concerns with respect to sustained production (Politanee et al., 1998) and to sustainability in its broadest sense (Smyth and Dumanski, 1993; Lefroy and Konboon, 1998; Lefroy et al., 2000). In their framework for evaluation of sustainable land management (SLM), synonymous to sustainable natural resource management (SNRM), Smyth and Dumanski (1993) distinguish five ‘pillars of sustainability’ that need to be satisfied simultaneously: productivity, stability or risk avoidance, economic viability, socio-cultural acceptability, and maintenance of the resource base, or protection (Chapter, 1). Konboon et al. (2001) suggest that, because of the complexity of the issue, bottlenecks that constrain rural research and development (R&D) can only be addressed efficiently through innovative approaches, particularly participatory and interdisciplinary activities within the context of resource management domains (RMDs) (Syers and Bouma, 1998). This involves considering the overall biophysical, economic, socio-cultural and political setting of the activities, so that development strategies can be implemented effectively in the particular location and their performance assessed, with the purpose of deriving general rules for extrapolation and scaling-up of R&D activities to more or less identical RMDs (Syers and Bouma, 1998). Both, the spatial dimensions of an RMD and its non-spatial level of complexity are purpose- and information-driven (Kam and Oberthür, 1998). In addition to the broader disciplinary and spatial context, the temporal context is an important determinant of the success of R&D activities (Wijnhoud et al., 2001; Wijnhoud and Lefroy, 2001; Wijnhoud et al., 2003). The broader concept of dynamic resource management domains (DRMD) therefore, is a valuable addition to the RMD concept, as it explicitly emphasizes the relevance of temporal variability, change and development.

Nutrient balance analyses (NBA) are considered useful for interdisciplinary and participatory R&D activities in Northeast Thailand, especially those primarily aimed at
designing improved and sustainable nutrient and land management systems (Konboon et al., 2001). This also holds for partial nutrient balance analyses (PNBAs), if consideration is given to additional factors required for full nutrient balance analyses (FNBA; Wijnhoud et al., 2001; Wijnhoud et al., 2003). P/FNBA are important components of biophysical sustainability assessments and may serve as component indicators in broad-scale sustainability assessments (Smyth and Dumanski, 1993; Lefroy et al., 2000; Coughlan and Lefroy, 2001). Because of the relatively simple logic utilized, nutrient budget analyses are useful for training farmers and extension workers in appropriate nutrient management practices (Defoer et al., 1998; 2000). In addition, NBA can serve as a template for economic accounting and financial assessment of nutrient depletion and surpluses (UNSD, 1993; De Jager et al., 1998a, b; Drechsel and Gyiele, 1999; Moukoko-Ndoumbe, 2001). Moreover, in combination with socio-economic data, nutrient budgets can support identification of factors important for sustainable management of land, and development of improved recommendations aimed at both biophysical and socio-economic aspects of sustainability. Hence, nutrient budgets are expected to be useful as core elements in integrated decision support systems (DSS) and related decision support tools (DST), aimed at improved and sustainable land management. However, problems remain in measurement and interpretation of nutrient budgets and, at best; they represent one component of sustainability. Added analyses, for example of livelihood patterns and development, form part of a broader framework for decision support on pathways towards sustainable and improved land management and improved livelihoods in a DRMD-context.

The case reported here, started as nutrient balance studies in Northeast Thailand (NBS-NET), a collaborative R&D programme between Ubon Ratchathani Rice Research Center (URRC), under the Rice Research Institute (RRI) of Thai Department of Agriculture (DOA), and the International Board for Soil Research and Management (IBSRAM). The programme was pivoted around PNBA in Ubon Ratchathani Province of Northeast Thailand, initiated in 1998 (Konboon et al., 2001; Wijnhoud et al., 2000, 2003).

The study focused on farms characterized by land-use systems (LUS) based on rainfed lowland rice, the dominant LUS in the province and in much of the region. Predominantly, these LUSs are mono-crop rice systems in a seasonal lowland environment; however, where irrigation water or sufficient residual soil moisture is available, pre- and/or post-rice crops, such as peanuts, vegetables or dry-season rice, may be included. This chapter is the first of four (Chapters 2–5), constituting the overall report of the collaborative R&D programme at the core of this thesis.
2.1.2. Goal and objectives

One direct aim of NBS-NET was sustainability assessment of rainfed lowland rice-based systems. In addition to sustainability assessments and direct decision support for SNRM and livelihood development, NBS-NET aimed to contribute to methodology development for flexible and user-friendly approaches and decision support for SNRM and livelihood development.

Initially, emphasis was on PNBA at farm and sub-farm levels, as an input in recommendations aiming at protection or maintenance of the resource base, a condition for continued or sustainable production. A multi-scale nutrient balance study, supplemented by socio-economic analyses and discussions of farmer perceptions, served as the basis for a more extensive analysis aimed at highlighting and discussing some of the potential applications of nutrient budgets within integrated R&D approaches aimed at SNRM and improved and sustainable livelihoods. The study therefore aimed at designing prototype analysis methods and at identifying a paradigm for integrated development studies with similar elements for – scaling-up to and implementation in – more or less similar DRMDs.

The ultimate goal was to illustrate the usefulness of and need for more holistic and interdisciplinary approaches, and the possible contribution of NBA, livelihood analysis and integrated environmental and socio-economic accounting, in generating information relevant in addressing the daunting twin challenges of SNRM and improved and sustainable livelihoods. Methodologically, the study might serve as a paradigm. Moreover, it includes prototype elements and analyses that could be applied in other studies.

Within the study, a first objective was DRMD characterization, both with respect to general aspects and developments and with respect to bottlenecks and challenges for R&D aimed at SNRM, emphasizing soil fertility management, and improved livelihoods (Chapter 3). In the introductory part of the methodological section (Section 2.2.1), consideration is given to the feasibility of implementation of innovative R&D approaches, in relation to context and constraints.

A second set of core objectives relates to the assessment of some biophysical aspects of sustainability through multi-scale assessment and interpretation of partial nutrient balances (Chapter 4). Partial nutrient balances were assessed at four levels, increasing in scale from the land utilization type (LUT), via the field and farm to the sub-district. A LUT is a unique cropping system-management combination implemented at the field level or a section of it. Theoretically, a LUT could cover more than one field, but in the present study the (sub-)plot level was taken as the smallest and unique data collection unit. Hence, several different LUTs may occur in the same field, if the field is managed differently in terms of inputs, cropping systems/varieties, or other distinct management factors. Specific objectives were:
• To study the sustainability of rainfed lowland rice-based systems, within the limits set by the methodology.
• To study spatial variability in partial nutrient budgets and sustainability among and within farms and at broader scales, by considering data sets for a range of farms.
• To study biophysical, management and methodological factors that influence partial nutrient budgets.
• To relate partial nutrient budgets to full balances through investigation of direction and magnitude of factors in the full nutrient balances that are not included in the partial balances. This includes considerations about spatio-temporal variability and therefore site-, time- and case-specific aspects.
• To investigate the applicability and practical use of the methodology for assessment of the biophysical sustainability of LUTs, including identification of bottlenecks and specific points of attention.

A third set of objectives dealt with the relation between agricultural production, biophysical sustainability and socio-economic characteristics, which was investigated by studying the relationships between farm performance and various biophysical and socio-economic factors (Chapter 5).

Specific objectives were:
• To identify and investigate socio-economic factors that are relevant for land management and farm performance, as well as the influence of land management and farm performance on socio-economic well-being.
• To analyse the variability in farming systems (FS) and livelihood patterns and their possible linkage to SNRM, also in a dynamic context.

A fourth objective was to investigate the possibilities for integrated environmental and socio-economic accounting, starting from nutrient management, partial nutrient balances and the valuation or costing of nutrients and partial nutrient balances (Chapter 5).

A fifth objective was to identify and develop some of the basic elements of a DST based on partial nutrient balances, aimed at dynamic and site-specific decision support for improved soil fertility management, SNRM and improved and sustainable livelihoods. This objective is dealt with throughout the description of the case study, in particular in Chapters 4 and 5.
2.2. Methodology

2.2.1. New approaches and concepts for SNRM and improved livelihoods

R&D efforts, including those in Northeast Thailand, too often have failed in the past, because of their too narrow focus in space and time and/or a too narrow focus on technical aspects (Wijnhoud et al., 2003) For example, it would be inappropriate for R&D in Northeast Thailand to focus on improving rice systems without considering alternative agricultural and rural development options. The ultimate aim is to arrive at improved and sustainable livelihoods for the rural population as a whole, in combination with protection of the natural resource base. In this process, some people may move to specialized non-agricultural livelihoods, at the same location and/or in urban centres, and others to better managed and less risky farm enterprises, possibly with strongly reduced reliance on rainfed rice. The focus of overall R&D agendas at district, provincial, regional and national levels should therefore not exclude, but rather anticipate on and contribute to diverse options, covering economic diversification, agricultural innovation, SNRM and livelihood development (Wijnhoud et al., 2003; Chapters 1, 3 and 6).

Attaining SNRM and improved and sustainable livelihoods in the complex and dynamic reality of Northeast Thailand (see Chapter 3), needs broad participatory and interdisciplinary efforts (Konboon et al., 2001). Such efforts are indispensable in order to breach the vicious circle of unsustainability (Rhoades and Harwood, 1992) and counteract the environment-poverty downward spiral (McCowan and Jones, 1992), associated with the interrelated unfavourable biophysical and socio-economic conditions and constraints (see Chapter 3).

Rhoades (1998, 2000) provided an important contribution to the discussion on the relevance and bottlenecks of new approaches to rural R&D, mainly dealing with the successes and failures of participatory and interdisciplinary catchment approaches. Part of that discussion is relevant in the context of the nutrient balance activities in Northeast Thailand. Participatory and interdisciplinary approaches and the DRMD concept, although useful in theory, cannot be easily implemented in all situations. Many projects applying these methodological approaches do not realize their objectives, because assumptions are unrealistic and/or bottlenecks related to implementation are overlooked. Such bottlenecks can be institutional, socio-cultural, or relate to time and resource constraints. Comprehensive participatory and interdisciplinary R&D is difficult and, in practice, is rarely implemented in full. It may often be better to follow a more gradual and realistic approach in projects; awareness of the need for participatory and interdisciplinary methods can be an important first step towards making R&D more relevant to society and efficient in reaching its
objectives. Partial implementation of some elements of the approaches can result in major improvements in R&D.

Although the research reported here did not follow a full participatory and interdisciplinary approach, research questions were assessed from different disciplinary angles, while the problems and demands of farmers, as well as the anticipated dynamics were considered with great care. In part, when data were collected and analyses were done together with farmers and findings were used for improved nutrient management, ‘participatory learning and action research’ (PLAR) principles were followed, in line with developments that took place for soil fertility management systems in sub-Saharan Africa (Defoer and Budelman, 2000). Besides, research was, as much as possible, placed within its DRMD context, even though the current project capacity only allowed for approximate identification and delineation of the various DRMDs within Thailand and the region. They include the, under the influence of internal and external driving factors, ever-changing and currently diversifying, rainfed lowland rice-based rural economies of Thailand and other parts of Southeast Asia (Rigg, 1997).

2.2.2. General DRMD characterization
Based on the study goal, objectives, priorities and available capacity, NBS-NET started with a general DRMD characterization (Chapter 3). On the basis of available statistical data and introductory studies, with major emphasis on soil fertility, livelihoods, rainfed lowland rice-based systems and bottlenecks and opportunities for R&D, the DRMD characterization followed a purpose- and information-driven approach (Kam and Oberthür, 1998). Attention was paid to analyses of some of the dynamic aspects of the DRMD, which especially dealt with land-use and agricultural change over two decades, also considering some of the most recent developments, including the effects of the economic crisis of the late 1990s. More focused analyses were provided by the introductory explorative desk study on nutrient balances for land-use systems in Northeast Thailand (Lefroy and Konboon, 1998) and an introductory state-of-the-art overview on R&D for nutrient management in rainfed lowland rice-based agro-ecosystems in Northeast Thailand (Konboon et al., 2001). This includes an overview of promising research topics for agricultural, environmental and rural development. Major aspects and conclusions of these studies contributed to the overall DRMD characterization, relevant to a wide spectrum of work that followed within NBS-NET.

2.2.3. General survey method and issues of scale
During the 1998 growing season, a pilot study was performed on 10 farms in Muang
Chapter 2

District of Ubon Ratchathani Province (Figure 2.1), characterized by the dominant rainfed lowland rice-based LUS (Wijnhoud et al., 2000). During the 1999 growing season, a more comprehensive survey of 30 farms with similar LUSs, was carried out in two sub-districts of the province: in Seped, Trakan, Phutphon District, and in Naruang, Nayea District (Figure 2.1). The 30 farms included a total of 58 fields, in which 78 LUTs could be distinguished (Wijnhoud et al., 2001 and 2003). Biophysical, socio-economic and farming systems data were collected during the survey, through a combination of semi-structured interviews and direct field observations. Data collection took place in three additional districts of Ubon Ratchathani Province (Figure 2.1), but these data have not been included for most of the analysis, partly because data sets were incomplete and/or not accurate enough. Nevertheless, in Chapter 4 reference is made to the results of basic analyses for a larger data set of 80 farms spread out over six Districts (Figure 2.1) (Konboon et al., 2002).

Primary data collection focused at farm level, however included the collection of data for sub-farm units such as fields and LUTs. As the survey covered three (sub-) districts, results of this survey may be considered representative for rainfed lowland rice systems at the provincial level and, to some degree, also for more or less identical rainfed lowland rice-based DRMDs elsewhere in Northeast Thailand, the country and the Mekong Region.

Figure 2.1: Ubon Ratchathani Province and the (sub-)districts where primary data were collected for NBS-NET (Source: Wijnhoud et al., 2001).
For the bulk of the analyses, a two-scale, or sometimes multi-scale approach has been followed, with analyses from lower to higher spatial scale, *i.e.* from LUT to field, farm, (sub-)district and provincial level, respectively. In this approach, the district level is represented by the multi-variate data set of the 40 (sometimes 30) representative farms in 3 (2) (sub-)districts and the farm level by each set of farm data.

This approach generates a scale-synergistic effect, as outcomes of analyses at district level may support analyses, decision support and possible interventions at farm and field levels, and *vice versa*. In addition, multi-scale characterization and analyses support identification of constraints and challenges, *i.e.* different types of factors influencing SNRM and livelihood development at different interrelated scales (Andriesse *et al.*, 1994). Scales and scale-related factors cannot always be separated by distinct boundaries, but may be interrelated across or be separated by diffuse spatial boundaries, another phenomenon that contributes to the overall complexity and another reason for adoption of integrated approaches.

In addition to the pilot survey for the 1998 growing season (Wijnhoud *et al.*, 2000), for the main survey, data collection took place in the period March 1999–February 2000, covering the 1999 growing season (Wijnhoud *et al.*, 2001, 2003). As no perennials are included in the LUS, climatic conditions were rather average and major emphasis is on methodological issues, rather than on temporally accurate analyses, the use of an annual ‘snapshot’ rather than multi-annual monitoring seems justified.

From 2000 onwards as a parallel study, a semi-structured on-farm crop, water-nutrient-crop monitoring activity was undertaken at three positions – upper, middle and lower – of three toposequences (micro-topographic catenae), each with different relief characteristics, that covered the ‘typical’ range for the region (Konboon *et al.*, 2002; Chapter 4). An experimental component was added to the monitoring activity for eight of the nine plots. Two soil fertility treatments, namely zero-fertilizer and farmer nutrient applications, were imposed on sub-plots, separated by impenetrable sheets, within each of the eight paddy fields. Soil hydrological parameters, nutrient dynamics, and crop growth were monitored (Konboon *et al.*, 2002; Chapter 4).

### 2.2.4. Data collection, storage and management

Most of the quantitative data, such as crop yields, nutrient inputs, and on residue management strategies, were provided by the farmers during a single, rather extensive interview, in some cases with follow-up interviews. Every effort was made to check these estimates with follow-up questions and through field observations. Units were standardized, which involved conversions such as volumes to weights, and fresh weights to dry weights, and these conversions were checked carefully in the field. Nutrient contents in fertilizers, products, stubble, organic amendments, etc. were
collated from a mixture of available data from within the region and measurements. Although the errors or inaccuracies during data collection could not be quantified, it was clear that there was variation in the accuracy with which different characteristics were measured. Indications were that accuracy declined in the following order: nutrient inputs in fertilizers, yields, nutrients removed in products, residue yields, nutrients in residues, and nutrient inputs in organic amendments (Chapters 1 and 4). Fortunately, the first three characteristics are, generally, the most significant factors in the partial nutrient balance calculations.

From the additional wide range of socio-economic and farming systems data, special attention was paid to income from different activities and prices and costs for fertilizers and rice.

For on-farm data collection, hardcopy farm inventory forms (FIF) were used. Collected data were subsequently entered into a compatible relational database system (RDBS) that was designed for storage, management and analyses of data, and includes a user-interface (front-end) developed in Visual Basic® that is compatible with the FIF (Figure 2.2). The database back-end is in Microsoft Access® and comprises two main components, a primary data component, including farm-specific data and a
primary or ‘default’ data component, including secondary and analytical data from samples that have been collected and that may serve to provide default values for soil and plant characteristics. The RDBS may serve a wide-range of farm, farm household and farming system analyses. Especially relevant for this study, it includes utilities to generate semi-automatically partial nutrient balances for N, P, and K at the LUT, field and farm level (Figure 2.3) and cost-benefit analysis (CBA) for rice cultivation at the farm level. Some of its components may be of value for incorporation in a DST for dynamic and site-specific decision support based on NBA and CBA (Chapters 4–6).

### 2.2.5. Data analyses

The conceptual nutrient balance model, used in the nutrient balance study of Stoorvogel and Smaling (1990) includes five nutrient input components and five output components:

**Inputs:**
1: Mineral fertilizers
2: Manure and other organic inputs
3: Deposition by rain and dust
4: N-fixation
5: Sedimentation

**Outputs:**
1: Harvested product
2: Removed crop residues
3: Leaching
4: Gaseous losses
5: Erosion
Starting from this conceptual model, annual partial nutrient balances (also referred to as ‘farm gate balances’) for N, P and K were calculated as:

\[ \text{Balance} = \text{Input} - \text{Output} \]
\[ = (\text{fertilizers + organic inputs from outside the field/farm}) - \]
\[ (\text{removal from field/farm in products and crop residues}) \]

These balances exclude inputs through (biological) nitrogen fixation, wet and dry deposition, sedimentation, run-on, and nutrient uptake from exploration of sub-soil layers by deep roots and outputs by leaching, erosion, run-off, and gaseous losses.

While it is acknowledged that partial budgets must be interpreted with caution, the relatively accurate, rapid, and simple assessment of partial nutrient budgets can be of great value, especially if consideration is given to the plausible magnitude of the full balance factors that are not included. Such considerations require a combination of local and expert knowledge on relevant site characteristics. Moreover, PNBA fits in an overall approach aimed at creating most impact with limited resources. This means that instead of the resource-intensive accurate assessment of small-scale full balances, a choice has been made for somewhat less accurate, flexible large-scale assessment of partial nutrient balances. However, due attention is given to magnitudes and directions of omitted factors, a more appropriate and efficient procedure to create impact in situations with considerable knowledge and development gaps, especially if resources and capacity are limited. The semi-structured on-farm water-nutrient-crop monitoring activity along micro-topographic catenae was also a useful auxiliary for the interpretation of the PNBA results and for decision support purposes (Konboon et al., 2002; Chapter 4).

The nutrient balance study of the 30 farms (main survey) served as basis for further, more integrated biophysical and socio-economic analyses. Analyses of organic and inorganic nutrient inputs, partial nutrient budgets and relationships between on- and off-farm income were followed by integrated environmental and socio-economic accounting at district, farm, field and LUT levels. These analyses were based on introductory analyses of average prices/values of elemental N, P and K, based on fertilizer use and price data derived from a fertilizer survey, an integral part of the overall data collection (Chapter 5). These integrated analyses provided additional insights and contributed to conclusions that could not have been made by mere mono-disciplinary analyses.

2.2.6. Paradigmatic relevance, prototyping analyses and contributions to dynamic and site-specific decision support

The case-study outcomes themselves are relevant; however, the study’s paradigmatic
value is equally important and highlighted within the discussions about integrated rural development strategies (Chapters 1 and 6). The flexible use of a combination of conceptual and analytical elements is critical.

Basic elements for a DST for dynamic and site-specific decision support for improved soil fertility management and SNRM are identified and discussed (Chapters 3–6). With regard to nutrient and soil fertility management, some prototype nutrient- and scenario-specific examples are provided and discussed (Chapter 4). This is followed by some prototype economic analyses, relevant to the economic viability of SNRM (Chapter 5), and additional elaborations on integrated decision support, explicitly addressing both, improved and sustainable land management and improved and sustainable livelihoods (Chapters 5 and 6).

2.3. Conclusions
In NBS-NET, an integrated and flexible approach was followed to address environmental and socio-economic sustainability in a holistic context. The approach is pivoted around NBA, livelihood and additional integrated analyses as methodological elements that appear to fit in very well with the advocated approach. The combination of an innovative, i.e. participatory, integrated and holistic, approach with strict priority setting by combining holistic concepts and a small selected set of participatory, integrated and/or complementary analyses is considered powerful in addressing the needs for integrated rural R&D as targeted at complex realities both in Northeast Thailand, the Mekong region and developing countries in general.

The case study contributes to the identification of important elements for participatory decision support with the involvement of and targeted at relevant stakeholders, including farmers, extension workers, fertilizer retailers and producers, other private sector actors, policy makers and other development facilitators, including civil society organizations, at different levels (Chapters 4–6).
CHAPTER 3

Case study in Northeast Thailand: Dynamic resource management domain (DRMD) characterization, R&D bottlenecks and opportunities*

Abstract
In Northeast Thailand, the sustainability of rainfed lowland rice-based systems, the dominant land-use system (LUS) in the region, is a concern for the welfare of the population in this relatively poor area of the country. Poor soil fertility and low inputs are considered major causes of sustainability problems. Appropriate decision support for sustainable agricultural production, natural resource management and livelihood development is required, but attainment of these objectives is hampered by the complexity of these systems. The complexity arises, in part, from the high spatio-temporal variability, as a result of micro-topographic and related biophysical heterogeneity, combined with erratic rainfall and the prevailing dynamic socio-economic environment. Many of the bottlenecks that constrain rural research and development (R&D) can only be addressed through innovative approaches, particularly participatory and interdisciplinary activities within the context of dynamic resource management domains (DRMD). The degree of adoption of such innovative approaches and the detail in DRMD characterization, i.e. contextual analyses, should be based on strict priority setting, considering the available capacity (resources), and already existing or easily generated information with a certain focus towards the objectives of the overall R&D effort and bottlenecks to be expected.

This chapter covers DRMD characterization for Northeast Thailand, both with respect to general aspects and developments in the region and with respect to bottlenecks and challenges for R&D aimed at sustainable land management, emphasizing both soil fertility management and livelihood development in rainfed lowland rice-based DRMDs. Within the complex reality, attaining sustainable land management and improved livelihoods needs broader participatory and interdisciplinary efforts to break the vicious circle of unsustainability and resource degradation and to escape from the environment-poverty downward spiral that is due to interrelated unfavourable biophysical and socio-economic conditions and constraints. Besides, it requires partnership building based on genuine multi-level and multi-stakeholder collaboration; a key requirement that is confronted with many challenges itself.

3.1. Introduction
Many of the bottlenecks that constrain rural research and development (R&D) can only be addressed through innovative approaches, particularly participatory and interdisciplinary activities within the context of dynamic resource management domains (DRMD) (Chapter 2; Wijnhoud et al., 2003; Syers and Bouma, 1998; Kam and Oberthür, 1998). The extent to which such innovative approaches should be applied and the degree of detail in DRMD characterization, i.e. contextual analyses, may need to be based on strict priority setting, taking into account the overall objectives of the R&D activity, available capacity and expected bottlenecks (Rhoades, 1998, 2000). A first objective of the DRMD concept is placing R&D activities as much as possible within their broader spatio-temporal context, to improve the chances

* Major excerpts of this chapter were derived or adapted from: Konboon et al. (2001) and Wijnhoud et al. (2001).
for useful outcomes and adoption of recommended practices. A second objective is comparison of more or less similar DRMDs or DRMD aspects in order to facilitate extrapolation of R&D results (Syers and Bouma, 1998; Kam and Oberthür, 1998). Contextualization, i.e. DRMD characterization, was purpose- and information-driven (Chapter 2; Wijnhoud et al., 2003; Kam and Oberthür, 1998), as determined by the availability of relevant data and information and with major emphasis on soil fertility, livelihoods and rainfed lowland rice-based systems (Chapter 2).

3.2. Land-use and agricultural change over two decades

Data provided by OAE (1977, 1979, 1988, 1989, 1997 and 1999) were used to visualize land-use change (LUC) and agricultural change over a period of two decades, from the late 1970s until the late 1990s (Figures 3.1–3.8). In Northeast Thailand, covering an area of approximately 17 million hectares, agricultural land-use has increased considerably at the expense of non-cultivated lands (unclassified/forests) over the last two decades with a substantial increase in paddy fields and land used for field crops between ’78 and ’87, which stagnated between ’88 and ’97 (Figure 3.1). Even though these data suggest a rather slow rate of deforestation during the period ’88–’97, the rate of environmental decline, including deforestation, likely increased substantially during the economic crisis at the end of the 1990s (ADB, 1999), a tendency not yet accounted for in Figure 3.1. Areas of grassland, fruit trees, vegetables, flowers, housing and other non-agricultural uses, all have increased (Figure 3.2), somewhat blurring the increase in deforestation in Figure 3.1. There was

![Figure 3.1: Land-use dynamics in Northeast Thailand over the period '77/'78–'97/'98 (Source: OAE, 1979, 1989, 1999).](image-url)
a substantial increase in non-rice field crops during ’78–’87 followed by a small decline during ’88–’97 (Figure 3.3). In addition to an increased area of paddy fields, mainly through cultivation of relatively infertile soils in higher topographic positions (Konboon et al., 2001), there has been encroachment into former forest areas of so-called upland crops, such as cassava, sugar cane, maize and kenaf (Figure 3.3). Kenaf, with maize for a long time the most important upland crop, rapidly lost ground (Figure 3.3). During ’78–’87, cassava rapidly covered the largest area among the upland crops

Figure 3.2: Dynamics of non-rice land use in Northeast Thailand over the period ’77/‘78–’97/‘98 (Source: OAE, 1979, 1989, 1999).

Figure 3.3: Changes in crop areas harvested in Northeast Thailand over the period ’77/‘78–’97/‘98 (Source: OAE, 1979, 1989, 1999).
(Figure 3.3), partly in response to attractive animal fodder export markets in Europe. However, during '88–'97, partly due to a decline in those export markets, the area of cassava declined, associated with a dramatic increase in area of sugar cane, which had become the second most important upland crop in 1998 (Figure 3.3). The relative values of agricultural products over two decades show similar trends (Figure 3.4). Rice remained by far the largest contributor to the overall agricultural production value. Even more remarkable than the change in area of cassava, is the trend in the relative agricultural production value of the crop. Its economic importance increased dramatically during ’78–’87, while the crop encountered an unprecedented downfall during ’88–’97, which was more extreme than its area reduction (Figure 3.3). On the other hand, after a slow increase in economic importance during ’78–’87, the relative agricultural production value of sugar became really significant during ’88–’97, economically approaching cassava as the second most important agricultural crop, but still far behind rice (Figure 3.4). Kenaf, having the second highest value in ’78, had become macro-economically irrelevant in ’97.

As a result of the introduction of new varieties and increased inputs, the yields of some major crops, such as maize, rice and sugar cane, have doubled over the last 20 years, with for sugarcane and rice the largest increase during ’78–’87 (Figure 3.5). In contrast, yields of cassava stagnated after 1987. This may be partly explained by the extensive management of cassava, characterized by low inputs and limited anti-erosion measures. Cassava cultivation, under poor management and on marginal soils, strongly

![Figure 3.4: Dynamics of relative monetary values of agricultural products (total = 100%) over the period ’77/’78–’97/’98 (Source: OAE, 1979, 1989, 1999).](image-url)
contributes to soil erosion and nutrient depletion, especially on the vulnerable soils of the sloping lands of Northeast Thailand (Lefroy and Konboon, 1998).

Remarkably, the total number of large farm animals, slightly decreased over the last two decades (Figure 3.6). One important factor is the gradual replacement of animal draught of buffalos by hand-tractors (Konboon et al., 2001). Buffalos, in 1978 by far the most dominant large farm animals, were reduced by more than half within two decades. A second important factor may be the substantial increase in specialized pig stock-farms, evidenced by the strong increase in consumption of pork (Figure 3.7), but explaining the restricted growth of swine at ‘regular’ farms (Figure 3.6). The sharp decline in buffalos, associated with the introduction of hand-tractors (Section 3.3.1), was partly compensated by an increase in beef cattle that have become the dominant large farm animals in 1998 (Figure 3.6). The overall decline in livestock numbers, however, has led to a reduction in farm manure production, negatively affecting soil fertility management (Konboon et al., 2001). The increasing relative (and absolute) importance of non-farm household income is striking (Figure 3.8). In 1978, farm income and non-farm income were equally important, but even with considerable growth in farm income, the contribution of non-farm income increased annual household income in the period ’75–’95 by an order of magnitude, a typical phenomenon for a country in full development transition. In this perspective, study of the relationship between non-farm and farm income, as well as their effects on soil fertility management and farm performance are relevant to nutrient balance studies in Northeast Thailand (NBS-NET) (see Chapters 2 and 5).

![Figure 3.5: Dynamics of crop yields (Mg ha⁻¹) in Northeast Thailand over the period ’77/’78–’97/’98 (Source: OAE, 1979, 1989, 1999).](image-url)
Figure 3.6: Dynamics of livestock numbers in Northeast Thailand over the period '77/'78–'97/'98 (Source: OAE, 1979, 1989, 1999).

Figure 3.7: Number of livestock slaughtered in Northeast Thailand over the period '77/'78–'97/'98 (Source: OAE, 1979, 1989, 1999).

Figure 3.8: Dynamics of farm and non-farm annual household income in Northeast Thailand over the period '75/'76–'95/'96 (Source: OAE, 1977, 1988, 1997).
3.3. Rainfed lowland rice-based farming systems

3.3.1. General characteristics and developments
As a consequence of an increasing demand for agricultural produce, deforestation, increased cultivation of marginal land and soil fertility decline are affecting large parts of Northeast Thailand. Results of an explorative desk study on partial nutrient balances for land-use systems in Ubon Ratchathani Province and the whole of Northeast Thailand confirmed the prevailing opinion of declining soil fertility (Lefroy and Konboon, 1998).

Rainfed lowland rice-based farming systems, the dominant farming system in Ubon Ratchathani Province and Northeast Thailand, typically are characterized by some lowland fields with rainfed rice cultivation and a small home garden for vegetables and fruits, located next to the farmhouse and some cows and/or buffaloes (1–10). In certain areas, additional field crops are cultivated, such as cassava, maize, kenaf and different types of beans at a larger than the home garden scale, although the cultivation of upland crops is rather concentrated in non rice-based upland farming systems that are dominant in the higher parts of other provinces in Northeast Thailand, but also in some districts of Ubon Ratchathani Province.

Growing season
The growing season for rainfed lowland rice starts around the third week of July with harvest in November, thus covering a period of about four months. Climate is characterized by two clearly distinct seasons, the rainy season (May–October) and the dry season (November–April), with mean, but rather erratic, annual rainfall for Ubon Ratchathani Province of 1600 mm (Pairintra et al., 1985). Some areas with a high groundwater table may offer possibilities for two crops a year. This opportunity usually is not used, sometimes because of labour shortage, but mainly because the rather poor soils would not support two harvests a year. Variations in depth of the groundwater table lead to variations in water availability for the rice crop, with rice cultivation in areas with a low groundwater table being more vulnerable to dry spells in the rainy season.

Crop management
Seed preparation involves soaking the seed bags for one night in water, followed by covering them for two days with wet tissues. The seeds then should show some signs of germination and are broadcast in seedling beds or directly in the paddy fields for direct seeding. During the growing season, weeding is an important and labour-intensive activity. Almost all rice is grown in paddy fields, for which building and
maintenance of bunds, as well as land levelling are essential. The main advantage of these ‘paddies’ is that water is retained on the surface, and therefore rainfall (or irrigation) water is used more effectively.

For ploughing, currently most farmers are using motorized hand-tractors that most often are hired, but owned by the relatively rich farmers. In addition to transplanting and weeding, harvesting, threshing and milling are labour-intensive, if done traditionally. Commonly, harvesting is done by hand, by cutting the panicle and a small part of the stem, the panicle straw. Some farmers hire machinery for threshing and milling. After threshing, panicle straw usually serves as fodder for the cattle.

Chemical fertilizer use is increasing and it is applied to over 90% of the rice area in Ubon Ratchathani province (Miyagawa et al., 1998). About 85% of the lowland rice area is manured with manure available from the cattle and poultry pens, but sometimes purchased, at an average dose of 139 kg ha\(^{-1}\). Where possibilities exist (biophysical/technical and financial), it has become popular to use small motorized pumps for small-scale irrigation and drainage. These developments are closely correlated with the past economic growth in the country. Until the economic crisis in Southeast Asia in the late 1990s, it led to increasing investments in chemical fertilizers and small-scale irrigation. As diversification of farming systems and increasing off-farm activities created pressure on the labour resources, direct seeding of rice has been introduced as a major labour-saving technology.

The harvested area to total planted area ratio for the period 1992–1995 was 0.92, with an average yield of 1.71 Mg ha\(^{-1}\) for the harvested area, having increased to 1.8 Mg ha\(^{-1}\) by 1999 (see Chapter 2).

**Rice varieties**

Two types of rice, glutinous (sticky) and non-glutinous (non-sticky) rice are cultivated in Northeast Thailand, where sticky rice is preferred for consumption. Non-sticky rice is mainly cultivated for the market, including export markets, generating some cash income (ACIAR PN9448, 1998). However, gradually, glutinous varieties are being replaced by non-glutinous ones (Miyagawa et al., 1998), each covering currently about 50% of the rice area. RD6 is the most common sticky rice variety, accounting for about 80% of all sticky rice grown in Northeast Thailand. KDML105 is the most common non-sticky variety, accounting for about 70% of all non-sticky rice. Sticky rice normally is grown in relatively small plots yielding enough to cover family needs and local market demands. The area for non-sticky rice generally increases with farm size.

**Developments**

Rainfed lowland rice-based farming systems are gradually changing in many aspects.
Over the last two decades, the farming systems have become more mechanized and, above all, more diversified. In the past, transplanting was the common practice for rice cultivation in Northeast Thailand, but at the moment dry seeding accounts for more than 10% of the area in Ubon Ratchathani province and more than 25% in many other parts of the Northeast. The advantage of dry seeding is its much lower labour demand. The average yield of dry seeded rice for the period 1992–1995 was 85% of that of transplanted rice (Miyagawa et al., 1998).

In addition to the major activity of rice cultivation, evermore farms are raising chickens, ducks and/or fish, with fish ponds having the additional advantage of enabling watering of the home garden and/or plots of rice land during dry spells. Raising other animals, such as pigs, is less common. Cultivation of non-rice field crops, vegetables and fruits is also increasing. The produce of ‘secondary’ farm activities is predominantly for home consumption, but increasingly it brings in additional income. In some cases, income from non-rice farming activities may exceed income from rice, thus having become the primary farming activity. Nevertheless, large-scale cultivation of off-season rice and other off-season crops within the farming systems has remained restricted to a small minority of farms that have access to off-season water sources.

Off-farm income appears to play an increasingly important role in household income (Figure 3.8; see also Chapter 5), a tendency reversed for some time during the economic crisis of the late 1990s, but slowly regaining its role.

Even though the farming systems are in transition, involving many changes and innovations, these developments were not uniformly spread throughout the region and among farmers, resulting in development of a technological and social rural divide. Access to capital for the necessary investments appears to be one of the critical factors, as may be the right skills, motivation, partnerships and social environment, and access to other production factors, such as labour and quality land.

3.3.2. Effects of the economic crisis

The economic crisis of the late 1990s has resulted in increased rates of environmental and social decline. Many people lost their jobs in Bangkok and other cities and returned to the resource-poor rural areas, creating increased pressure on the land resources. The direct effects of the economic downturn on rice cultivation in Northeast Thailand are not fully appreciated. During the time of relative prosperity before the economic crisis, many farmers committed themselves to high loans to improve their farms, leading to repayments problems during the crisis.

Relatively high interest rates contributed to high levels of indebtedness (Miyagawa et al., 1998). Rice prices fell to a record low and exacerbated the debt problems of rice
farmers (Bangkok Post, 1998). The economic recession exacerbated the unequal distribution of wealth, and contributed to an even greater poverty trap for the rural population in Northeast Thailand, particularly for disadvantaged groups and for the population of the resource-poor areas in the region (ADB, 1999). As long as the economic situation prevents higher off-farm income, solutions for income generation have to be sought on-farm, through farm diversification and/or adoption of improved management strategies. The Asian Development Bank diagnosed that improved agricultural practices are critical to restoring export competitiveness and to alleviating poverty, and that this process, including overcoming the negative effects of the economic crisis, will require substantial investments, including for water resource management projects, and institutional and policy reforms (ADB, 1999).

3.3.3. Current nutrient management and soil fertility R&D

Introduction

Soil fertility decline is widespread in many agro-ecosystems in Northeast Thailand, including those based on rainfed lowland rice. Improved nutrient management therefore appears one of the key interventions to increase the productivity and/or sustainability of the rainfed lowland rice-based systems. In recent years, in spite of and/or due to agricultural R&D efforts, simultaneous changes took place in the agricultural systems of Northeast Thailand and in the efforts aimed at improving soil fertility management within these systems. Konboon et al. (2001) provide a summary overview of the R&D efforts during the past 30 years on management strategies to overcome soil fertility problems. These management strategies include the use of mineral fertilizers, addition of organic materials, more integrated approaches to nutrient management, and modifications in cropping and farming systems, relying on system approaches and integrated nutrient management strategies.

Mineral fertilizers

Consumption of mineral fertilizer in rainfed lowland rice-based systems remains low, with nitrogen (N) as the most common yield-limiting nutrient. The Department of Agriculture recommends the use of 40 kg N, 12 kg P and 0 to 10 kg K ha\(^{-1}\), which is well below the maximum rates at which crops respond. A 1997 survey in Si Saket and Surin Provinces of Northeast Thailand indicated that farmers applied rates of approximately 6–12 kg N, 2.5–5.0 kg P and 2.5–5.0 kg K ha\(^{-1}\) (ACIAR PN9448, 1998), i.e. far below government recommendations. Average data from the NBS-NET survey much closer resemble the government recommendations, but the high standard deviations indicate that fertilizer consumption is highly variable among farms and
fields, with many farms and plots receiving doses far below recommendations (Chapters 4 and 5; Wijnhoud et al., 2003). Major constraints for the increased use of mineral fertilizer are the high sand and low soil organic matter contents of the majority of the soils in Northeast Thailand, implying low nutrient and water holding capacities, which can result in significant leaching of applied fertilizer, leading to low nutrient use efficiency. Moreover, considerable micro-topographic variability, in combination with rather erratic spatio-temporal rainfall patterns, results in variable and uncertain spatio-temporal soil moisture conditions, crop growth and, thus, fertilizer requirements. It is very difficult, if not impossible, for farmers to respond adequately to such conditions. The risks associated with spatio-temporal agro-climatic uncertainties make farmers reluctant to take risks when investing in fertilizers, especially where their financial situation is weak, and access to capital limited and risks with borrowed money are logically to be avoided.

Where increasing fertilizer consumption may not be an option, and because of general environmental and economic considerations, scope for improvement should be sought in improving the efficiency of nutrient use. One of the keys to improving the efficiency of nutrient use and reducing losses is synchronization of nutrient supply, particularly of N, with crop requirements. This can be achieved through split application of fertilizers (Konboon et al., 1998), the use of controlled-release N fertilizers (Wonprasaid and Chaiwat, 1997), and/or sub-soil compaction to reduce leaching (Sharma, 1993). However, these techniques are not without problems. The coincidence of prolonged submergence with basal applications and drought with later applications are common features in rainfed situations in the Northeast, making synchronization difficult. In practice, farmers apply N fertilizers according to water availability, regardless of crop requirements. The use of chlorophyll meters or calibrated leaf colour charts to improve the timing of split applications, or of controlled-release N fertilizers, may help to achieve better synchrony between demand and supply, although, at present, these options are too expensive or require further (site-specific) development. Sub-soil compaction is not practical for farmers. Increasingly, evidence shows that fertilizer recommendations need to be dynamic and site-specific (e.g. Witt et al., 2000), and that blanket recommendations are of limited value or may even be counter-productive (e.g. Eyasu Elias, 2002).

Following implementation of improved N nutrition, attention can be directed to improved management of other nutrients. Information already exists on the requirements for some nutrients, including P (e.g. Lefroy et al., 1988; Rouaysoongnern, 1997), K (e.g. Hatsathon et al., 1997) and S (e.g. Kurmarohita et al., 1978; Blair and Lefroy, 1990).

Some key issues with respect to the application of inorganic fertilizer to rainfed
lowland rice-based systems are the possible impact on rice quality and leaf blast disease. There is evidence that application of high rates of N has a negative impact on the quality of the aromatic rice varieties widely grown in Northeast Thailand, such as KDML 105 (the dominant non-glutinous variety), while higher K fertilizer doses can improve aromatic quality (Hatsathon et al., 1997). In addition, there is evidence of higher prevalence of leaf blast associated with high application rates of N, which may be partly avoided by split applications (Konboon et al., 2001). However, the nature of the yield response to fertilizer application and its effect on quality need to be clarified to improve recommendations to farmers.

Organic materials
Organic materials have been used widely and successfully as soil amendments to improve soil fertility and increase yields in Northeast Thailand. Traditionally, organic materials were recycled within the farm systems, although rates of application must have been low. Research into the benefits of application of organic materials has included crop residues, such as rice stubble and rice husk (Supapoj et al., 1998), plant residues, such as leaf litter of leguminous trees (Konboon et al., 1999), and animal wastes, such as dung (Supapoj et al., 1998).

Animal dung, traditionally, has been an important form of organic material for use as a soil fertility amendment. The total supply of animal manure in the whole of the Northeast increased, but the distribution among farms and species has changed, with the manure produced at pig and chicken stock farms being out of reach of the average rice farm (Section 3.2). Hence, manure application, on-the-spot manuring by livestock roaming the fields after harvest, as well as residue-livestock interactions were affected on many farms.

Tree or shrub leaf litters from on-farm sources show promise for increasing soil organic matter and improving soil fertility. Some studies have demonstrated very large and rapid responses to large applications of legume leaf litter (Rathert et al., 1991), however, in many cases the levels applied are impractical. Konboon et al. (1999) demonstrated promising results with the addition of plant material and leaf litters.

Considering the relatively low crop production and low soil fertility in Northeast Thailand, the use of on-farm residues, such as rice stubble and rice husks, in combination with on-farm leguminous leaf litters, appears a promising technology for long-term improvements in soil fertility and sustainable higher yield levels. The use of off-farm organic resources appears a less feasible option, except in highly productive areas or in areas close to a major source of such materials, such as near rice mills or intensive livestock production systems (Konboon et al., 2001).

Although the research on the addition of organic materials shows promising results,
these results have been unavailable to extension workers, and have had limited impact on rainfed lowland rice-based systems at large or even specific farming areas, so far.

*Integrated nutrient management and the systems approach*

In Northeast Thailand, application of chemical fertilizer alone has been shown to improve soil chemical properties, and increase yields, in the short-term; however, in the longer term, nutrient use efficiencies are lower, and, if application is interrupted, soil chemical properties may deteriorate and yields decrease quickly again. While application of organic materials can increase soil organic matter content and improve soil physical, chemical and biological properties, it may not be sufficient to satisfy the nutrient demand of the rice crop. Therefore, combined application of inorganic fertilizers and organic materials may be more appropriate to increase soil organic matter content and soil fertility, the more so, because increased levels of soil organic matter may catalyse nutrient retention and therefore increase nutrient use efficiencies in the longer term.

Much research has focused on nutrient management in the course of the growth cycle of the rice crop. It is equally important to direct attention to generating management strategies that focus on a systems approach to integrated nutrient management to sustain productivity and protect the resource base. The introduction of leguminous species into rice mono-cropping systems can significantly enhance soil fertility, as a result of the net input of biologically fixed N into the system, thus reducing the need for external inputs. In the long run, the introduction of legumes can improve the nutrition of rice with respect to other nutrients, particularly P, as the improved nitrogen fertility resulting from the legume can increase the vigour of the rice plants, resulting in more extensive root growth, and thus improved nutrient acquisition and nutrient use efficiency. Moreover, the successful introduction of legumes requires addressing other nutrient problems, particularly P-deficiency. This can be of indirect benefit to rice productivity through the improved P status of the soil.

On-station and on-farm trials on the use of pre-rice green manures have shown promising results (Herrera *et al.*, 1989), in that it resulted in substantial increases in rice yields. However, adoption of the technology by farmers presents problems, *i.e.* shortage of labour for green manure incorporation, chemical fertilizer requirements of the green manure crop and shortage of seed.

Legume crops, such as mungbean and cowpea, have been extensively investigated, both as pre- or post-rice crops. This technology is unlikely to produce the large increases in rice yield in the short term observed from green manures (Herrera *et al.*, 1989); however, the problems of adoption are smaller. Nevertheless, this technology is risky in rainfed lowland conditions where inundation in pre-rice crops and water
shortage in post-rice crops may pose significant problems (Supapoj et al., 1998).

Even though burning of crop residues, a practice detrimental to soil fertility maintenance has become rare, in the NBS-NET pilot survey, fields were encountered where crop residues were burnt in preparation for a post-rice crop (Chapter 4; Wijnhoud et al., 2000).

Some integrated approaches appear promising, but their adoption in general is restricted by socio-economic constraints, such as a lack of labour and/or access to capital (Konboon et al., 2000).

Conclusions and additional needs
The irregular topography, the prevalence of inherently poor sandy soils and the relatively erratic rainfall pattern combine into very difficult agro-ecological conditions, complicating agricultural activities and effective nutrient management. In addition, even though a major R&D focus on nutrient management appears justified, these efforts need to be embedded in a broader view on DRMD aspects. Though farmers have adopted some of the technologies originating from soil fertility R&D, many others have not been adopted for various reasons. The next section will provide some more insight in the likely reasons and identify general bottlenecks and challenges for R&D in Northeast Thailand.

3.4. Research impacts, opportunities and trends

3.4.1. The low impact of research
Although agricultural research in Northeast Thailand may have been successful in some instances, its impact in terms of adoption of improved land and nutrient management, in general, is insufficient. This holds for research in agricultural systems in many countries. Although the reasons for this limited impact of research are complex, they can be divided into three broad categories:

- The research undertaken is simply wrong, particularly with respect to the biophysical and environmental limitations and constraints, thus leading to incorrect or inappropriate results.
- Results that are appropriate in the biophysical sense are not adopted by potential end-users for cultural, social, and/or economic reasons, or due to their low or negative impact on longer-term sustainability.
- Appropriate research results may not be successful in the transition from research to the development and implementation of strategies.

Methods for overcoming problems associated with the first two categories lie in
improved problem identification and the research required, which is outlined in the following sections. Many of these approaches will reduce problems associated with the third category; however, a number of issues remain, not directly related to the research *per se*, but more associated with implementation, professional and institutional structures and the policy context.

First, many research programmes do not include a dissemination and implementation phase, *i.e.* promotion, scaling up and implementation of relevant research findings, or this phase is poorly planned, funded and/or executed. Unfortunately, in many research programmes production of reports and/or publications in scientific journals is considered more important than the impact on end-users. Optimal dissemination and implementation of results generally receives less attention, because this process does not match the skills and interests of the planners and implementers, or because career possibilities within institutions are based on easily measurable factors, such as numbers of reports and publications, not on the impact on farmers, which is much harder to measure.

Second, lack of consensus on guidelines results in minimal standardization in data collection, management, interpretation, storage and dissemination. The resulting limited accessibility of reliable data leads to repetition of research, which is inefficient. In general, this problem results from lack of research collaboration and co-ordination at all scales, and within as well as between institutions and countries. This is associated with the problem of overlapping mandates and responsibilities among different groups involved in the research, development and extension chain, which is common for R&D in many parts of the world. These problems occur both intra- and inter-institutionally, particularly between the research units and the extension services and end-users.

Many of these problems are difficult to address directly, as they are rooted in inadequate staff and funding, as well as in competition for human and financial resources and ideas.

There is lack of donor coordination and long-term donor commitments to structural development needs. Above all, there is a lack of demand-driven, development- and client-oriented collaborative and genuinely participatory R&D efforts based on clear multi-level partnerships among community members, communities, government agencies, NGOs involved in participatory research and piloting, regional, national and international research institutions, the private sector and last but not least donor organizations.

However, some of these problems might diminish or disappear, if greater emphasis would be placed on translation of scientific research results into user-friendly recommendations and tools for general use by extension workers, farmers and other end-users. Achieving and assessing impact from research aimed at improved
sustainable land management must be considered from the inception of the research programme (Maglinao, 1998). This may also require involvement of multi-disciplinary teams from the design and inception of R&D initiatives onwards, in order to deal with the integrated and holistic character required for the adoption of research outcomes based on technical, biophysical, socio-cultural, economic and political considerations.

Partnership building based on genuine multi-level and multi-stakeholder collaboration may be a key requirement that is confronted with many challenges itself (Chapter 6).

3.4.2. Improving the use of existing data
Extensive information on nutrient management has been collected in national and international research projects in Northeast Thailand and in similar agro-ecosystems in neighbouring countries, but this information is insufficiently accessible to farmers and/or extension services. Much of this information is unpublished or reported in so-called ‘grey-literature’ sources that are not widely available and, like due to staff turnover and clean-up of filing systems, even may partly disappear from the records as years go by. Conservation and availability of this information might lead to better understanding of likely responses to fertilizer and better assessment of the value and management of organic materials in the cropping systems of the region. Collation, re-analysis and reassessment of these data through appropriate training programmes, supplemented with some focused research, could significantly enhance the value of past research. Development of easily accessible databases that contain nutrient management data for rice-based systems is essential. Such databases should be developed for use by extension services and their impact could be enhanced significantly by including targeted extension materials and decision support systems. New approaches in information management and dissemination must be utilized.

3.4.3. Participatory and interdisciplinary research methods
A solution to some of the problems associated with the limited impact of past research may be provided by greater use of more participatory and interdisciplinary research methods. Participatory and interdisciplinary approaches are dealt with simultaneously as they are strongly related. Interdisciplinary and multi-disciplinary methods are characterized by participation of a range of disciplines, while participation of the major stakeholders ensures that the critical disciplines are involved and the research is placed in an appropriate social and environmental context; normally that of the farmer and of the farming community. The combination of interdisciplinary and multi-disciplinary methods – most appropriately on the basis of disciplinary neutrality (Chapter 1) – has been defined in recent literature as ‘trans-disciplinary’ (Fink, 2002).
Tailor-made participatory research and extension methods can result in improved dissemination of research results and implementation of recommendations (Defoer, 2000). They help in better targeting of research towards practical problems within their context. The participatory approach does not mean that farmers take the lead, but rather that a joined top-down bottom-up approach of aided participation is started, based on structured mutual interaction between farmers, extension workers and researchers (e.g. Shumba et al., 1995). This will also allow exploitation of the synergy between conventional knowledge and indigenous technical knowledge (ITK), including indigenous taxonomic systems (cf. Oberthür et al., 1999).

Knowledge about the heterogeneity and complexity of an environment has major implications for the formulation and promotion of extension messages proposed for specific sets of environmental conditions, both biophysical and socio-economic (De Wit et al., 1995). Following the agro-ecological zoning initiative by FAO (1978–1981), research questions were formulated within a broader environmental context, such that research was managed in a more eco-regional (Rabbinge, 1995) or agro-ecological context. The latter two terms may suggest that biophysical aspects are of greater importance to agricultural development than socio-economic aspects, which is not necessarily the case. All the environmental and other components and their dynamics that need to be considered in a holistic fashion are included more implicitly in the DRMD-concept (Chapter 2). In this concept, the dynamic biophysical, agro-ecological, socio-economic, political and management setting of R&D activities are integrated, as deemed necessary for increased impact of R&D efforts, as well as for scaling up and extrapolation of efforts (Chapter 2; Syers and Bouma, 1998).

Recommendations for adoption of different land-use systems within a DRMD must be developed within the context of potential conflicts with respect to the use of the various biophysical, social and economic resources of all end-users. Thus, extension packages should be tailored to the total resource base of farmers, and not to individual production activities. Such targeted packages are best achieved through participatory and interdisciplinary research methods.

The examples and guidelines of Participatory Learning and Action Research, (PLAR), aimed at developing appropriate soil fertility management systems in sub-Saharan Africa (Defoer and Budelman, 2000) appear promising for implementation in other parts of the world that experience serious soil fertility problems, such as Northeast Thailand. In fact some of the PLAR principles were followed as part of this case study, but such efforts were restricted by resource and time constraints that were inherent to the limitations of the study itself (Section 2.2.1).
3.4.4. Integrated agro-ecological research

Research to improve agricultural practices often focuses on individual problems and solutions. While this approach has resulted in significant progress, it may be insufficient or of limited relevance in addressing more complex and practical R&D questions in an integrated and holistic reality with multi-stakeholders. This situation has improved with the adoption of more integrated research approaches, dealing with multiple and complex problems: the integration of soil, water and nutrient management, and by addressing critical socio-economic issues in agricultural R&D efforts. In the context of nutrient management research, still from a biophysical, but more integrated perspective, this implied a move to multi-nutrient problems, to integrated management of inorganic and organic materials, and to attention for the interaction between nutrient and water supply. However, further innovative approaches are necessary.

Understanding the DRMDs of Northeast Thailand involves their clear classification in terms of the specific combinations of biophysical and socio-economic characteristics and their dynamics. Many of the R&D activities in Northeast Thailand could benefit from such a classification. To this end, integrated biophysical research aimed at developing improved nutrient management systems needs to focus on critical factors that control nutrient availability. Considering climate as given, the main agro-ecological characteristics that influence nutrient availability include soil type and topography. These characteristics influence indigenous nutrient supply, nutrient holding capacity, soil hydrology, and thus the balance between nutrient supply and the various nutrient loss processes. In combination, they dictate current land use and define the potential land use capability. The large variability in Resource Management Domain (RMD) characteristics over short distances means that developing location-specific technology packages can be very difficult.

The short-range variability in biophysical characteristics, that is characteristic for Northeast Thailand (Kam and Oberthür, 1998), implies that some critical aspects of RMD characteristics cannot be mapped as homogenous units. Data for such spatial resolution are not available and data collection at that scale is impractical. Nevertheless, the fine details of resource characteristics, that are critical for selection of appropriate management strategies, can be described within the context of the spatially defined RMDs. Whenever these characteristics can be recognized by farmers as components of a spatially defined RMD, e.g. within indigenous knowledge systems, they can be used as important criteria to select appropriate management practices.

It is important that integrated agro-ecological approaches to research include assessment of these domain characteristics so that the locations for implementation of research outcomes can be identified accurately.
3.4.5. Specific research topics
In addition to the more general aspects of improving research and development (implementation) in an integrated context, based on participatory and interdisciplinary methods, a number of important research topics can be identified that need to be addressed or are being addressed in Northeast Thailand.

Responses to nutrient applications
Although information is available on responses to different nutrients, particularly N, and to a lesser degree P and K, there is a need for improved fertilizer recommendations to farmers. This will mainly require targeted analysis of existing data, although there may be a need for further research that should be identified on the basis of such an analysis. New research needs to be aimed at better understanding responses to individual nutrients, nutrient availability from different inorganic and organic sources, and interactions between different nutrients, and between nutrients and soil organic matter.

Rice quality
It is essential that strategies that increase the production of aromatic rice in the Northeast, for national consumption and export, do not result in reduced quality. Analysis of existing data might indicate areas for further research on the interactions between the supply of different nutrients, yield and quality, and for better identification of areas most suitable for production of aromatic rice.

Nutrient supply and soil moisture
Variations in rice yield in Northeast Thailand are related to water supply and nutrient supply and their interactions. Increasing water supply will require fairly large-scale infrastructural developments, such as land levelling, water harvesting and on-farm water storage, or establishment of irrigation schemes; however, there may be some scope for improving water management through selection of crop rotations.

Optimizing nutrient management may significantly affect water use in some upland farming systems in Northeast Thailand. This may also be the case in some rainfed lowland rice-based systems, although to a lesser extent. In addition, availability of water has a significant effect on nutrient use efficiency, through its impact on crop growth and nutrient loss processes. These interactions need to be better understood to improve recommendations on timing, method and rates of application of different chemical fertilizers and organic materials.

Crop establishment
Periodic and overall shortages of labour have significant impacts on rice production
systems in the Northeast. One critical change in production systems is the move to crop establishment by broadcasting (direct seeding), rather than transplanting. The consequences of this development for nutrient management require attention, within the context of crop establishment, weed management, and evaluation of varieties.

**Crop rotations**
There is a need to evaluate species, particularly legumes, for their suitability as components of the farming systems of the region, either as pre- and/or post-rice crops or elsewhere in integrated farming systems without serving as rotation crops for rice as such. Such evaluations should pay attention to management requirements for establishment, nutrient supply, harvesting practices, and water use within the whole system. In addition, other aspects should be considered, such as the quality of the residues as a criterion for the value of a species as a soil amendment, for increasing nutrient supply and soil organic matter (SOM) content (Palm *et al.*, 2001), and as forage for animals (Schiere and De Wit, 1993). Within this context, crop residue production may take precedence over economic yield (Schiere *et al.*, 2004).

In all research on crop species and varieties as possible components of rotations within the farming system, it is critical that they will be evaluated from both the socio-economic and the biophysical perspective.

**Economic analyses**
True interdisciplinary R&D efforts aimed at improved land management and livelihoods should not only cover different biophysical aspects, but also critical socio-economic, political and cultural aspects. Assessment of management strategies is not complete without economic evaluation. Ideally, such economic evaluation should include some sensitivity analyses to assess the risk associated with different strategies. In many cases, the difference between recommendations and farmers’ practice results from farmers’ assessments, correct or not, of the risk associated with a particular strategy, based on other important social and economic factors. Risk analysis should therefore assume a more important role on the research agenda for the purpose of translating research results on fertilizer responses and other management practices into recommendations for farmers.

**Nutrient balance studies**
Critical components of land management that are affected by factors important in DRMD classification are nutrient balances. Nutrient balances are characteristics of the land use system and its current management and relevant for integrated R&D approaches aimed at sustainable land management and improved livelihoods (Chapters
Assessment of nutrient balances can support the development of improved land management systems for specific land use systems within particular DRMDs. Research on nutrient balances in the last decade, especially those in sub-Saharan Africa, has shown that assessment of nutrient balances is a powerful tool in evaluating the sustainability of agro-ecosystems at different spatial scales (Smaling, 1998; Defoer et al., 1998). At the farm and household level, assessment of nutrient balances can help to identify ways of optimizing nutrient transfers and reducing and replacing losses. Nutrient balances can be linked to socio-economic data and can be used to develop improved recommendations aimed at both the biophysical and socio-economic aspects of sustainability (Wijnhoud et al., 2003; Chapters 2, 4 and 5). Nutrient budgets have a significant learning role within farmer participatory research (FPR) and farmer participatory extension (FPE) methods (Defoer, 2000). Nutrient balance analyses (NBA) were pivotal to NBS-NET (Chapters 2, 4 and 5).

Interregional and international transfer of nutrients

Consumption of agricultural products, whether by the household, in national urban centres, or following export, involves significant transfers of nutrients. In Thailand, as in many countries, increasing population and urbanization generates an increasing supply of household and other wastes, with a concentration in urban and peri-urban regions, resulting, in part, from the movement of agricultural produce. This movement of produce to population centres leads to waste management problems in these centres and nutrient losses from the areas of production. Waste materials provide a potentially valuable source of organic matter and plant nutrients for agricultural areas. As the distances for products, and thus nutrient transfers increase, the possibilities for, and ease of, recycling nutrients decrease and the issue of minimizing nutrient removal becomes more critical.

The large exports of rice, cassava, and other agricultural products from Northeast Thailand to Bangkok, where they largely disappear in the Chao Phraya River and are not recovered as plant nutrients (Færge et al., 2001), other parts of the country and abroad, involve considerable nutrient transfers and losses. While the opportunities for using household and urban wastes are limited in the Northeast, compared to other areas, particularly around Bangkok (Færge et al., 2001), recycling of these materials in agricultural production in Northeast Thailand should be increased and ways should be identified to minimize nutrient removal from sites of agricultural production, and maximize the return of nutrients. More research is needed to find appropriate solutions for the effective recovery and safe use of these materials for agricultural production.
3.5. Conclusions
The low and declining soil fertility in many agro-ecosystems in Northeast Thailand and the poverty of many farm households in the region provide strong incentives for research and development (implementation) efforts to improve agricultural productivity and the sustainability of the rural production and livelihood systems. As long as the economic situation does not provide opportunities for increased off-farm income, efforts aimed at income generation should concentrate on-farm, through farm diversification and adoption of improved management strategies. Overcoming the negative effects of the economic crisis on the agricultural sector, will require substantial investments, including for water resource management projects, and institutional and policy reforms (ADB, 1999).

Many national and international institutions involved in agricultural research have recommended improved farm management strategies, with special emphasis on nutrient management, which should lead to increased agricultural productivity in Northeast Thailand. These management strategies include the use of inorganic fertilizers and various organic inputs, integration of inorganic and organic inputs, more integrated approaches to nutrient management, and modifications in cropping and farming systems. It appears that, for various reasons, farmers have adopted only a limited number of the recommendations.

R&D needs to be set in the context of the biophysical and socio-economic constraints of the farming communities with extension materials and methods to be developed in a participatory way. Identification of (D)RMDs, and strategies that match these domains, must become a major focus of research and part of an approach for adoption and implementation of improved and sustainable land management practices. As part of it, increased use of participatory and multi/interdisciplinary research methods is required to increase the quality and impact of research and increase the likelihood of adoption of improved strategies by farmers.

A number of highly specific research topics could be addressed in comparative isolation; however, the majority requires attention at the farming system level. An agro-ecosystems, eco-regional, or most appropriately RMD or DRMD approach, with co-ordination of collaborative research efforts across and within institutions and, with farmer participation defined in a client-oriented, demand-driven and site-specific way, should increase their efficiency to the greater benefit of the rural poor.

3.6. Summary of bottlenecks and challenges for R&D in Northeast Thailand
Major challenges exist to realize the twin objectives of improved and sustainable land management and improved and sustainable livelihoods in Northeast Thailand. A wide range of problems have to be solved in the fight against the daunting associated
Table 3.1: Bottlenecks and challenges for R&D in Northeast Thailand.

### A. Biophysical constraints and challenges

**Constraints**
- Dominance of inherently marginal soils
  - Coarse textures, limited nutrient pools, low effective cation exchange capacity (ECEC), low base saturation (BS), low soil organic matter content (SOM), etc.; large areas of saline soils
- Erratic rainfall and lack of irrigation water
- Micro-topographic variability

**Possible solutions**
- Design and adoption of innovative dynamic and site-specific water and nutrient management strategies/land-use systems
  - Combinations of organic and inorganic inputs and cropping system approaches; inputs synchronized with crop requirements and weather conditions; slow-release fertilizers; leaching and erosion control; improved G×E interaction; site-specific (topographic position) land use systems and nutrient management.
- Integrated farming, focus on farm (and off-farm) activities not merely relying on the quality of natural resources alone, but very much on farming system innovations (e.g. zero-grazing, fish farming, etc.)
- Small-scale irrigation (ponds, pumps); larger irrigation systems and biophysical improvements (e.g. land levelling), but only if and where biophysically and socio-economically appropriate and feasible

### B. Socio-economic constraints and challenges

**Constraints**
- Generally low education level (partly because of brain drain to urban centres)
- Limited capacity of private sector; lack of capital
- Limited economic diversification; vulnerability
- Relatively weakly developed markets and unstable (world) market prices
- Insecure land rights and lack of quality land (partly a biophysical constraint) for resource-poor farmers
- Increasing rural population and increasing demand for agricultural products (partly related to economic crisis and international market situation)

**Possible solutions**
- Main focus on quality education, equity and empowerment of rural poor, gender equity
- Create enabling conditions and opportunities in rural areas
- On- and off-farm (livelihood) diversification (agriculture not only focus).
- Start-up initiatives, partnership building, creation of interest groups (institutional development at community level).
- Improved land use policy based on multi-stakeholder involvement and insights
- Emphasis on environmental protection; reduced pressure on marginal lands
- Reduced dependence on, or influence of fluctuations in international markets

### C. Inherent (including institutional and policy-related) R&D constraints and challenges

**Constraints**
- Sometimes technically inappropriate
- Inappropriate in broader (holistic) context: biophysical, socio-economic, cultural and/or political constraints may be overlooked.
- Too static (focussed on current state, instead of taking into account possible development trends; subject may become outdated before results appear)
- Too much site-specific/too little orientation on site-specificity; how to scale-up or account for site-specificity/diversity?
- Disregard for or lack of time to realize ultimate objectives/implementation/impact (often due to deviating agendas)
- Lack of capacity (time, human, financial, organizational, and institutional)
- Lack of coordination and priority setting (lost time and double, isolated or irrelevant efforts partly due to competition for financial and human resources and ideas)
- Inappropriate extension

**Possible solutions**
- Participatory and interdisciplinary approaches
  - Identification of constraints for proper implementation
  - Strengthen institutional settings for the use of participatory approaches
- More sharing, collaboration and partnerships both vertically and horizontally.
  - Strengthen partnerships between research and extension systems on one hand, and farmers and their organizations on the other hand.
  - Strengthen partnerships among national and international R&D institutions, among different farmer and community-based organizations and among donor organizations and between these different stakeholder groups.
- Improved research planning, including priority setting
  - Consistent focus on objectives, final goals, sustainability (exit strategies) and impact
  - Reduction or elimination of non-constructive deviating (personal / secondary) agendas
- Quality education
- Changes in attitudes
problems of land degradation and poverty. These problems can be categorized in biophysical, socio-economic and R&D-related issues (Table 3.1). It should be emphasized, however, that such a categorization is always somewhat arbitrary, and thus a simplification of reality, as the problems are very much interrelated. Moreover, the true bottleneck will be different for different situations, and despite critical notes with respect to the overall impact of rural R&D in general, it did produce some excellent and highly successful results. These notes rather emphasize that in general, for various aspects, there is considerable scope for improvement in the efficiency and effectiveness of R&D efforts. At the organizational and institutional levels, this could be achieved through improved priority setting, improved coordination and continuity in efforts, requiring effective collaboration among R&D stakeholders. Hence, investment in capacity development aimed at institutional innovations and considerably improved organizational and institutional effectiveness should be at the top of the development agenda (Fukuda-Parr et al., 2002; Chapter 6).

A wide range of solutions could be suggested to solve or reduce, as much as possible, the range of problems identified (Table 3.1). Similarly to the problems, solutions have been categorized as partly based on disciplinary considerations, but it is re-emphasized that care should be taken not to lose out on the interdisciplinary and multi-scale character, involving many less tangible aspects (Chapter 6), of problems and their solutions. Hence, solutions should comprise interrelated components in integrated approaches, as attainment of sustainable land management and improved livelihoods in a complex reality requires broader participatory and interdisciplinary efforts to break the vicious circle of land degradation and unsustainability (cf. Rhoades and Harwood, 1992) or counteract the resource-poverty trap (McCowan and Jones, 1992), because of interrelated unfavourable biophysical and socio-economic conditions and constraints.
CHAPTER 4

Case study in Northeast Thailand:
Multi-scale nutrient balance analyses (NBA)*

Abstract

Large areas of Northeast Thailand are dominated by rainfed lowland rice-based land-use systems (LUS). Poor soil fertility, low inputs and modifications in current rainfed lowland rice-based farming systems are considered as major causes of sustainability problems. Nutrient balance analyses (NBA) are powerful for assessing some aspects of sustainability of these land-use systems.

Partial nutrient balances are useful indicators for some critical components of sustainability and important for decision support on soil fertility management when considered with the additional factors that are required for a full nutrient balance.

A pilot study was carried out at 10 farms in one district of Ubon Ratchathani Province, Northeast Thailand. More comprehensive biophysical, socio-economic and management-related data on the farming systems were collected, and well verified, down to the sub-farm level for 30 additional farms located in two sub-districts in the same province. A relational database system (RDBS) has been developed to manage and analyse the data. The database includes a utility to generate semi-automatically partial nutrient balances. Partial nutrient balances were assessed for land utilization types (LUTs), distinguished cropping system-management combinations at the sub-farm level, and aggregated up to the farm and sub-district levels. Outcomes are compared and discussed.

Mean partial N, P and K farm balances for the rice-based systems of the 30 farms are 12, 8 and 7 kg ha⁻¹ y⁻¹, respectively. Large variations in partial N, P, and K balances exist among and within farms, especially at the LUT level. Although the mean values were positive, many negative partial balances were observed, especially at the LUT level. The relatively high lower-scale variability in partial nutrient balances was about similar for the two sub-districts of the main survey and the district of the pilot-study. The results confirm the high inter-farm and intra-farm variability for partial N, P and K balances of preliminary studies and were re-confirmed again based on analysis of a broader data set of 80 farms spread out over six Districts. As such, similar tendencies appear to exist in large parts of Ubon Ratchathani Province and in major parts of Northeast Thailand with similar LUS.

Farmers manage nutrients for similar parcels of land in very different ways, which results in large variations in the partial nutrient balances, even for the same type of land-use within the same farm. The appreciation of biophysical variability together with constraints in financial and labour resources, are significant factors that result in unequal resource allocation, and thus management, between and within farms. There is a real risk that short-distance variability is hidden as a result of inappropriate scaling up of data. Policy makers and other users will make far better use of data at broader scales, if they are supplemented by indications of the variability at lower scales. Data outcomes are valued with specific emphasis on biophysical aspects, in line with a discussion on methodological aspects. This chapter also elaborates on how Partial NBA can be made useful for decision support like for policy development and the development of decision support tool (DST) aimed at participatory, dynamic and site-specific nutrient and land management.

4.1. Introduction

Large areas of Northeast Thailand are dominated by rainfed lowland rice-based land-use systems (LUS). Poor soil fertility, low inputs and modifications in current rainfed lowland rice-based farming have been identified as major causes of sustainability

* Major parts of this chapter were derived or adapted from: Wijnhoud et al. (2000), Wijnhoud et al. (2001) and Wijnhoud et al. (2003).
Chapter 4

problems (Chapters 2 and 3; Konboon et al., 2001).

Nutrient balance analyses (NBA) are powerful tools in the assessment of the sustainability of these land-use systems (Chapters 1–3). In combination with socio-economic data, nutrient budgets can indicate factors that are important in sustainable management of soils and that should be taken into account in developing improved recommendations aimed at both biophysical and socio-economic aspects of sustainability. Partial nutrient balances are useful indicators for some critical components of sustainability and important for decision support in soil fertility management, provided attention is paid to the additional factors that are required for assessing full nutrient balances.

A pilot study was carried out, covering 10 farms in Muang District of Ubon Ratchathani Province, Northeast Thailand (Wijnhoud et al., 2000). More comprehensive biophysical, socio-economic and management-related data on the farming systems were collected down to the field level for 30 additional farms located in two other districts in the same province (Chapter 2; Wijnhoud et al., 2001; 2003). Data obtained by semi-structured interviews were verified as much as possible by field checks. A relational database system (RDBS) has been developed to manage and analyse the data that includes a utility to generate semi-automatically partial nutrient balances (Chapter 2).

This chapter presents the results of multi-scale nutrient balance analyses (NBA) as largely based on partial nutrient balance analyses (PNBA) and elaborations about omitted factors and full balances. Apart from some direct conclusions their relevance heeding the relevance of multi-scale NBA for decision support to farmers, extension workers and policy makers. In addition to the rationale provided in Chapters 1–2 and general methodology of NBS-NET in Chapter 2, methodological issues and challenges are addressed in more depth throughout this chapter, and more in particular in Section 4.3.2.

4.2. Results

The farming systems of the 10 farms in the pilot study (Table 4.1) were rather similar to those of the 30 farms in the main survey (Tables 4.2 and 4.3), except that on three farms in the pilot survey peanuts were cultivated as off-season crop after rice harvest (Table 4.1), a crop that was absent on the farms in the main survey. Nevertheless, there is a wide range in rice productivity, nutrient use (Tables 4.1–4.3), and other farming system characteristics (Table 4.1).

Within the main survey, rice was grown as a single crop on 73 out of the total of 78 rice-based land utilization types (LUTs). In the remaining 5 LUTs, covering only 1.8% of the overall area, post-rice crops, mainly vegetables, were grown during the dry
Table 4.1: Characteristics of 10 farms and 18 fields surveyed in Muang District of Ubon Ratchathani Province, Northeast Thailand (adapted from Wijnhoud et al., 2000).

<table>
<thead>
<tr>
<th>Farm /household</th>
<th>Number</th>
<th>Total</th>
<th>Field Number</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>10</td>
<td>10</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Female farm manager</td>
<td>2</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Off-farm income</td>
<td>7</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Income by rice sale</td>
<td>7</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Non-rice farm income</td>
<td>10</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Fish pond(s)</td>
<td>10</td>
<td></td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Buffaloes /cattle</td>
<td>9</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Agricultural education</td>
<td>3</td>
<td></td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

**B: Major non-rice farm income sources, limitations and priorities**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Primary</th>
<th>Number</th>
<th>Secondary</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main non-rice on-farm income</td>
<td>Poultry/fish/cattle</td>
<td>6</td>
<td>Peanuts</td>
<td>3</td>
</tr>
<tr>
<td>Main limitation according to farmer</td>
<td>Topography / drought</td>
<td>7</td>
<td>No money to invest</td>
<td>2</td>
</tr>
<tr>
<td>Farm priority according farmer</td>
<td>Farm diversification</td>
<td>6</td>
<td>Water management</td>
<td>4</td>
</tr>
</tbody>
</table>

**C: Farm/household and field statistics**

<table>
<thead>
<tr>
<th>Farm/household and field statistics</th>
<th>Number</th>
<th>Max1</th>
<th>Mean1</th>
<th>Median1</th>
<th>Min1</th>
<th>Sum2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household size</td>
<td>10</td>
<td>13</td>
<td>6.5</td>
<td>6.5</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Age of farm manager</td>
<td>10</td>
<td>50</td>
<td>43</td>
<td>43</td>
<td>35</td>
<td>-</td>
</tr>
<tr>
<td>Farm labour (household)</td>
<td>10</td>
<td>6</td>
<td>2.7</td>
<td>3</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Cattle / buffaloes (head)</td>
<td>9</td>
<td>10</td>
<td>3.1</td>
<td>2.5</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Chickens / ducks (head)</td>
<td>10</td>
<td>500</td>
<td>79.8</td>
<td>18.5</td>
<td>6</td>
<td>798</td>
</tr>
<tr>
<td>Pigs (head)</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Paddies (ha)</td>
<td>10</td>
<td>6.1</td>
<td>3.3</td>
<td>3.0</td>
<td>1.2</td>
<td>32.5</td>
</tr>
<tr>
<td>Yield paddy (kg ha⁻¹)</td>
<td>10</td>
<td>3,526</td>
<td>2,088</td>
<td>2,108</td>
<td>927</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field</th>
<th>Number</th>
<th>Max1</th>
<th>Mean1</th>
<th>Median1</th>
<th>Min1</th>
<th>Sum2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ha)</td>
<td>18</td>
<td>4.5</td>
<td>1.8</td>
<td>1.4</td>
<td>0.3</td>
<td>32.5</td>
</tr>
<tr>
<td>Yield paddy (kg ha⁻¹)</td>
<td>18</td>
<td>4,688</td>
<td>2,028</td>
<td>2,086</td>
<td>250</td>
<td>-</td>
</tr>
<tr>
<td>Cattle manure N-P-K (kg ha⁻¹)</td>
<td>14</td>
<td>89-17-75</td>
<td>24-4-19</td>
<td>12-2-10</td>
<td>0.2-0.1-0.2</td>
<td>-</td>
</tr>
<tr>
<td>Input poultry manure (kg ha⁻¹)</td>
<td>7</td>
<td>15-13-16</td>
<td>6-5-7</td>
<td>2-2-2</td>
<td>0.4-0.3-0.4</td>
<td>-</td>
</tr>
<tr>
<td>Mineral N-P-K (kg ha⁻¹)</td>
<td>17</td>
<td>97-42-80</td>
<td>24-10-14</td>
<td>17-6-8</td>
<td>6-3-3</td>
<td>-</td>
</tr>
<tr>
<td>Organic N-P-K (kg ha⁻¹)</td>
<td>18</td>
<td>89-19-75</td>
<td>20-5-17</td>
<td>13-3-11</td>
<td>0.2-0.1-0.2</td>
<td>-</td>
</tr>
<tr>
<td>Total N-P-K input (kg ha⁻¹)</td>
<td>18</td>
<td>120-46-101</td>
<td>42-14-30</td>
<td>30-11-19</td>
<td>2-1-1</td>
<td>-</td>
</tr>
<tr>
<td>Organic N-P-K (% total N-P-K)</td>
<td>17</td>
<td>100-100-100</td>
<td>41-36-50</td>
<td>39-36-46</td>
<td>1-1-4</td>
<td>-</td>
</tr>
</tbody>
</table>

1 Statistical parameters only based on non-zero values as specified by ‘number’.

2 Only calculated if considered relevant.

season. Although these crops were considered in the assessment of partial balances, due to their diversity and limited area, no meaningful comparison was possible with the mono-cropped areas (Wijnhoud et al., 2000, 2001, 2003).

Mean rice yield was 2.5 Mg ha⁻¹ (2.1 Mg ha⁻¹ in the pilot survey), *i.e.* higher than the average for Northeast Thailand of 1.8 Mg ha⁻¹, but relatively low by Southeast
Table 4.2: Rice cultivation for the 30 farms, and the associated 78 rice-based LUTs (within 58 fields), surveyed in Northeast Thailand (Source: Wijnhoud et al., 2003).

<table>
<thead>
<tr>
<th></th>
<th>30 Farms</th>
<th></th>
<th>78 LUTs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD*</td>
<td>Mean</td>
<td>SD*</td>
</tr>
<tr>
<td>Rice cultivation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area (ha)</td>
<td>3.3</td>
<td>1.5</td>
<td>1.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Yield (Mg ha⁻¹ y⁻¹)</td>
<td>2.5</td>
<td>0.6</td>
<td>2.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Rice Production (Mg)</td>
<td>7.8</td>
<td>3.3</td>
<td>3.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

* SD = standard deviation.

Table 4.3: Nutrient inputs and partial N, P and K balances for the 30 farms, and the associated 78 rice-based LUTs, surveyed in Northeast Thailand (Source: Wijnhoud et al., 2003).

<table>
<thead>
<tr>
<th></th>
<th>Farms</th>
<th></th>
<th>LUTs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>Nutrient inputs (Mg ha⁻¹ y⁻¹)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral N</td>
<td>30</td>
<td>35</td>
<td>18</td>
<td>77</td>
</tr>
<tr>
<td>P</td>
<td>30</td>
<td>14</td>
<td>6</td>
<td>77</td>
</tr>
<tr>
<td>K</td>
<td>26</td>
<td>13</td>
<td>9</td>
<td>64</td>
</tr>
<tr>
<td>Organic N</td>
<td>28</td>
<td>4</td>
<td>4</td>
<td>52</td>
</tr>
<tr>
<td>P</td>
<td>28</td>
<td>1</td>
<td>1</td>
<td>52</td>
</tr>
<tr>
<td>K</td>
<td>28</td>
<td>5</td>
<td>5</td>
<td>52</td>
</tr>
<tr>
<td>Total N</td>
<td>30</td>
<td>39</td>
<td>19</td>
<td>77</td>
</tr>
<tr>
<td>P</td>
<td>30</td>
<td>16</td>
<td>7</td>
<td>77</td>
</tr>
<tr>
<td>K</td>
<td>30</td>
<td>16</td>
<td>10</td>
<td>73</td>
</tr>
<tr>
<td>Partial balances (Mg ha⁻¹ y⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>12</td>
<td>17</td>
<td>78</td>
</tr>
<tr>
<td>P</td>
<td>30</td>
<td>8</td>
<td>6</td>
<td>78</td>
</tr>
<tr>
<td>K</td>
<td>30</td>
<td>7</td>
<td>10</td>
<td>78</td>
</tr>
</tbody>
</table>

* For nutrient inputs, n, mean and SD are for non-zero values.

Asian standards. Annual nutrient inputs at the farm level, in the form of inorganic fertilizer and organic materials, averaged 39, 16 and 16 kg ha⁻¹ (Medians are 30, 11 and 19 in the pilot survey) for N, P and K, respectively. All farms used fertilizers, and all but two applied organic amendments; but not on all fields and LUTs. One LUT received neither fertilizer nor organic amendments, and one third of the LUTs received no organic amendments (Wijnhoud et al., 2003).
Yields and nutrient input rates strongly varied among farms and, even more so, among LUTs. Although yield and rates of application were significantly positively correlated (P ≤ 0.05), not surprisingly, yields could not be predicted from the application rates, due to the many other confounding factors, such as differences in initial soil fertility, be that as a result of previous fertility management or of inherent soil properties. Multiple regression techniques could be used to predict yields from application rates and a range of additional factors, but this would require a much larger and biophysically more diverse data set (Wijnhoud et al., 2003).

Mean partial farm level N, P, and K balances for rice production for the 30 farms were 12, 8 and 7 kg ha$^{-1}$ y$^{-1}$, respectively (Wijnhoud et al., 2003), however with large variations, particularly for N, among farms and even larger among LUTs, with many negative partial balances (Figure 4.1). These large variations are the result of substantial differences in nutrient management for different fields, even for the same type of land-use within the same farm (Figure 4.2).

These results confirm the high inter-farm and intra-farm variability in partial N, P, and K balances observed in the pilot study (Wijnhoud et al., 2000), which is well portrayed in the picture that shows the variability in partial N balances among the 18 fields of the 10 farms (Figure 4.3a). Similar observations were made in a preliminary nutrient balance study in the region (Lefroy and Konboon, 1998) and the results of basic analysis for the larger data set of 80 farms spread out over six Districts (Konboon et al., 2002), including the 30 farms covered by the main survey (Wijnhoud et al., 2003).

Figure 4.1: Mean partial balances of N, P, and K for 78 LUTs from 30 farms, with 10 and 90 percentiles (Source: Wijnhoud et al., 2003).
Figure 4.2: Variations in N, P, and K partial balances for four LUTs on two fields of one farm in Seped sub-District, Ubon Ratchathani Province (Source: Wijnhoud et al., 2003).

Even though the mean partial N balance at the LUT level for the main survey is higher than the mean partial P and K balances (Figure 4.1), the number of LUTs with negative partial P and K balances is much lower than that with negative partial N balances, similar to the results from Wijnhoud et al. (2000) for the pilot study (Figures 4.3a, 4.3b and 4.3c).

In the main survey, yield was not correlated significantly with either the N or P partial balances ($P > 0.05$), but yield was significantly positively correlated ($P = 0.03$) to the partial K balance (Wijnhoud et al., 2003). Six rice varieties were grown on the 78 LUTs surveyed, but two varieties were cultivated on 70 of the sites. These are the non-glutinous KDML105, primarily grown as a cash crop, and the glutinous RD6, primarily grown for home and local consumption (Chapter 3, Section 3.3.1). There were no differences between the rates of fertilizer applied to these two varieties, but the partial N balances were significantly higher for KDML105, mainly as a result of the lower average yield.

Results from the pilot study (Wijnhoud et al., 2000) revealed that the range in partial N and K balances for the rice-peanut cropping systems surveyed is much less favourable than that for the rice mono-cropped systems (Figure 4.4). Even if inputs of N from Biological Nitrogen Fixation and N and K from other sources would be considered, the differences in the ranges of balances between these systems would persist. Hence, supplementary inputs for the rotation crop are insufficient to compensate for the higher nutrient outputs (Wijnhoud et al., 2000). Sufficient
Figure 4.3a: The variation in partial N balances among fields of 10 farms in Muang District, Ubon Ratchathani Province (adapted from Wijnhoud et al., 2000).

Figure 4.3b: The variation in partial P balances among fields of 10 farms in Muang District, Ubon Ratchathani Province (adapted from Wijnhoud et al., 2000).

Figure 4.3c: The variation in partial K balances among fields of 10 farms in Muang District, Ubon Ratchathani Province (adapted from Wijnhoud et al., 2000).
availability of P and K is a condition for taking full advantage of the N-fixing characteristics of leguminous crops within sustainable cropping systems (Konboon et al., 2001). Moreover, N fixation by a leguminous crop does not fully cover its total N-requirements.

Apart from incorrect insights due to interpretation of averages only, spatial data integration may result in blurred outcomes, as illustrated for partial N-balances at
different aggregation levels (Figure 4.5). Especially, the existence of a significant number (10%) of LUTs with substantially negative partial N-balances of below 14 kg ha$^{-1}$ y$^{-1}$ would not have been revealed if analysis would have been limited to the farm level.

A general look at the results for Trakan Phutphon District (20 farms, 1999 growing season), Nayea District (10 farms, 1999 growing season), and the pilot study for Muang District (10 farms, 1998 growing season), shows only minor variations in the values of partial N, P and K balances. The lowest values for the median partial N and P-balances are recorded in Muang District and the lowest median partial K-balance in Trakan Phutpon District (Figure 4.6). The fact that 1998 data from Muang district are compared with 1999 data from the other two districts is expected to have limited influence. The larger number of fields with negative partial N and K balances in Muang District, may be due to the presence of relatively more rice-peanut cropping systems (Wijnhoud et al., 2000) and possibly to lower rainfall in 1998, as farmers tend to apply less fertilizers in the higher parts of the toposequence at lower rainfall (Konboon et al., 2001). Within all three districts the partial balances, especially for N and K, are highly variable (Wijnhoud et al., 2000, 2003), which was not evident from the lumped mean partial balances in two districts (Figure 4.1).

The semi-structured on-farm water-nutrient-crop monitoring activity with experimental component revealed that position in the landscape has a significant affect on the growth of rice in the NE of Thailand and partial nutrient balances. In general, rice yields were greater in the middle and lower parts of the toposequence. For the

Figure 4.6: Median N, P and K partial LUT balances for three Districts in Ubon Ratchathani Province (Source: Wijnhoud et al., 2001).
sites monitored, average yields were 40% greater in the lower parts of the toposquence. The lower partial nutrient balances in the lower parts of the field, largely due to greater off-take, were not reflected in the soil-N status, presumably as a result of movement of nutrients down the toposquence (Konboon et al., 2002).

4.3. Discussion of results
The results of the semi-interactive interviews and field surveys (Chapter 2) illustrate the impact of different biophysical and socio-economic factors on the inter- and intra-farm variability in partial nutrient budgets, although it was difficult to quantify these relationships (Wijnhoud et al., 2003). The impact of biophysical factors and methodological aspects will be addressed here, with occasional reference to socio-economic aspects. In the Chapters 1, 5 and 6, livelihood dimensions and socio-economic linkages of land and nutrient management are dealt with comprehensively.

4.3.1. Biophysical characteristics of land and nutrient budgets
The interactions between the biophysical conditions of the land and nutrient balances are complex. Firstly, as biophysical conditions affect water and nutrient flows, strong correlations would be expected with yields and nutrient exports, both of which are included in partial balances. However, because of the complexity of the processes, even with 78 samples, there were no significant relationships between yields, nutrient balances and biophysical characteristics (P > 0.05) (Wijnhoud et al., 2003). Secondly, it is clear that the biophysical conditions, especially slope and position in the toposquence, soil texture and surface structure, have a direct impact on the balance between some critical inputs and losses. This holds in particular for the balance between inputs from subsurface inflow, run-on and sedimentation and losses through leaching, run-off and erosion. As these components are not taken into account in partial balances, areas with favourable biophysical conditions, for instance those in the lower parts of the topography, are more likely to have more positive complete nutrient balances than suggested by the partial balances, and vice versa for less favourable areas (Wijnhoud et al., 2003). Thirdly, the survey indicated that farmers’ decisions on management of land with different biophysical conditions are governed by complex considerations, partly based on socio-economic factors associated with subjective behaviour, which at first sight may not always appear fully consistent (Chapter 5). In many cases, the more marginal lands were less well managed, as priority was given to fields or parts of fields with higher potential, except for fields that are known to farmers as being characterized by a relatively high production without addition of nutrient inputs. Hence, the more marginal lands in the highest topographical positions and the scarce very fertile lands in the lowest topographical positions receive less
fertilizer and organic amendments. The former, because priority is given to fields with higher potential in intermediate topographical positions, the latter because of their relative high ‘natural’ fertility resulting from continued nutrient inflow from higher positions. For the farmers in these conditions, decisions on the fertilizer dose applied to different fields or sections of fields were based on soil texture and/or micro-topography, characteristics that play a role in their estimates of rice production potential, largely determined by water supply at the end of the crop cycle and during mid-season droughts. Discussions with farmers indicated that these factors were important in decision-making for some, but not for others. Despite these strong indications, there were no significant correlations between these management factors and nutrient application, as the different groups of managers could not be separated statistically on the basis of any of the factors that were assessed (Wijnhoud et al., 2003).

Acknowledging the impact of leaching and subsurface flow, Vityakorn (1989) concluded that rice cultivation in the lower paddies is likely to be biophysically more sustainable than in the higher positions in the toposequence, because of inflow of nutrients from the surrounding higher positions. Similarly, a nutrient balance study in the Khon Kaen and Udon Thani provinces in Northeast Thailand indicated a range in balances for paddy fields related to their position along a toposequence (Poltanee et al., 1998).

In general, the 78 LUTs at 30 farms in this study were characterized by relatively sandy soils and were situated on the old alluvial middle and high parts of the toposequence within the gently undulating landscape; very few LUTs were located in the lowest micro- and meso-topographical positions. It is likely, therefore, that losses that are not included in the partial balances, such as leaching, run-off (mainly N and K), and gaseous losses of N, will exceed the inputs that are not included, such as surface and subsurface inflow, biological nitrogen fixation, wet and dry deposition, and gains from the subsoil by deep rooting weeds and trees. With well-managed bunds between the paddy fields, sedimentation, unlike subsurface flow, appears to be irrelevant (Wijnhoud et al., 2003). Thus, full nutrient balances, particularly in the higher and middle topographical positions, can be expected to be more negative than partial nutrient balances, the magnitude of the difference varying with site characteristics such as the exact topographical position and soil texture, and with nutrient element, because of their different loss pathways (Konboon et al., 2002; Wijnhoud et al., 2003). The opposite is true for lower topographic positions where partial nutrient balances are expected to be more negative than full nutrient balances (Konboon et al., 2002).

In addition to the effect of bunds around the paddy fields, drainage characteristics are dominated by the combined effect of topographical position and soil texture. Other
Chapter 4

factors, however, do affect drainage rates and thus the nutrient balance. For instance, the presence of shallow compacted or impermeable layers, resulting from tillage or shallow iron pans and lateritic layers, can impede drainage. In general, presence of such layers has positive effects on nutrient balances, by reducing leaching losses, as well as the important positive effect of maintaining water supply towards the end of the rice-growing season (Wijnhoud et al., 2003).

There was little evidence of major nutrient inputs of N, P and K through inflow of water on the paddies, except for two fields on two different farms in this survey, where inflow of nutrient-rich water added significantly to nutrient inputs, resulting in relatively high yields on fields with sandy soils and low fertilizer inputs. Farmers explained that the high yields were due to wastewater inflow from the households located directly above the fields. Although not widespread, such off-field sources of nutrients are not rare.

Animal wastes may constitute a significant on-farm source of nutrients in inflow waters on a limited number of fields. While nutrient balances will be underestimated where such sources are present, they can only be quantified accurately through very intensive monitoring and analysis; qualitative adjustments can be made to the interpretation of partial nutrient balances where relevant. Many farmers appear aware of the inflow of nutrients in lower topographical positions and through wastewater inflow and some farmers adjusted their nutrient management accordingly (Wijnhoud et al., 2003).

The importance of site-specific conditions in the interpretation of partial nutrient budgets further emphasizes the risk of blanket nutrient or other management recommendations. Oberthür et al. (1999) also demonstrated the micro-topographical and related spatial variability in the natural resource base characteristics of the region, on the basis of soil samples and mapping, and suggested that these short-range variations may create problems in scaling up of data.

Hence, indigenous knowledge and/or careful observations on spatial variability of biophysical and non-biophysical factors over short distances can and should provide additional information for interpretation, particularly in data-sparse environments (Wijnhoud et al., 2003).

4.3.2. Methodological aspects

Problems and shortcomings of nutrient balance analyses (NBA)
The development and use of nutrient budgets has a logical appeal to many farmers, extension officers, and researchers; however, there are problems in calculating balances and limitations in their interpretation. Many of the weaknesses in nutrient
budgeting arise from the complexity of nutrient flows and interactions between nutrient pools, while others are related more directly to measurements (Wijnhoud et al., 2000; Chapter 1). Firstly, the fairly simple model used in accounting for nutrient flows does not take into account temporal or spatial variations in nutrient supplying capacity or relate to other aspects of short-, medium-, and long-term availability of nutrients, as depending on total nutrient contents, their release and crop uptake potentials. Secondly, calculation of balances relies on accurate quantification of inputs and outputs, either for the particular case being studied or from appropriate default values and estimates. In the former situation, the results of nutrient balance analyses (NBA) must be judged with caution, in the latter, quality data must be collected and research undertaken to develop easy methods of assessment, most appropriately incorporating the indigenous knowledge system and/or appropriate default values. As the method is data-intensive, strict priority setting, relying partly on expert knowledge, is needed to identify the most relevant factors within the nutrient balance and determine the level of accuracy required. Optimal priority setting will depend on objectives, capacity and scale, both spatial and temporal, and, as such, will be site-specific and dynamic (Chapter 1; Wijnhoud et al., 2000).

In many nutrient balance studies, the nutrient balance model as specified by Stoorvogel and Smaling (1990) has been used; implicitly considering it a model for full nutrient balance analyses (Chapters 1–2). That model, however, does not account for factors such as the redistribution of nutrients from the subsoil by deep rooting crops, weeds, and trees, inputs through weathering and immobilization in stable compounds or in trees and other perennials, which deserve further attention (Chapter 1). Neither does it include directly the impact of subsurface inflow, including nutrient inputs through capillary rise, although this may be included, if estimates of subsurface flows, including leaching, refer to net flows (Wijnhoud et al., 2000).

Simultaneous application of methods from social and economic sciences could strengthen the nutrient balance approach and could provide the broader context within which the use of nutrient balances for wider practical implementation and for policy making need to be set (Scoones and Toulmin, 1998; Chapters 1, 5 and 6).

**Shortcomings and advantages of partial nutrient balance analyses (PNBA)**

Assessment of partial instead of full nutrient budgets has shortcomings. Partial balances provide quantitative data from which conclusions with respect to aspects of the sustainability of land use can be drawn, but only with caution. The importance of appraising omitted factors within partial balances has been emphasized already. This needs to be done in site- and nutrient-specific ways, especially in spatio-temporally highly variable environments, such as the micro-topographic catenae with
superimposed erratic rainfall, as in the study area. It is difficult to obtain accurate information on inputs in dry and wet deposition, BNF, and subsurface inflow and outputs in gaseous losses, leaching, other subsurface outflows and erosion. However, there is some understanding of the order of magnitude of and variability in these inputs and outputs. Their spatial variability is associated with specific sets of environmental conditions per input and output term. In this study, assessment of drainage patterns and hydrological flows will be most relevant for estimation of full N and K balances, while assessment of gaseous losses, through denitrification and volatilization, and BNF may be relevant for estimation of full N balances. Similarly to e.g. leaching, also gaseous losses are site- and case-specific, depending on the type of N-inputs applied, timing and method of application and a wide range of spatio-temporally varying environmental conditions. BNF is only relevant where leguminous species have been included within cropping systems, such as peanuts for some LUTs in the pilot study (Wijnhoud et al., 2000).

Paradoxically, a major strength of partial nutrient balance analyses (PNBA) derives from the omission of difficult-to-assess factors. The option of flexible, dynamic, site-specific appraisal of the omitted factors may be preferable to the use of transfer functions or disproportional investments in their accurate measurement. Assessment of partial nutrient balances fits in much better than that of full balances with the participatory decision support efforts and the elaboration of a decision support tool for nutrient management to be applied by farmers and extension workers (Section 4.4; Chapter 5). The use of transfer functions might easily result in major mistakes or inaccuracies, especially if recklessly extrapolated and applied without sufficient calibration and validation (Færge and Magid, 2004). Moreover, the need for investments and capacity for calibration and validation in itself can be considered disadvantages. Similarly, intensive measurement / monitoring of difficult-to-assess factors may be a waste of capacity and resources, especially in highly variable data-sparse environments, when R&D capacity and time are limited and when the focus is rather on applied research, practical implementation and site-specific decision support than on in-depth scientific (strategic) research.

Accuracy of measurement and estimation
The weakest points with respect to the accuracy of the partial balances in this, and most other studies, are probably the estimates or default values that are used (Wijnhoud et al., 2000; Chapter 1). Estimates of the nutrient contents of fertilizers and the amounts applied should be reasonably accurate. Estimates of product off-takes should be the next most accurate. Estimates of the quantities and nutrient contents of crop residues will be less accurate, although the impact depends on the proportion of
residues removed or lost and their management. For instance, substantial inaccuracies are associated with estimation of nutrient losses during burning of rice stubble, which occurred during preparation for cultivation of peanuts after rice. The estimate for N-loss (65%) was based on a relatively reliable experimental measurement (Chaitep, 1990); however, the estimates for losses of P (25%) and K (25%) are less accurate. Although accuracy of nutrient balance calculations would be improved by better estimates of nutrient losses on burning and their relation to characteristics such as the degree of burning and environmental conditions, this may not be that critical, as burning is decreasing in Northeast Thailand.

The largest inaccuracies in these partial budgets originate from the estimates of amounts and, more particularly, nutrient contents of organic manures applied (Wijnhoud et al., 2000, 2003; Chapter 1). In the pilot survey, two different combinations of estimates of N content in organic manure were used for the assessment of partial N balances for the 10 farms (Wijnhoud et al., 2000). These different combinations resulted in considerable differences in partial N balances (Figure 4.7), with balances decreasing for farms using cattle manure and increasing for those using large amounts of poultry manure, compared to the original balances, based on default values (default 1). Nutrient contents in manure vary considerably and better estimates must be obtained to increase the accuracy of nutrient balances.

![Partial N-balance graph](image)

**Figure 4.7: The effect of using different default values for N contents in manures on the range of partial N balances for the 10 farms (adapted from Wijnhoud et al., 2000).**

**Default 1:**
- cattle manure N (%) = 1.58 (Dhanyadee, 1984);
- poultry manure N (%) = 1.23 (average for chicken and duck manure according to Dhanyadee, 1984);

**Default 2:**
- cattle manure N (%) = 0.9 (Naklang et al., 1988);
- poultry manure N (%) = 3.52 (Ariyathaj et al., 1988).
Again, strict priority setting is needed in maximizing accuracy, considering the limited capacity available. The process will be facilitated where easy access exists to relevant secondary data sets. There is a great need to collate and analyse existing data for specific combinations of climates, cropping systems, crops and soils, and, where required, supplement these data with results from new sampling programmes and analyses. In this perspective, the secondary or ‘default’ data component of for instance the NBS-NET RDBS (Chapter 2) could serve as a NBA-sustaining secondary data set for other studies and applications, such as decision support tools (Wijnhoud et al., 2003; Section 4.4 and Chapter 5).

4.4. Towards decision support for nutrient management and environmental protection

Nutrient budgets are very useful as indicators of some aspects of biophysical sustainability of land and land-use systems. In spite the challenges of proper implementation, extension workers and farmers can easily understand the logic of nutrient balance calculations (Defoer et al., 1998; Defoer and Budelman, 2000). As such, a nutrient budget is a suitable land quality indicator (Dumanski and Pieri, 2000) for inclusion in a simple DSS for farmers and extension workers. The first and most logical application of NBA is assessment of the biophysical impact of land-use and land management practices on productivity and sustainability. The RDBS and other outputs of NBS-NET can provide a basis for the development of a dynamic and site-specific DSS and a related DST for improved and sustainable nutrient and land management. Such a system will be pivoted around the assessment of partial nutrient balances, which is expected to be more useful for a flexible inexpensive approach than directly incorporating full nutrient balances.

The spatio-temporal variability revealed in the data results, provides a good entry point for the development of improved and sustainable dynamic and site-specific water, nutrient, and land management along the toposequences of rainfed lowland rice-based systems in Northeast Thailand (Konboon et al., 2002). Partial nutrient balances, in combination with other relevant information and observations, allow extrapolation to full nutrient balances. Such full nutrient balances are derived through inclusion of default menus and correction factors to account in a dynamic and site-, nutrient- and case-specific way for some of the relevant factors not included in the current partial balance calculations. The semi-structured on-farm water-nutrient-crop monitoring activity along micro-topographic catenae was also a useful auxiliary for the interpretation of the PNBA results and for decision support purposes (Section 4.2; Konboon et al., 2002).

Therefore, PNBA will serve predominantly, but not solely, to assess the biophysical
aspects of sustainable land and nutrient management within the DST.

The conceptual DST should be user-friendly and allow NBA for different scenarios, defined in terms of alternative land-use and land-management options, on the basis of a range in default values for nutrient concentrations in products, residues and manure. Scenarios, characterized by specific partial balances, and the associated economic consequences, need to be constructed to generate, in combination with other relevant information on spatio-temporal environmental characteristics, insights in sustainability and associated environmental and socio-economic risks. Expert knowledge or expert systems may be required to provide yield estimates under different scenarios. Although nutrient budgets and crop production potentials do not constitute the full set of component factors of biophysical sustainability, reasonably accurate estimates of these factors should provide a useful basis for its evaluation for different land-management systems.

Nutrient budgets are a necessary, but not sufficient component of sustainability evaluation. For instance, nutrient budgets can be positive in a situation of low productivity, if the initial soil fertility status is very low, or negative and associated with high productivity, if the initial soil fertility status is very high. In addition to nutrient balances, a DST must take into account the nutrient status of the soil and the situation with respect to other production limiting constraints. Further development of a DST requires linking of nutrient balances to soil fertility status (stocks) and soil fertility targets (Bindraban et al., 2000). In addition, consideration must be given to the indigenous soil nutrient supply, nutrient recovery as related to yield targets, and related internal nutrient efficiencies (Janssen et al., 1990; Witt et al., 1999). Estimated target yields and target or threshold fertility levels should be realistic and should therefore be site- and case-specific. Target yields may be derived from model results in relation to yield potentials. In this perspective, Bindraban et al. (2000) emphasize the synergism of NBA with yield gap analysis. Target or threshold fertility levels depend on crop requirements associated with a realistic target yield, on soil characteristics and on soil fertility management alternatives. It would be unrealistic to try to maintain sandy soils at a high fertility level year-round, while nutrient recovery of applied fertilizers is very low and losses are high, both from an environmental and economic point of view. In LUS characterized by sandy soils, optimizing recoveries, especially for N, for instance through synchronizing soil nutrient supply and crop nutrient requirements is a major challenge (Chapter 3). In fine-textured soils more or less constant fertility levels may be pursued and K and P re-capitalization may be useful to sustain production and pursue Sustainable Natural Resource Management (Sanchez et al., 1997; Buresh et al., 1997), although not being a panacea everywhere and under all circumstances. It may for instance not be appropriate in situations characterized by the absence of fertilizer.
markets and/or the existence of other socio-economic and cultural constraints, but also in situations where soil and other land characteristics are not suitable for unconditioned fertility replenishment. For example, among soils with identical textures, those predominantly characterized by 1:1 clay minerals in general are much less suited for re-capitalization than soils predominantly containing 1:2 clay minerals.

Considering the highly variable mobility of different pools of nutrients associated with highly variable availability to crops, black-box NBA may not be sophisticated enough for decision support in precision agriculture. For such systems, NBA, most appropriately, could be based on measurement and assessment of different nutrient pools and their balances for one specific nutrient (cf. Janssen, 1993). Defoer et al. (2000) distinguish different reserves of N, P and K, based on their availability, as approximations for soil nutrient balances. As an example, some soil analytical data from the topsoil of a rice paddy in Ubon Ratchathani Province have been interpreted in the context of NBA for rainfed lowland rice production (Table 4.4).

Table 4.4: Prototype nutrient stock assessment for NBA-based decision support (partly adapted from Defoer et al., 2000).

<table>
<thead>
<tr>
<th>Soil analytical data of a paddy topsoil (0–20 cm) in Ubon Ratchathani Province</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density: 1.5 kg dm$^{-3}$</td>
</tr>
<tr>
<td>P-Bray #: 5 mg kg$^{-1}$</td>
</tr>
</tbody>
</table>

Calculation of weight for 1 ha topsoil:
10,000 × 0.2 × 1.5 × 1.000 = 3,000,000 kg

Available nutrients in topsoil and (grain) export in average rice crop (2.5 t ha$^{-1}$):

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Available (kg ha$^{-1}$)</th>
<th>Average crop export (kg ha$^{-1}$ y$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>56 ##</td>
<td>26</td>
</tr>
<tr>
<td>P</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>K</td>
<td>105</td>
<td>8</td>
</tr>
</tbody>
</table>

# Roughly represents labile P
## Directly available N has been calculated from the overall N reserve of 4,500 kg ha$^{-1}$ as:
4,500 × 50% (dynamic reserve) = 2,250 kg N ha$^{-1}$
2,250 × 2.5% (estimated directly available to crop) = 56 kg N ha$^{-1}$
An average rice yield of 2.5 t ha\(^{-1}\) (Tables 4.2 and 4.4) implies a nutrient export (in the grain) for N, P and K of respectively 26, 7 and 8 kg ha\(^{-1}\) (Table 4.4). Following partial NBA principles, this would mean that under zero-input on this soil, N, P and K balances would be respectively \(-26\), \(-7\) and \(-8\) kg ha\(^{-1}\) yr\(^{-1}\), and more negative, particularly for K, if nutrients harvested in the panicle straw would have been accounted for. Thus, the available soil N and P reserves can sustain an average yield for about two subsequent crops. K-reserves are sufficient to satisfy demand for more than 10 subsequent crops, implying that K reserves are sufficient in the short term, but are certainly not inexhaustible. In reality, the farmers in the area of the main survey apply inputs at an average rate that would sustain average yield on this soil, but only if recoveries would be high enough. Unfortunately, recoveries are not expected to be that high, especially not for N and K in the middle and higher parts of the toposequence, where most of the LUTs in the survey were located. As nutrient inputs to LUTs are strongly variable, for many LUTs current nutrient inputs are far from sufficient to sustain production, even if maximum recoveries could be attained.

Soil analytical data and partial nutrient balances need to be interpreted cautiously. Nutrient losses omitted from the partial balances are at the base of the low nutrient recoveries by crops, which, as the partial balances, need dynamic and site-specific interpretation. Non-recovered nutrients will end up in non-readily available nutrient reserves or disappear completely out of the system. At the same time, nutrients from relatively stable reserves are gradually transformed into crop-available forms. Therefore, after some years, annually available N in the topsoil will probably be somewhat higher than 56 kg ha\(^{-1}\). This means that assessment of pool-specific balances on the basis of differences in availability, related to differences in chemical form, might be a useful method in providing accurate decision support. Performing pool-specific NBA, however, may be difficult and expensive in practice. Apart from the underlying complexity, regular measurement of soil nutrient pools, through soil sampling and soil analyses will not be feasible in the developing world. Moreover, large investments in comprehensive analyses are not the first priority in a situation where substantial knowledge gaps may be filled by much cheaper, less accurate methods. This does not mean that insight in the behaviour of nutrients and systems would not be useful for the interpretation of the results of NBA. And of course, where and when available, sets of well-referenced and reliable soil analytical data that can be extrapolated to identical LUSs, can improve the appraisal of nutrient budgets. Development of user-friendly guidelines for the agro-ecological interpretation of soil analytical data may result in more efficient use of existing data by a wider group of users. Such guidelines are indispensable within a DST for farmers and extension workers. It may be desirable not to expose users directly to some of the complex
underlying principles, but then it will be necessary to develop simplified specifications for soil fertility status and targets. Indicators for site-specific evaluation of soil fertility and nutrient balance components need to be developed that match existing farmer knowledge and terminology (Lefroy and Konboon, 1998; Oberthür et al., 1999; Lefroy et al., 2000). In addition to simple rules for interpretation of natural soil fertility based on soil analytical data or simple indicators, user-friendly decision trees may be developed for the use of organic and inorganic inputs, such as developed by Palm et al. (2001) for the use of organic inputs and by the International Fertilizer Centre (IFDC) for the use of phosphate rock (Struif Bontkes and Wopereis, 2006).

The following more or less simple tools could be used as components of a decision support tool for general nutrient management:

(i) A sustainability indicator like adapted from Stoorvogel (1999):

\[ \Delta S D s_{dx} (%) = \frac{\Delta S D_x}{(S D_x - S D_{c,x})} \times 100\% \]  \hspace{1cm} (1)

With:
\[ \Delta S D s_{dx} (%) = \text{Rate at which the nutrient surplus or shortage, i.e. the nutrient amount above or below the critical level (nutrient specific fertility target) is depleted or replenished.} \]
\[ S D_{c,x} = \text{Critical level at which a certain nutrient becomes limiting for current (or anticipated) land-use (following scenario analyses), or at which there will be a surplus.} \]

(ii) Sengxua and Linquist (2000) presented the following decision support aid to identify fertilizer requirements:

\[ X = A - B \]  \hspace{1cm} (2)

With:  
\[ X = \text{Nutrients required in fertilizer (kg ha}^{-1}) \]
\[ A = \text{Nutrients removed in anticipated yield (kg ha}^{-1}) \]
\[ B = \text{Nutrients available from the soil (kg ha}^{-1}). \]

The tool ignores some relevant factors, but depending on site and management characteristics may be effective as an auxiliary tool.

(iii) The above tool (ii) could be somewhat further elaborated towards a fertilizer recommendation Decision Support Tool that directly incorporates nutrient balance principles:

\[ X = ((A - M) + IS + L + E + RO - WFS - BNF - D - SSR) \times \frac{1}{FRC} \]  \hspace{1cm} (3)
With:  
X = Nutrients required in fertilizer (kg ha\(^{-1}\)).
A = Nutrients removed in anticipated yields (kg ha\(^{-1}\)).
M = Management/Crop-related variable depending on crop residue management of the crops incorporated in the land-use system (kg ha\(^{-1}\)).
IS = Indigenous nutrient supply (kg ha\(^{-1}\)).
L = Nutrient- and land-use system-related variable, representing nutrients lost through leaching (kg ha\(^{-1}\)).
E = Nutrient and land-use system related variable (mainly depending on slope gradient, topographic position within catenae, soil texture and surface structure, and rainfall intensity in relation to soil cover) representing nutrients lost through erosion (kg ha\(^{-1}\)).
RO = Nutrients in run-off (kg ha\(^{-1}\)).
WFS = Nutrients available from the soil; nutrient-specific and related to soil fertility status and weathering characteristics of the soil (kg ha\(^{-1}\)).
D = Nutrient-, LUS- and site-specific estimate of nutrient deposition (kg ha\(^{-1}\)).
BNF = Cropping system- and yield-related factor for Biological Nitrogen Fixation-input for N (kg ha\(^{-1}\)).
SSR = Nutrient and LUS dependable factor for nutrient regained from the sub-soil by deep rooting crops, trees, capillary rise etc (mainly dependent on soil type, groundwater level, crops/trees included) (kg ha\(^{-1}\)).
FRC = Nutrient-, fertilizer-, and LUS-specific recovery fraction of applied nutrients.

As yet, these decision support aids have not been integrated into a simple – i.e. user-friendly – DST in which complex parameters related to indigenous nutrient supply and critical nutrient levels depend on soil analyses with soil types and soil (management) characteristics being linked to surrogate indicators and/or indigenous knowledge systems. For most of the data requirements (parameters), tables with default values based on transfer functions could be developed from which directly the required input data can be derived for use in a decision support system. Such tables and transfer functions should be considered first approximations and their reckless use should be avoided. Field/site-specific data are always better if on-site measurements and data collection are feasible and justified within the priority setting of and existing capacities for land and farm management.

Some data on the soil fertility (NPK) status of the most important soil types for rainfed lowland rice in Northeast Thailand can be presented and conclusions can be drawn with respect to their fertility status and to the extent to which fertility/nutrient status can reasonably be improved (generic soil fertility targets), if necessary site-specific and during different periods within the growing season, as illustrated for
synchronization of nutrient supply for N management (Konboon et al., 2001; Chapter 3). In addition, some of the nutrient balance data (different scenarios) can be added and conclusions (decisions) on anticipated improvements can be drawn within different scenarios. Also time estimates could be made with regard to the moment that soil fertility targets will be reached, going upwards or downwards, under different land management scenarios. The socio-economic feasibility of maintaining the balance and reaching targets should be taken into account as well (Chapter 5).

A user-friendly DST should allow management scenario analyses, in terms of alternative land-use and land management options. Within each scenario, partial nutrient budgets, with the associated extrapolated full balances, should be derived from the biophysical state of the land, and the associated economic consequences should be analysed. Within a RDBS or simplified ‘ready reckoner’, field level results may be easily generated to allow adequate scenario assessment, including assessment of the associated financial and sustainability risks. If nutrients are perceived to have an economical value, i.e. as natural capital, also the economics of nutrient depletion and replenishment can be linked to the scenarios if regional market prices of nutrients are known, based on (alternative) fertilizers used within specified land-use systems /scenarios (Chapter 5).

Therefore, there is advocated for an overall approach in which land use and related nutrient management are tailored towards the spatio-temporal variability that results from the combination of erratic rainfall imposed on the micro-topographic catenae (Section 4.2; Konboon et al., 2002) while taking the dynamic socio-economic context into account as well.

4.5. Conclusions
Partial nutrient balances are useful indicators for some critical components of sustainability and important for formulation of recommendations on soil fertility management, if interpreted in combination with considerations on the omitted factors in the full balances. In NBS-NET the existence of large variations in partial N, P, and K balances among and within farms were observed, especially at the LUT level. Although mean values were positive, many negative partial balances were encountered. The tendencies of relatively high lower-scale variability in partial nutrient balances were about similar for both sub-districts of the main survey and the sub-district of the pilot-study and appear to occur in large parts of Ubon Ratchathani Province and Northeast Thailand with similar LUS.

Evidence from yields, nutrient balances and field observations indicates a wide variability in the dynamics of natural resource qualities among and within farms. This has obvious implications for the longer-term sustainability of these farming systems.
Due to the large number of factors that influence decision making, the difficulties associated with their accurate measurement, and the relatively small number of farms and fields sampled in this survey, it is not surprising that no strong statistical relationships could be identified between the multitude of factors and management (Wijnhoud et al., 2003).

Farmers themselves indicated that the appreciation of biophysical variability, in combination with constraints in financial and labour resources (Chapter 5), is a significant factor that results in unequal resource allocation, and thus management, between and within farms. Moreover, farm managerial behaviour will not only depend on appraised biophysical and socio-economic factors, but also on rather ‘intractable’ factors, e.g. related to personal problems and opportunities, as well as to individual skills and capacities and purely subjective behaviour (Chapter 5; Wijnhoud et al., 2003).

Short distance variation in the sustainability of land management (systems), within and between farms, points at the real risk of scaling up data without care. Decision-makers, be they farmers, policy makers or other users, will make far better use of data at broader scales, if they are fully aware of the variability at lower scales. Research needs to address more thoroughly the variation over short distances in biophysical factors and socio-economic, or socio-economically driven factors (see also Chapters 3 and 5) to elucidate the relationships between these factors, decision-making, and sustainability (see also Chapters 2, 3, 5). Appreciation of nutrient budgets and underlying variability will enhance the ability of (government) policy makers and the private sector to make well-informed decisions with respect to improved management of the inputs and products of the rural sector. In combination with efforts at the farm level, these outcomes should have a positive impact on the rural communities that occupy the large areas of arable land that are characterized by poor fertility and threatened by degradation.

NBA has its shortcomings. It is relatively data-intensive and sensitive to inaccuracies in measurement and assessment. The accuracy of partial balances is highly influenced by the accuracy of default values and transfer function used for these analyses, and by the accuracy of primary data collected in the survey. Improved default values and more efficient survey techniques are required. In addition, strict priority setting is needed to ensure that main factors of the full nutrient balance are included in interpretation of the partial balances, and to eliminate the more serious and most easily avoided inaccuracies. Reliable estimates of the factors not included in these partial balances will provide more accurate approximations of the full balances. More comprehensive topography-related soil, water and nutrient management research with major emphasis on topography-related nutrient flows, like those initiated by Konboon et al. (2002), should be high on the research agenda.
A major strength of partial NBA compared with full NBA paradoxically derives from its omission of difficult-to-assess factors, making its implementation, as based on priority setting, easier. Dynamic and site-specific appraisal of difficult-to-assess factors, based on both local and expert knowledge, may be more efficient and practical, especially, as in the current development stage, participatory decision support for improved nutrient management is pursued to fill those major knowledge and development gaps that could be filled most easily (see also Chapters 5 and 6). Identification of the major biophysical and socio-economic factors that affect nutrient budgets, and that encompass the major variations at different scales, will increase the possibility of developing effective decision-support tools. Such tools can support farmers and extension officers in designing improved management strategies that are appropriate in social, economic and biophysical terms (see also Chapters 5 and 6). Oberthür et al. (1999) show a good example of how local farmer knowledge can contribute significantly to R&D efforts in data-sparse environments in coping with short-distance variability.

NBA, thus, are useful as a major component for multi-scale, multi-stakeholder and interdisciplinary and participatory R&D activities in Northeast Thailand (see also Chapters 1, 2, 5 and 6).
CHAPTER 5

Case study in Northeast Thailand: Integrated analyses*

Abstract

In Northeast Thailand, the sustainability of rainfed lowland rice-based systems, the dominant land-use system (LUS) in the region, is a concern for livelihood development of the population in this relatively poor region of the country. Poor soil fertility and low inputs are seen as major causes of these problems and appear to be interrelated with relatively poor socio-economic development.

Nutrient balance analysis (NBA) is a powerful tool for assessing the sustainability of these land-use systems. In combination with socio-economic data, nutrient budgets can indicate factors that are important for sustainable management of soils and that can be used to develop improved recommendations aimed at both biophysical and socio-economic aspects of sustainability.

The multi-scale assessment of nutrient balances was followed and used for more integrated environmental and socio-economic analyses, which involved livelihood and correlation analyses, as well as integrated environmental and socio-economic accounting. In part, a two-scale approach was followed with outcomes of analyses and insights at the district level, based on the complete data set, serving as input for analyses at the farm and field levels, and vice versa.

Diversification of income sources, through off-farm employment, non-agricultural on-farm income, such as weaving, and diversification of the agricultural system beyond rice, has a large impact on household wealth. In turn, this can affect the capacity of the household to manage the natural resources of the farm. For a range of 30 households covered by the study, off-farm employment has the greatest impact on household income (P < 0.001), in particular for higher income households. At the lower income-end, rice provides the main income, but in absolute terms rice provides more and significant at the higher income-end. No significant correlation was found between total income or non-rice income and nutrient inputs; however, this does not mean that they are unrelated. Information obtained from farmers indicates strong, but opposing, relationships for different households. Where some households improve management of rice production with increased access to capital from non-rice activities, others do not or even decrease their efforts. No factors were identified to statistically separate these groups.

Based on fertilizer use and price, mean elemental N, P and K retail prices were calculated as 12.4, 60.0 and 13.1 THB kg\(^{-1}\), respectively. These values were used for integrated environmental and economic accounting, based on the mean partial N, P, and K balances to calculate partial N, P and K balances in monetary terms. The results follow the average positive partial balances for rice-based systems of 30 farms with large variability among different farms and, even more so, among different Land Utilization Types, distinguished cropping system-management combinations, however, for each nutrient to a degree depending on its price. Partial nutrient balances were most extreme for N and K. In contrast, in monetary terms P balances were most extreme. These analyses reveal that, due to the customary use of N-P or N-P-K compound fertilizers, too much is invested in P, which is generally non-limiting and rather expensive. Although information on mean district balances can be useful for policy makers, fertilizer retailers and the fertilizer industry, improved nutrient application must rely on additional farm-level data. Outcomes at the farm level may be used for correction of on-farm fertilizer allocation, from both agronomic and economic points of view.

5.1. Introduction

In Northeast Thailand, the sustainability of rainfed lowland rice-based systems, the dominant land-use system (LUS) in the region, is a concern for livelihood development in this relatively poor region of the country. Low soil fertility and low

* Major parts of this chapter were derived or adapted from: Wijnhoud et al. (2001) and Wijnhoud et al. (2003).
levels of external inputs are considered major causes underlying the sustainability problems and these appear to be interrelated with the relatively poor socio-economic development state of the region (Chapters 2–4).

Because of the complexity of the intertwined biophysical and socio-economic constraints on rural research and development (R&D) (Chapters 1–4), existing bottlenecks can only be addressed efficiently through innovative and integrated approaches, in which nutrient balance analysis (NBA) appears to be a very useful tool (Konboon et al., 2001; Chapters 1–4). In combination with socio-economic data, nutrient budgets can indicate factors that are important for sustainable management of soils and that can be used to develop improved recommendations, aimed at both biophysical and socio-economic aspects of sustainability (Chapters 1–2). NBA can serve as a template for socio-economic accounting and financial assessment of nutrient depletion and surpluses (UNSD, 1993; De Jager et al., 1998a, b; Drechsel and Gyiele, 1999; Moukoko-Ndoumbe, 2001).

Within NBS-NET (Nutrient Balance Studies in Northeast Thailand, Chapter 2), based on the main survey of 30 farms in Trakan Phutphon and Nayea districts of Ubon Ratchathani Province (Chapter 2), multi-scale NBA was performed (Chapter 4) and used for more integrated environmental and socio-economic analyses, which involved livelihood and correlation analyses, as well as integrated environmental and socio-economic accounting. In part, a two-scale approach was followed with outcomes of analyses and insights at the district level, based on the complete data set, serving as input for analyses at the farm and field levels, and vice versa. Additional details and methodological aspects were described in Chapter 2.

5.2. Links between socio-economic factors, rice production, and natural resource management

Diversification of household activities, through off-farm employment, non-agricultural on-farm income, such as weaving, and diversification of the agricultural system, beyond the rice base, has a large impact on household wealth. As such, the various forms of diversification can affect the capacity of the household to manage the natural resources of the farm (Wijnhoud et al., 2000). The pilot survey revealed that most of the farms raise fish on a commercial basis and some raise poultry and cultivate vegetables commercially, which is evidence of this tendency and wish towards greater farm diversification (Chapter 4, Table 4.1). Farm diversification may not only provide the cash needed for intensification of rice cultivation, but also may reduce the risks associated with sole reliance on rice cultivation. It must be emphasized that a sample of the 10 farms covered by the pilot survey (Chapters 2 and 4) is too small to test hypotheses, but the results of the main survey, covering a sample of 30 farms in two
other districts (Chapters 2 and 4), support the tendency towards and relevance of farm and income diversification.

Data analyses based on the main survey show that off-farm employment has the greatest impact on household income (Figure 5.1). In fact, in terms of disposable income, off-farm income is even more important than indicated by the components of income in Figure 5.1, because net off-farm income is compared to gross farm income and the gross value of rice production. Cost-benefit analyses for rice production at some of the farms surveyed revealed benefit:cost ratios between 2.5 and 3.5 (e.g. Table 5.7), implying production costs amounting to between 29 and 40% of the gross rice value. Calculated benefit:cost ratios of non-rice farm activities were highly variable, but exceeded 2, meaning production costs below 50% of the gross benefits, in general (see Section 5.4 and Table 5.7).

Across the 30 farms, there was a strong and highly significant positive correlation between net off-farm income and the sum of net off-farm income and gross farm income (P < 0.001), although this relationship is strongly affected by a small number

Figure 5.1: Net annual income from off-farm employment, gross non-rice farm income, plus the gross value of rice production (sold plus home consumption) for 30 farms surveyed in two sub-districts (Seped, in Trakan Phutphon District, and Naruang, in Nayea District) of Ubon Ratchathani Province in Northeast Thailand. (US$1 ≈ THB 42, October 2000) (adapted from Wijnhoud et al., 2003).
Table 5.1: Income characteristics for the 30 farms surveyed in Northeast Thailand (adapted from Wijnhoud et al., 2003).

<table>
<thead>
<tr>
<th>Income components ('000 THB)*</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross rice</td>
<td>30</td>
<td>51</td>
<td>21</td>
</tr>
<tr>
<td>Gross other on-farm</td>
<td>28</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Net Off-farm</td>
<td>27</td>
<td>58</td>
<td>85</td>
</tr>
<tr>
<td>Total of 3 components</td>
<td>30</td>
<td>127</td>
<td>94</td>
</tr>
</tbody>
</table>

* US$1 ≈ THB 42, October 2000 (THB = Thai baht).
* n indicates the number of non-zero values, but Mean and SD-values are for all 30 farms.

of higher-income households with more than THB 100,000 annual income from off-farm employment (Wijnhoud et al., 2003). Although non-rice income sources, particularly off-farm income, were the most important income sources for many of the better-off households, rice production provided a significant contribution to their income, which placed them among the households with the highest gross values of rice production (Figure 5.1). This confirms the findings from the pilot survey of ten farms in another district of the province (Wijnhoud et al., 2000).

The importance of rice is further indicated by the fact that even the households with a high off-farm income identified themselves primarily as rice farmers. The gross value of household rice production, which, on average, comprises approximately 40% of the sum of gross farm and net off-farm income (Table 5.1), plus the correlation between rice income and total income, show that this is more than a perceived social typology. For many less well-off households, rice was the most important source of income and, as such, essential for their livelihoods (Wijnhoud et al., 2003).

As shown in Chapter 4, there was a positive correlation between nutrient inputs, as chemical fertilizer and organic amendments, and rice yields, while nutrient inputs and nutrient balances were only weakly correlated (Wijnhoud et al., 2003). There was little evidence, however, of a strong correlation between fertilizer use and the financial situation of the farm household (P > 0.05). Despite this lack of correlation, interviews indicated that income was a factor in decisions on fertilizer use. Some of the better-off farmers chose to invest in soil fertility management and fertilizers, while others appeared to ignore nutrient management, because of their focus on off-farm activities. With a sample of only 30 households, there was little possibility of statistically identifying the wide range of socio-economic or biophysical factors that might distinguish these two groups (Wijnhoud et al., 2003).
As long as the socio-economic situation does not permit an increase in off-farm income, solutions have to be sought on farm. Possibilities for improvements might include farm diversification and increased use of alternative organic and inorganic inputs, which may require greater access to capital and credit (Wijnhoud et al., 2003).

5.3. Integrated environmental and socio-economic accounting

5.3.1. Introduction
Conventional economic accounting (CEA) for agricultural and farming systems largely ignores externalities, i.e. the costs associated with degradation and/or depletion of natural resources on one hand, and pollution and other negative environmental impacts on the other hand (Moukoko-Ndoumbe, 2001). From a different angle, during the last two decades, both agricultural and environmental scientists have worked on methods to assess nutrient dynamics in agricultural systems through NBA. These were largely driven by agricultural and biophysical research interests and aimed at the improvement and biophysical sustainability of agricultural production systems (Penning de Vries and Djitève, 1982; Stoorvogel and Smaling, 1990; Hartemink and Van Keulen, 2005). Stimulated by ‘Agenda 21’, the Plan of Action of the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 (UNCED, 1992), the discipline of environmental economics gained rapidly in importance. Various steps have been made towards methodological improvement in integrated environmental and socio-economic accounting (UNSD, 1993; Drechsel and Gyiele, 1999; Moukoko-Ndoumbe, 2001). Based on data of the 30 farms surveyed, a case-specific application of integrated environmental and socio-economic accounting is illustrated.

5.3.2. Fertilizer survey and calculation of N, P and K retail prices
Average retail prices, i.e. the values of elemental N, P and K, have been derived from a fertilizer consumption and price survey. For all 78 land utilization types (LUTs), distinguished cropping system-management combinations on the 30 farms (Chapters 2 and 4), data on type and consumption of mineral fertilizer have been collected for the 1999 growing season (Table 5.2).

The price ratios between elemental N, P and K were derived from the prices of their raw materials (Table 5.3).

Subsequently, from their price ratios and the conversion rates from oxides into elemental form, the cost per unit nutrient (N, P and K), has been expressed in N-price equivalents (N-eq.) for each macro-nutrient (N, P or K) and the total of all macro-nutrients per fertilizer (Table 5.4).
Table 5.2: Mineral fertilizer (MF) application to 78 LUTs* at 30 farms in 1999 (97.8 ha)

<table>
<thead>
<tr>
<th>Fertilizer type</th>
<th>Nr.**</th>
<th>N kg</th>
<th>%#</th>
<th>P kg</th>
<th>%#</th>
<th>K kg</th>
<th>%#</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-15-15</td>
<td>9</td>
<td>112</td>
<td>4</td>
<td>49</td>
<td>4</td>
<td>93</td>
<td>10</td>
</tr>
<tr>
<td>16-16-8</td>
<td>61</td>
<td>2012</td>
<td>65</td>
<td>885</td>
<td>69</td>
<td>835</td>
<td>90</td>
</tr>
<tr>
<td>16-20-0</td>
<td>15</td>
<td>646</td>
<td>21</td>
<td>356</td>
<td>28</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(NH₄)₂SO₄</td>
<td>3</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Urea</td>
<td>16</td>
<td>302</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MF (97.8 ha)</td>
<td>77</td>
<td>3083</td>
<td>100</td>
<td>1290</td>
<td>100</td>
<td>928</td>
<td>100</td>
</tr>
</tbody>
</table>

| Input (kg ha⁻¹) | 32    | 13   | 9   |

* LUT = Land utilization type: Unique cropping system-management combination.
** Number of LUTs to which indicated fertilizer has been applied (no application for one LUT).
# Percentage of total mineral fertilizer from fertilizer type.

Table 5.3: Calculation of the price ratios among elemental N, P and K (Source: Wijnhoud et al., 2001).

<table>
<thead>
<tr>
<th>Fertilizer type</th>
<th>Ammonia</th>
<th>H₃PO₄</th>
<th>KCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price US$/Mg*</td>
<td>140</td>
<td>276.8</td>
<td>94.7</td>
</tr>
<tr>
<td>Element</td>
<td>N</td>
<td>P</td>
<td>K</td>
</tr>
<tr>
<td>Element content (%)</td>
<td>80</td>
<td>23</td>
<td>49.8</td>
</tr>
<tr>
<td>US$/kg</td>
<td>0.18</td>
<td>0.87</td>
<td>0.19</td>
</tr>
<tr>
<td>Price ratio</td>
<td>1</td>
<td>4.8</td>
<td>1.1</td>
</tr>
</tbody>
</table>


Table 5.4: Cost per unit N, P and K, expressed in N price equivalents per fertilizer; fertilizer price survey and N equivalent prices (Source: Wijnhoud et al., 2001).

<table>
<thead>
<tr>
<th>Fertilizer type</th>
<th>Price ratio</th>
<th>El. Conv.*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>0.44</td>
</tr>
<tr>
<td>(N equivalents)</td>
<td></td>
<td>Prices kg</td>
</tr>
<tr>
<td>(THB)</td>
<td>100 kg N-eq.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fertilizer type</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Sum</th>
<th>100 kg N-eq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-15-15</td>
<td>15</td>
<td>32</td>
<td>13</td>
<td>60</td>
<td>862</td>
</tr>
<tr>
<td>16-16-8</td>
<td>16</td>
<td>34</td>
<td>7</td>
<td>57</td>
<td>712</td>
</tr>
<tr>
<td>16-20-0</td>
<td>16</td>
<td>43</td>
<td>0</td>
<td>59</td>
<td>692</td>
</tr>
<tr>
<td>(NH₄)₂SO₄</td>
<td>21</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>400</td>
</tr>
<tr>
<td>Urea</td>
<td>46</td>
<td>0</td>
<td>0</td>
<td>46</td>
<td>531</td>
</tr>
</tbody>
</table>

* Conversion ratio oxide → elemental form.
Table 5.5: Calculation of weighted mean N-equivalent price based on NPK-source (input) consumption (Source: Wijnhoud et al., 2001).

<table>
<thead>
<tr>
<th>Fertilizer type</th>
<th>Input Proportion of total use</th>
<th>Price N-eq. (THB kg⁻¹)</th>
<th>Weighted N-eq. (THB kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-15-15</td>
<td>254 0.05</td>
<td>14.3</td>
<td>0.7</td>
</tr>
<tr>
<td>16-16-8</td>
<td>3732 0.70</td>
<td>12.5</td>
<td>8.8</td>
</tr>
<tr>
<td>16-20-0</td>
<td>1002 0.19</td>
<td>11.8</td>
<td>2.2</td>
</tr>
<tr>
<td>(NH₄)₂SO₄</td>
<td>12 0.00</td>
<td>19.0*</td>
<td>0.0</td>
</tr>
<tr>
<td>Urea</td>
<td>302 0.06</td>
<td>11.5*</td>
<td>0.7</td>
</tr>
<tr>
<td>Sum</td>
<td>5301 1</td>
<td>Mean 13.8</td>
<td>12.4**</td>
</tr>
</tbody>
</table>

* (NH₄)₂SO₄ is the most expensive and urea the cheapest N-source.
** Weighted mean equivalent price amounts to 12.4 THB kg⁻¹.

A fertilizer price survey for the 30 farms yielded data on average farm gate prices per 100 kg of the 5 types of mineral fertilizer used in the area (Table 5.4). For each type of fertilizer, the N-equivalent price (per kg) is obtained from the average price of the fertilizer and its N-equivalent-content (Table 5.4). By averaging the values for the 5 fertilizers, an average N-equivalent price is derived (Table 5.4), which is converted into the weighted N-equivalent price (N-eq., 12.4 Thai baht per kg), by taking into account the share of each of the fertilizers in total consumption (Table 5.5). Based on the existing price ratio of elemental N, P and K, their mean elemental retail prices, as corrected for the relative purchase of mineral NPK-sources, were calculated (Figure 5.2). They amount to respectively, 12.4, 60 and 13.2 THB per kg N, P and K. This directly shows the relatively high price of P compared to that of N and K.

5.3.3. Monetary assessment of inputs and monetary partial balances

From the calculated mean prices of elemental N, P and K, input costs per nutrient for mineral fertilizers were assessed (Table 5.6). The real costs for mineral fertilizer application will be somewhat higher than the costs of elemental nutrients, as packaging, transport and labour costs have not been accounted for. The ratios indicate that the proportions in which macronutrients are applied to the system are imbalanced, even more so if crop requirements would be considered. Remarkably, farmers tend to invest about twice as much in P than in either N or K, although evidence suggests that especially N and K are limiting crop growth in rainfed lowland rice-based systems of Northeast Thailand (Konboon et al., 2001; Chapter 3).
Figure 5.2: Mean retail price of elemental N, P and K, based on prices of raw materials and mineral fertilizers and their relative consumption (Source: Wijnhoud et al., 2001).

Table 5.6: Mean nutrient inputs and their costs / value for 78 LUTs on 30 farms (Source: Wijnhoud et al., 2001).

<table>
<thead>
<tr>
<th></th>
<th>N*</th>
<th>Mean** SD**</th>
<th>Mean** SD**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(kg ha(^{-1}) y(^{-1}))</td>
<td>(THB ha(^{-1}) y(^{-1}))</td>
<td>(THB ha(^{-1}) y(^{-1}))</td>
</tr>
<tr>
<td>Mineral</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>77</td>
<td>35</td>
<td>22</td>
</tr>
<tr>
<td>P</td>
<td>77</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>K</td>
<td>64</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Organic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>52</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>P</td>
<td>52</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>K</td>
<td>52</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>77</td>
<td>39</td>
<td>25</td>
</tr>
<tr>
<td>P</td>
<td>77</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>K</td>
<td>73</td>
<td>18</td>
<td>17</td>
</tr>
</tbody>
</table>

* N (number of non-zero values); One LUT did not receive inputs.
** Mean and SD (standard deviation) refer to non-zero values.

Macronutrients in organic inputs were valued on the basis of the calculated ‘equivalent’ retail prices of N, P and K in mineral fertilizers (Table 5.6). Their monetary value comprises a small, yet significant, share of the overall value of nutrients added to the system. The word ‘value’ instead of ‘costs’ is used, as not all organic inputs may have been purchased. Even if all organic inputs would have been
purchased, it would be hard to estimate the costs of their nutrients, as unlike mineral fertilizers, valuation of organic inputs should not be based on their nutrient contents only (Drechsel and Gyiele, 1999). Hence, it is virtually impossible to estimate the relative value of nutrients in these multi-functional materials. Functions of organic inputs may vary per land use system, but in general they improve soil structure and increase water and nutrient retention capacity and, thus, usually will result in increased nutrient recovery from mineral fertilizers. The monetary NPK-ratio in organic inputs is much more balanced than in the applied mineral fertilizers, while in physical terms it appears to better match the NPK-ratio required by crops. Even though organic amendments appear to contribute only marginally to crop nutrient requirements, they appear to be especially relevant for adding K to the system (Konboon et al., 2001), in particular in nutrient management systems where applied mineral fertilizers contain disproportionally low quantities of K (Table 5.6). It should be emphasized that nutrient availability may vary per input type, depending on recovery efficiency which is both input type- and LUS-specific.

Organic inputs may or may not have been purchased. If purchased, additional transport and labour cost may be involved, due to their bulkiness. In valuing the nutrients in organic and inorganic sources, differences in nutrient release and recovery under different circumstances have not been taken into account (Konboon et al., 2001). In general, nutrient release will be much slower from organic than from inorganic inputs. Overall recovery efficiencies in the long term, including multi-season residual effects, will generally be higher for organic than for inorganic sources, if recovery efficiency includes storage, whereas short-term recovery efficiency by crops in general is much higher for inorganic inputs.

Using the weighted average retail prices for elemental N, P and K (Figure 5.2), costing and valuation may be performed in a similar way for (partial) N, P and K balances, transforming physical N, P and K balances into monetary N, P and K balances. Such monetary balances provide direct insights into the monetary aspects of nutrient management practices and are relevant as input in economic analyses and for business evaluation and planning purposes. It should be emphasized that where assessments are made of partial physical balances, the same holds for monetary balances. As monetary balances are mirror images of the physical balances, amplified or dampened, depending on prices and price ratios, this also holds for the partial balances. In Chapter 4, it was concluded that physical partial balances may be very useful, provided due consideration is given to the likely magnitude of the full balance terms that are not included. The same holds for the partial monetary balances.

Mean monetary partial N, P, K farm balances for the 30 farms are positive (Figure 5.3). For P, the average is even strongly positive with a positive 10-percentile value.
Figure 5.3: Partial monetary N, P and K farm balances for 30 farms (including 10 and 90 percentiles), based on average market prices of nutrients (Source: Wijnhoud et al., 2001).

Comparison between physical partial N, P and K balances and their corresponding monetary values at the LUT level reveals that absolute values of physical partial balances are most extreme and variable for N and K, while monetary partial balances are most extreme and variable for P (Figure 5.4), because of the prevailing prices and price ratios. Therefore, similar trends are observed at the LUT-level within one farm (Figure 5.5). Comparison of trends at the farm and LUT level, respectively reveals that the monetary partial balances, similar to the physical partial balances (Chapter 4), depend on the scale of analysis. The negative 10 percentile partial monetary balance for P recorded at LUT level (Figure 5.4) does not appear at farm level (Figure 5.3).

Results at district level, represented by complete data sets of farm and LUT data for the 30 farms (Figures 5.3 and 5.4), may be useful in assessing nutrient management in biophysical and economic terms, in support of policy makers, fertilizer retailers and industry, but also for farmer groups/associations and extension workers. They show that relatively too much is invested in P and not enough in N and K, as a result of the use of compound N-P-K and N-P fertilizers (Table 5.5), in which the relative price of P is high. The average investment in mineral P of 840 THB ha$^{-1}$ y$^{-1}$ comprises over half of the average overall investment in mineral fertilizer (Table 5.6). The relative over-investment in mineral P is even more pronounced, when taking into account the nutrient requirements for the rice crop within these systems (Konboon et al., 2001). N and K, rather than P, are generally most limiting to crop growth, where P only
becomes more critical in nutrient management strategies based on cropping systems that include leguminous crops, such as peanuts (Konboon et al., 2001; Wijnhoud et al., 2000). If leaching losses, mainly affecting N and K, and gaseous losses, mainly affecting N, that have not been accounted for in the partial balances (Chapter 4), would be included, the relative over-use of P would be more pronounced.

At the farm level, integrated socio-economic and environmental accounting could provide a very useful method to assess biophysical and socio-economic performance.
Figure 5.5: Comparison of biophysical partial balances and monetary partial balances, based on average market prices of nutrients for four LUTs, two each on one field, of one farm (first graph adapted from Wijnhoud et al., 2003).

and sustainability. In addition, the results of such analyses may be useful for decision support aimed at promoting biophysically and socio-economically more sustainable land use systems, in first instance to be achieved through changes in nutrient purchase and management. This may be explained further in relation to the partial physical and monetary N, P and K balances for a farm in Seped sub-District (see also Chapter 4), characterized by a high degree of intra-farm variability in partial balances (Figure 5.5). This farm cultivates two fields, each divided into two LUTs, with for each field one of the LUTs having positive physical and monetary partial N, P and K balances and the other LUT negative partial balances, with similar relations between physical and monetary balances.
A first technical conclusion is that inputs may not have been distributed homogeneously over the farm. Hence, possibilities might be examined to modify allocation of nutrients between the LUTs within one field, or if needed for a more optimal allocation, between fields. This means possibilities could be explored to filling shortages of one nutrient in one LUT, with the surplus of the same nutrient from another LUT. For monetary balances, unlike for physical balances, negative values for one nutrient may be compensated by positive values for any other nutrient, provided the positive values are due to investments in the wrong nutrients, so that re-direction of investments would be a possibility. In this way, integrated economic and environmental accounting, based on nutrient and monetary balance analyses may be used for decision support for nutrient management from both a biophysical and economic perspective.

Surely, this approach is too simple for formulation of fertilizer recommendations and thorough decision support, without considering additional information and the broader context. Background details about the context of the partial balances, i.e. full balance factors not considered within the partial balance and additional biophysical information, such as e.g. on fertility status and water availability, often may be helpful in getting insight in or making judgments. Likewise, simple observations, measurements and/or farmer and expert knowledge can be useful to draw relevant conclusions and for decision support purposes. A somewhat broader look, for example, might reveal that negative partial balances may be associated with high off-take in harvested products, rather than with insufficient use of inputs. This may be the case where relatively high yields are obtained on inherently fertile soils (Chapter 4; Wijnhoud et al., 2001, 2003). Such situations may occur at some places in the lower parts of toposquences, where sufficiently large nutrient pools are sustained by continuous nutrient inflows of especially N and K from higher areas (Poltanee et al., 1998), which is not accounted for in the partial balances. Such systems, characterized by negative partial balances may be sustainable and the result of judicious farmer management.

In this perspective, one should be aware that farmers may have their reasons for heterogeneous distribution of inputs, aiming at optimizing production and sustainability. Integrated physical and monetary partial nutrient balance assessment only will be useful in practice, if combined with simple field monitoring for site-specific aspects, preferentially led by the farmers themselves.

5.4. Analyses of economic viability
Economic viability has been identified as one of the five pillars of sustainability (Smyth and Dumanski, 1993), and its assessment for rainfed lowland rice cultivation may be pivoted around a set of cost-benefit related economic analyses. Here, cost-benefit analysis (CBA) refers to a variety of analyses in which the (investment) costs
for an activity are compared to its associated benefits in order to determine its absolute or relative profitability (Baum et al., 1999). This may be applied to the current production situation in a certain year or through scenario analyses to alternative land-use systems, as part of a land-use optimization exercise. Depending on data availability, CBAs may be performed in various ways, varying appreciably in accuracy and reliability.

Selection of the method to perform such a general CBA, depends on the availability or access to data, which, in turn, is determined by the availability of resources for data collection, and the willingness of farmers to provide insight in their financial situation. Confidentiality often implies that farmers prefer to perform their own cost-benefit analyses, instead of providing outsiders insight in their finances. Even though farmers, as other private entrepreneurs are continuously involved in CBA, on the basis of their current management practices, providing farmers with frameworks, methods, tools, training and guidance may make such exercises more efficient and accurate. As such, it may increase insights in socio-economic consequences of alternative scenarios and in general may stimulate or improve their skills in economic reasoning.

As an illustration of some of the complications that may arise with respect to data needs, some alternative CBAs have been carried out for rice cultivation in 1999 on a farm in Seped sub-District in Trakan Phutphon District, Ubon Ratchathani Province (Table 5.7). Such analyses may provide some insights in economic viability, as a basis for farm innovation and economic optimization at an individual farm. At the benefit side, either the sales prices at the two dates the farmer sold different quantities of rice, or the average sales price of rice, based on the survey of 30 farms may be used, if more detailed sale price information is not available (Table 5.7). At the cost side, labour costs may be based on the average labour requirements for rainfed lowland rice cultivation and the average cost of hired farm labour from the survey, or on labour input as specified by the farmer or the default value of the cost of hired labour. As the farm in the example only uses family labour, the alternative option, of using the costs of hired farm labour is irrelevant. With regard to the pricing of labour inputs, the reliability of the information provided by the farmer may be questioned, as the accuracy may vary among farmers; while there will be a certain degree of site-specificity, even if cultivation follows an exactly identical pattern. Hence, even for such simple calculations, judgment of data quality and selecting the right methods and default values may be complicated. Apart from binary alternatives for rice valuation and labour costing, also a binary alternative was applied for seed costing, i.e. based on the complete set of survey data and the zero, as specified by this specific farmer, introducing another source of uncertainty.

One may argue that even if farmers use their own seed, it has a price. For the rice
seed, alternative scenarios only slightly affect the result of the CBA. This may be different, however, for more costly inputs or production factors, such as e.g. farm labour.

Economic indicators were calculated, i.e. annual net production value (NPV), annual gross margin per hectare (GM), return on labour (RL) and benefit:cost ratio (B/C ratio) (e.g. Baum et al., 1999), for scenarios comprising binary options for two cost items and one benefit item (Table 5.7).

The mean NPV for rice cultivation as a whole is 25,010 THB, which comprises more than half of the overall household income, placing the farm among the three lowest income households within the survey (Figure 5.1). Annual GM per ha is about 19,500 THB. This value can be compared to GM of alternative land management practices, or if land is not the limiting production factor, to calculate the rice area needed to realize a target income. RL is about 340 THB per man-day. This value of about 3.4 times the cost of hired labour, appears high, and reflects that labour costs comprise a significant proportion of gross rice income. If farm labour would be valued as labour income, it should be realized that this relatively high value per man-day applies to a seasonal labour activity, outside of which the farmer may be considered unemployed. The actual average daily income from rice farming on an annual basis is much lower than the 340 THB per day, explaining the relevance of and search for alternative income sources (Section 5.2). Another relevant consideration is that, due to globalization and the economic crisis, the (world) market price went down 27.5% within a relatively short period of time, from 10 THB kg$^{-1}$ to the default price of 7.25 THB kg$^{-1}$, meaning the gross annual production value at an earlier stage was 51,200 THB against 37,120 THB in 1999. The difference of 14,080 THB means a significant loss of income for a resource poor household.

The B/C ratio of about 3.2 indicates that rice farming, at least in relative terms, is economically still viable, well beyond the break-even point. As the B/C ratio is a relative value, it should not be used as the only characteristic for evaluation of economic profitability, as it may discriminate against activities requiring relatively high investments with a lower B/C ratio, even though net monetary returns (NPV) may be much higher, so that they are economically more profitable. From the survey it may be deduced that, land and labour are often both limiting production factors. The major challenge for increased profitability thus is raising both GM and RL through internal innovations in the farming system, for which access to capital and knowledge appear to be critical factors.

If investments are made for yielding returns in the long run, as in systems of perennials and/or if money has been borrowed for fertility management, calculation of NPV and B/C ratio becomes complex, because interest and discount rates that are difficult to predict have to be taken into account (Baum et al., 1999; Enters, 2000).
Table 5.7: Prototyping economic analyses: Net production value, gross margin per hectare, returns on labour and benefit:cost ratio for rice production in 1999 for one farm in Seped sub-District, Trakan Phutphon District, Ubon Ratchathani Province, Thailand.

<table>
<thead>
<tr>
<th>Rice cultivation characteristics:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Area under rice cultivation = 8 rai (1.28 ha)</td>
<td>Hired labour = 0 man-day (md)</td>
</tr>
<tr>
<td>Rice varieties = 8 rai KDML-105</td>
<td>Farm labour = 73 md</td>
</tr>
<tr>
<td>Rice production = 5,120 kg (yield = 4 Mg ha⁻¹)</td>
<td>Default labour cost = 100 THB md⁻¹</td>
</tr>
<tr>
<td>Default KDML-price: 7.25 THB kg⁻¹</td>
<td>Default price rice seed = 7.0 THB kg⁻¹</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benefits:</th>
<th>Amount (THB yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1*: Production value</td>
<td></td>
</tr>
<tr>
<td>B1a: (P1 × sale) + (P2 × sale) + (home cons. × P-default)</td>
<td></td>
</tr>
<tr>
<td>= (6.6 × 3300) + (7.5 × 1820) + 0</td>
<td>35,628</td>
</tr>
<tr>
<td>B1b: P-default for KDML-105 × production = 7.25 × 5120</td>
<td>37,120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Costs:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C1*: Labour cost</td>
<td></td>
</tr>
<tr>
<td>C1a: (Hired + farm labour) × (default) cost hired labour = 73 × 100</td>
<td>7,300</td>
</tr>
<tr>
<td>C1b: Cultivated area × md/rai for system × labour cost /md</td>
<td></td>
</tr>
<tr>
<td>= 8 × 9.55 × 100</td>
<td>7,640</td>
</tr>
<tr>
<td>C2: Fertilizer</td>
<td>3,480</td>
</tr>
<tr>
<td>C3*: Rice seed</td>
<td></td>
</tr>
<tr>
<td>C3a: Cost as specified by farmer</td>
<td>0</td>
</tr>
<tr>
<td>C3b: Amount × default price = 24 × 7</td>
<td>168</td>
</tr>
<tr>
<td>C4: Renting machinery</td>
<td>330</td>
</tr>
</tbody>
</table>

**Net Production Value (=Benefits–Costs), Gross Margin (per ha) and Returns on labour**

(Min, Mean and Max of 8 values based on binary options for B1, C1 and C3):

<table>
<thead>
<tr>
<th>NPV Rice cultivation</th>
<th>Gross Margin per hectare</th>
<th>Returns on labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min: 24,010 THB y⁻¹</td>
<td>Min: 18,758 THB ha⁻¹ y⁻¹</td>
<td>Min: 329 THB md⁻¹</td>
</tr>
<tr>
<td>Mean: 25,010 THB y⁻¹</td>
<td>Mean: 19,539 THB ha⁻¹ y⁻¹</td>
<td>Mean: 343 THB md⁻¹</td>
</tr>
<tr>
<td>Max: 26,010 THB y⁻¹</td>
<td>Max: 20,320 THB ha⁻¹ y⁻¹</td>
<td>Max: 356 THB md⁻¹</td>
</tr>
</tbody>
</table>

**Benefit:cost ratio** (based on 8 values considering binary options for B1, C1, C3):

Min: 3.1  Mean: 3.2  Max: 3.3

*Average labour input per activity for transplanted rainfed rice cultivation (md/rai):*

<table>
<thead>
<tr>
<th>Activity</th>
<th>Input (md/rai)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedbed preparation</td>
<td>0.50</td>
</tr>
<tr>
<td>Soil preparation</td>
<td>0.25</td>
</tr>
<tr>
<td>Transplanting</td>
<td>2.00</td>
</tr>
<tr>
<td>Weeding</td>
<td>6.00</td>
</tr>
<tr>
<td>Harvesting</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9.55</strong></td>
</tr>
</tbody>
</table>

* Results account for binary options for two cost items and one benefit item.

(US$ 1 ≈ THB 42, October 2000)
Decision support objectives may vary between hands-on decision support for adaptive management of existing cropping systems and comprehensive decision support, anticipating on completely alternative land management and/or land-use options (Enters, 2000). Economic analyses will gain relevance through scenario analyses, including a range of alternative land management and/or land-use options, preferably derived from on-farm experiments. As this may be time-consuming, most farmers probably have to rely on support and guarantees from outside, and on secondary data, including experimental databases, if available. Databases containing results of well-referenced fertility and variety experiments, including value-cost ratios (VCR) of specific technologies and other economic analyses, could provide useful information.

5.5. Conclusions and discussion

This study has clearly shown that diversification of income sources, through off-farm employment, non-agricultural on-farm income, such as weaving, and diversification of the agricultural system, has a large impact on household wealth. This, in turn, can affect the capacity of the household to manage the natural resources of the farm; however, for individual farmers, depending on a multitude of factors, in different ways. Off-farm employment has, on average, the largest impact on household income, with a very strong influence from higher-income households. Therefore, the aim of perpetuating a predominantly agricultural society, even through introduction of innovative agricultural technologies, would be an inappropriate starting point for general R&D policy at regional level (Chapters 2 and 3).

The decisions on land management made by farmers are based on their integrated analysis of a wide range of biophysical, socio-economic, cultural and political factors. Therefore, sustainability analyses and agricultural R&D require interdisciplinary and participatory approaches. Farmers indicated that financial and labour constraints are significant socio-economic factors that, in combination with appreciation of biophysical variability, result in heterogeneous resource allocation, and thus management, between and within farms. Because of the large number of factors that influence decision making, the difficulties in accurately assessing these factors and the relatively small number of farms and fields sampled in this survey, it is not surprising that significant relations could not be established between the multitude of farm-specific individual factors and management. Moreover, farm managerial behaviour is not only determined by biophysical and tangible socio-economic factors like income, wealth, off-farm employment, but also by difficult-to-assess intangible factors, e.g. related to private constraints and opportunities, personal skills, capacity, attitudes and personal preferences, subjectively affecting behaviour (Wijnhoud et al., 2003; Chapter 4).
By investigating short-distance variability in management, adapted to variability in biophysical characteristics and variations in the socio-economic setting, improvements may be possible in decision-making by farmers that are constrained by resource limitations. Interesting research topics, related to socio-economic factors include the impact of non-rice agricultural income and non-agricultural income, both on- and off-farm, on land management; the impact of off-farm labour on farming practices through changes in the availability, gender, and education of farm labour; and the impact and opportunities for farm diversification and reduced reliance on rainfed rice (Wijnhoud et al., 2000). Identification of at least some relevant socio-economic and biophysical factors that affect nutrient budgets, e.g. through correlation and/or regression analyses, and that encompass major heterogeneities at different scales, will increase the possibility of developing effective decision support tools.

Transforming physical N, P and K balances in monetary terms may increase insights as a basis for improved nutrient management and sustainable land management, both from biophysical and socio-economic points of view. Monetary balances may provide direct financial insights into nutrient management practices. If such integrated environmental and socio-economic accounting is based on multi-scale NBA, scale-synergy may add to the inherent synergetic advantages of interdisciplinary analysis itself (Chapters 2 and 4). It needs to be emphasized that where partial physical balances are assessed, the monetary balances also are partial. Monetary balances are, in general, disproportional mirror images of physical balances, amplified or dampened depending on prices and price ratios. Integrated environmental and socio-economic accounting appears a promising venue for the design of improved farm and land management regimes, including the business dimensions, as well as for policy and marketing purposes.

The study revealed and emphasized aspects of inappropriate fertilizer use, in particular the too high P-content in compound fertilizers, leading to unnecessary high investments in relatively expensive P. At the farm level, the method provides useful insights for formulation of biophysically more balanced and economically more viable nutrient management.

In addition to the relevance of these case-study outcomes, the study may have a paradigmatic value and includes some prototyping elements. These could form the basis for decision support at the policy level and for the fertilizer branch and the development of a decision support tool (DST) for dynamic and site-specific decision support for farmers and extension workers (Chapter 4). The RDBS developed in the current research activity (Chapter 2), contains basic data from the farm enterprise up to the micro land-use system (LUS) level, referring to the household entity, farm, field, or sub-plot. It could be used as the basis for a DST for soil fertility management. In
addition, to farm household and farming system data obtained from farm surveys and partial NBA, some socio-economic components, such as those for livelihood analyses and integrated environmental and socio-economic accounting and CBA could be integrated into a flexible operational tool. However, based on objectives and priority setting, the number of DST components, including the required interfaces, algorithms, defaults, and output tables should be limited, to keep procedures and analyses focused and feasible. Hence, by preference, the DST should to some extent rely on knowledge-based assumptions about some biophysical, economic and socio-cultural aspects than building all of it into a DST. Secondary data can be included in the form of estimates and default values, particularly for nutrient contents in plants, soils, manures and fertilizers, nutrient flows into and out of specific sub-systems, and market prices of products and inputs. Generated output has to include indications of the accuracy of the analyses.

Above all, a conceptual DST for dynamic and site-specific decision support for spatio-temporally varying, demand-driven interdisciplinary research questions needs to be flexible in many ways. Depending on the spatio-temporal conditions and demand-driven objectives, this involves the judicious selection of a sub-set of the analyses included in the DST and will involve choices and priority setting based on trade-offs between the perceived relative importance of individual analyses and/or the synergy between combinations, but also trade-offs between on one hand required accuracy and on the other hand data availability and available – technical, human and financial – capacity for additional data collection.

Applications may vary from input-extensive rapid explorative analyses and appraisals to input-intensive and comprehensive detailed analyses. The former application largely needs to navigate on the judicious use of existing (default) data and farmer and/or expert knowledge. The latter may require comprehensive primary data collection through measurement and/or monitoring programmes.

Making strategic choices and the process of priority setting itself may have to be aided within a flexible DST framework. The absence of guidelines and support for that purpose may be one of the main reasons for the failure of DSTs in practice. This holds especially for more ‘rigid’ tools that only provide one methodological option, without the possibility to account for spatio-temporal, case-specific and demand-driven requirements. Spatio-temporal complexity and specific DRMD characteristics (Chapters 2 and 3), data availability, available capacity in general and the objectives aimed at, are the main driving factors for strategic choices and priority-setting. In addition, quality standards, minimum requirements, assumptions and concepts need to be explicitly defined, as results of analyses may have limited value, if too much generalization is applied.
CHAPTER 6

Conclusions, broader considerations and general discussion*

Abstract

This final chapter starts of with the synthesized conclusions of the first five chapters (Section 6.1). This is followed by a summary overview of missing links and broader perspectives (Section 6.2), starting with a summary overview of hiatus and issues that require additional attention for the design of more successful integrated rural development strategies. This includes opinions about their relevance and inherent challenges. Considerations often are relevant for both Asian ‘Tigers’, such as Thailand, and the least developed countries (LDCs) in the world, showing the largest capacity and development gaps. These broader considerations are partly referenced as well as based on a summary overview of major challenges for rural development in two of the least developed countries (LDCs) in sub-Saharan Africa, respectively Ethiopia and Mozambique, each facing rather different challenges. By starting from a policy perspective for both countries, different challenges and requirements to overcome them are identified. Some concrete elements for innovative rural development strategies are discussed, in particular for Mozambique. The chapter continues with general considerations on rural development strategies and the inherent relevance of sustainable natural resource management (SNRM). This is followed by arguments that SNRM can only be achieved by following a livelihood approach and by the consequent and rigid mainstreaming of NRM and environmental sustainability in business development and mainstream development programmes. In addition, major challenges are identified for multi-scale sustainable institutional development, which requires efforts aimed at good governance.

6.1. Conclusions

The first five chapters of this thesis provide evidence that for efficient and effective integrated rural development strategies, aimed at the twin-objectives of sustainable natural resource management and improved and sustainable livelihood development, synergy can be derived when navigating flexibly on a combination of holistic concepts and a selected set of participatory, integrated and/or complementary analyses. This was examined in an integrated and flexible collaborative research and development (R&D) programme in Northeast Thailand (Chapter 2). The collaborative R&D programme was pivoted around multi-scale partial nutrient balance analyses (PNBA), livelihood analyses and additional integrated analyses, like integrated environmental and socio-economic accounting, as methodological elements, that appear to fit in very well with the advocated approach. This combination of a participatory, integrated and holistic approach with strict priority setting by combining holistic concepts and a selected set of participatory, integrated and/or complementary analyses is powerful in addressing the needs for integrated rural R&D, targeted at complex realities. The challenge was and remains to find the appropriate balance between on one hand

* Some parts of this chapter have been adapted from Wijnhoud and Solomon Abate (2004), Wijnhoud (2005) and Hassam and Wijnhoud (2005).
Chapter 6

the demand for more comprehensive participatory, contextual and integrated analyses and on the other hand the requirement to keep such efforts manageable in terms of human and material resources (Chapters 1 and 2; Section 6.2) while developing evermore experience and gradually increase the capacity and institutionalization (see Section 6.2) for improved contextualization and integration of and participation within the R&D efforts. Ideally, the central case for this thesis should have been from a perspective of disciplinary neutrality, but due to existing institutional arrangements, its ‘trans-disciplinary’ character started from one disciplinary angle, i.e. biophysical aspects of SNRM within their broader interdisciplinary context (Chapters 3 and 4), but with a gradual shift of emphasis towards socio-economic analyses, such as integrated environmental and socio-economic analyses and livelihood analyses (Chapter 5).

The dynamic resource management domain (DRMD) concept proves to be useful to assess the spatio-temporal context (Chapters 2 and 3) as relevant for innovative and flexible R&D efforts and the scaling-up of efforts towards more or less identical (D)RMDs (Chapters 1, 2 and 3). Innovative R&D, and its institutionalization, may require partnership building based on genuine multi-level and multi-stakeholder collaboration; a key requirement that itself is confronted with many challenges (Chapter 3, Section 6.2.).

The collaborative R&D programme in Northeast Thailand (Chapters 2–5), supported by more theoretical elaborations on the multiple dimensions of sustainable natural resource management (SNRM) and sustainable livelihood development (Chapter 1, Sections 1.2 and 1.3), underscores the importance to envision and anticipate on ‘rural societal transitions’ as relevant for the achievement of both SNRM and, more diversified, improved livelihoods. This implies that SNRM should not rely on the achievement of more sustainable natural resource-based livelihoods alone, at least not for the majority of the rural population. It should also anticipate on diversification into alternative livelihoods with less direct reliance on natural resources, while assuring their environmental sustainability. This strongly argues against development programmes that – make the mistake to – contribute to the perpetuation of somewhat less marginal – but still marginal – smallholder farming by taking a static and uniform approach with blanket support to the majority of smallholders, without envisioning the relevance of livelihood diversification, let alone medium and longer term rural transitions. Within the context of economic diversification and growth, R&D efforts have to anticipate on rural transitions, which lead to a situation where, due to livelihood and economic diversification, a growing part of the population, including those that migrate to the towns for non-agricultural jobs, no longer depends directly on natural resources (alone) for their livelihoods. Such a process on one hand would reduce the pressure on natural resources and on the other hand, as part of
agrarian reform and rural transformation, may allow for investments in technological innovations in sustainable natural resource-based production practices by a smaller proportion of the population, (Chapters 2, 3, 5; Section 6.2). The focus of overall R&D and policy agendas at district, provincial, regional and national levels should therefore not exclude, but rather anticipate on and contribute to diverse options as related to agricultural innovation, SNRM, economic diversification, and livelihood development (Chapters 1, 2, 3, 5; Section 6.2).

Nutrient balances are relevant as indicators for SNRM (Chapters 1–4) with multi-scale PNBA (Chapters 1, 2 and 4), its socio-economic linkages, including the interpretation of partial nutrient balances in monetary terms and additional socio-economic analyses (Chapter 5), having answered relevant questions regarding soil fertility management, both from a biophysical and socio-economic perspective, and livelihood development in rainfed lowland rice-based DRMDs (Chapter 3). The multi-scale PNBA results reveal high inter-farm and intra-farm variability for partial N, P and K balances. Farmers manage nutrients for similar parcels of land in very different ways, which results in large variations in the partial nutrient balances, even for the same type of land-use within the same farm (Chapter 4). The appreciation of biophysical variability together with constraints in financial and labour resources, are significant factors that result in heterogeneous resource allocation, and thus management, between and within farms. There is a real risk that short-distance variability is hidden as a result of inappropriate scaling-up of data. Policy makers and other users will make far better use of data at broader scales, if they are supplemented by indications of the variability at lower scales (Chapter 4). Data outcomes are valuated with specific emphasis on biophysical aspects and considerations about methodological aspects. The position in the landscape has a significant effect on the growth of rice and therefore on the partial nutrient balances. In general, rice yields were higher in the middle and lower parts of the toposequence. For the sites monitored, average yields were 40% higher in the lower parts of the toposequence. The lower partial nutrient balances in the lower parts of the field, largely due to greater off-take, were not reflected in soil N status, presumably as a result of movement of nutrients down the toposequence (Chapter 4).

Diversification of income sources, through off-farm employment, non-agricultural on-farm income, such as weaving, and diversification of the agricultural system beyond rice, has a large impact on household wealth (Chapter 5). In turn, this can affect the capacity of the household to manage the natural resources of the farm. For a range of 30 households covered by the study, off-farm employment has the greatest impact on household income (P < 0.001), in particular for higher-income households. At the lower income-end, rice provides the main income, but in absolute terms rice provides significantly more at the higher income-end. No significant correlation was
found between total income or non-rice income and nutrient inputs; however, this does not mean that they are unrelated. Information obtained from farmers indicates strong, but opposing, relationships for different households. Where some households improved management of rice production with increased access to capital from non-rice activities, others did not or even reduced their efforts. The latter for instance after having taken more lucrative non-farming jobs. No factors were identified to separate these groups statistically (Chapter 5). This at least confirms a hypothesis that the aim of perpetuating a predominantly agricultural society, even through introduction of innovative agricultural technologies, would be an inappropriate starting point for broad based R&D efforts ( Chapters 2, 3 and 5).

Results of integrated environmental and socio-economic accounting revealed that partial balances in monetary terms follow the average positive partial biophysical balances with large variability among different farms and, even more so, among different land utilization types, distinguished cropping system-management combinations, however, for each nutrient to a degree depending on its price (Chapter 5). Partial nutrient balances are most extreme for N and K. On the contrary, in monetary terms this is true for P. These analyses reveal that, due to the customary use of N-P or N-P-K compound fertilizers, too much is invested in P, which is generally non-limiting and rather expensive. Although information on mean district balances can be useful for policy makers, fertilizer retailers and the fertilizer industry, improved nutrient management must rely on additional farm-level data. Outcomes at the farm level may be used for correction of on-farm fertilizer allocation, from both agronomic and economic points of view (Chapter 5).

The collaborative R&D programme identified important elements for decision support for SNRM at different levels, such as PNBA and integrated environmental and socio-economic accounting (Chapters 4 and 5). Basic aspects and elements of a decision support tool (DST) for dynamic and site-specific decision support were identified and discussed (Chapters 4 and 5). These include the format of the relational database system (RDBS) and default tables for essential parameters (Chapters 2–5). With regard to nutrient and soil fertility management, some prototype nutrient- and scenario-specific analyses were provided and discussed (Chapter 4), followed by some prototype economic analyses, relevant to decision support on the socio-economic viability of SNRM (Chapter 5).

When pursuing decision support for both SNRM and livelihood development, further economic and socio-cultural aspects may have to be taken into account, such as availability, accessibility and prices of inputs, (commodity) prices at existent and new markets, labour requirements, but also acceptability of new crops and production methods, including gender and age-group related preferences and aspects, personal...
preferences, and expectations for livelihood development. Alternative farm and livelihood options must be considered, including off-farm and on-farm options, the latter aimed at integrated nutrient management and/or nutrient cycling over larger distances (Konboon et al., 2001; Section 3.4.5), with or without farm diversification and livelihood changes (Wijnhoud et al., 2003; Section 2.2.1). The direct inclusion of alternative farm and livelihood options in a user-friendly DST may be too complex, but a DST for dynamic and site-specific land-use and nutrient management, both from a biophysical and socio-economic perspective, can be pursued by those that aim at improving their farm performance. Of all the factors that influence farmers’ decisions, farmers’ priorities are most important and, therefore, these should be integrated in a participatory decision support approach.

The collaborative research programme yielded practical applications of prototype analysis methods, such as multi-scale PNBA and integrated environmental and socio-economic accounting within a DRMD context. Besides, it sets a paradigm for integrated development studies elsewhere – for scaling-up efforts in more or less similar DRMDs – which partly could build on similar elements, but with recommendations being made for inclusion of additional aspects (Chapter 1; Sections 6.2 and 6.4).

6.2. Missing links: Hiatus and issues that require additional attention

Notwithstanding the innovative dimensions incorporated in the collaborative research trajectory that resulted in this thesis, the identification of major hiatus and deepening of the strategic and methodological dimension could be elucidative for the design of improved R&D activities as part of new strategies for integrated rural development. This refers to aspects that were left out or received insufficient attention due to either the inherent limitations and boundary conditions of the research trajectory, in particular the collaborative R&D programme in Northeast Thailand, or due to the fact that some of these issues, in current development efforts identified as gaps, were not widely recognized as relevant to integrated rural development strategies in 1998, at the start of the case study in Northeast Thailand. Some also may have been perceived as less critical in a relatively better-off country, an Asian ‘Tiger’ in full transition, such as Thailand, notwithstanding its vulnerability as evidenced by temporary disturbances due to the economic crisis in the late 1990s (Chapter 3), than in the least developed countries (LDCs) of the world. For some of these aspects, awareness about their relevance has partly been created by the contextual analysis (Chapter 3) and synthesized results of the case in Northeast Thailand itself (Chapters 3–5). Within the additional trajectory that led to this thesis, they were further shaped by additional literature study (Chapters 1, 3 and 6) and insights obtained during later – practical and
partly policy- and research-focused – work in sub-Saharan Africa (Wijnhoud and Solomon Abate, 2004; Hassam and Wijnhoud, 2005; Wijnhoud, 2005). Linking these latter experiences to the R&D programme in Northeast Thailand certainly adds more innovative dimensions. In turn, the lessons learned from the work in Northeast Thailand and the general exposure to a full rural development transition phase in an Asian ‘Tiger’, including observations on livelihood, economic and rural transitions, not only have inspired later work in sub-Saharan Africa, but serve as useful input for ‘envisioning’ and the design of rural development strategies in the LDCs.

It is beyond the scope of this thesis to provide an exhaustive analysis of all aspects that either have been missed or could be deepened much more. Nevertheless, adding some general explanations and statements may further clarify their relevance, whereas a number of issues are brought forward in broader elaborations on and recommendations for policy development and design of integrated rural development strategies (Sections 6.3 and 6.4). These issues include the partly overlapping or interrelated aspects elaborated below (Sections 6.2.1–6.2.15).

### 6.2.1. Organizational development

Organizational development is brought to the foreground, as it is argued that development and strengthening of local organizations, including farmer and other local business organizations, is essential for the sustainable institutionalization of innovative efforts aimed at integrated rural development (see Sections 6.2.2, 6.2.3, 6.2.6; Section 3.4.1).

Organizational development (OD) aims at enhancing the ability of an organization to develop itself in order to achieve its mission in the most effective and efficient way. Each organization is permanently engaged in and responsible for its own organizational development process. This entails transformation processes that improve their capacity to fulfil their mission. For farmer associations and development organizations, including research and development (R&D) organizations, this refers primarily to their involvement in or contribution to structural poverty alleviation.

One of the better known OD models is the ‘7-S’ Model (Figure 6.1), also known as the ‘McKinsey 7-S’ Model (Waterman et al., 1980; Pascale and Athos, 1981; Peters and Waterman, 1982). The model explains that an organization is built on seven pillars each starting with the letter ‘S’. Apart from three tangible hard ‘S’ components: Strategy, Structure and Systems, there are the four less tangible soft ‘S’ components: Style/culture, Staff, Skills and Shared Values/Subordinate goals. The latter are not very tangible, since capabilities, values and elements of corporate culture are continuously developing and changing. The soft ‘S’ components strongly depend on the people working in the organization. Therefore, it is much more difficult to plan or to
influence the characteristics of such less tangible aspects. Nevertheless, the soft components can have a great impact on the hard Structures, Strategies and Systems of the organization (Peters and Waterman, 1982).

As part of the OD approach, emphasis is given to improving the learning abilities and the means and manners of communication (SNV, 2002a). Within such a developmental approach, the change process will explore the underlying processes and causes that explain the organization’s behaviour. Improvements in functional areas and relations are imbedded in a systematic attempt to address the organization’s overall performance. The key issue is creating awareness of the way different components and processes interact within an organization and with the organization’s environment (SNV, 2002a). The latter is important, as the risk exists that efforts aimed at OD may fail if only focused on internal organizational aspects, such as based on generic organizational models, such as the ‘7-S’, while ignoring to integrate the organization’s core business and its specific dimensions into the picture. It is argued that successful OD is only possible if addressed both within the context of the core business of an organization and its specific context. As in the case of strengthening of commercial farmer associations, it is advocated that it will be essential to draw on synergies, by simultaneously targeting economic performance and the associated basic requirements of organizational development and institutional linkages (Hassam and Wijnhoud, 2005). Strengthening associations without strengthening their core business, the major

Figure 6.1: Representation of the ‘7-S’ Model, also known as the ‘McKinsey 7-S’ Model (Source: Themanager.org, 2006).
reason for their existence, would be of little value. In turn, business development may not be sustainable if not embedded in and owned by strong associations (Hassam and Wijnhoud, 2005).

6.2.2. Institutional development and the politics of integrated rural development
Institutional change or development entails a profound change in the patterns of behaviour that arrange a society, as largely embedded in structures, patterns and relationships among different types of organizations and interest groups at different levels, ranging from the grass root to global level. Institutions or ‘rules-of-the-game’ are the underlying norms and laws that structure a society (Eponou, 1996; Bechstedt, 2000; SNV, 2002a). More than changing the performance, institutional development is political in nature. It aims at poverty alleviation at the level of society (SNV, 2002a). Institutional development may have to rely on lobby and policy advocacy efforts, which is most powerful if backed by verifiable ground-truth, based on action-research (see Sections 6.2.4, 6.2.11), and if enabled by good governance, including involvement and support of large segments of the population within a democratic context (see Section 6.2.5).

6.2.3. Stakeholder collaboration and sustainable institutionalization of innovative R&D
Stakeholder collaboration and partnership building is essential for livelihood and rural development and in the end many organizations, including commercial farmer associations, cannot survive and grow without relevant institutional linkages required for their core business and organizational strength in general (see Sections 6.2.1, 6.2.2, Section 6.3.2). Most important is that quality partners are chosen in a selective and result-oriented way. Partnerships can be determined by existing institutional structures and/or formed for the provision of support and services, by – business and other – clients themselves. Besides, when looking for development synergies, partners might include organizations with which no direct business or service linkages exist, but that pursue similar objectives with respect to the policy and infrastructural environment, such as roads, water and energy for basic services and business development and the joint lobby and advocacy required for it (see Sections 6.2.2, 6.2.4)

As far as R&D is concerned, it is the responsibility of scientists to generate knowledge and provide and improve technical tools, approaches and strategies for SNRM, livelihood development and integrated rural development in general, from a technical perspective. The organizational and institutional dimensions (see Sections 6.2.1, 6.2.2), stakeholder discussions and negotiations and participatory piloting for adoption of new approaches and technologies are all part of this process. The latter
already may be a challenge to be dealt with in one single research programme, let alone in one single PhD research trajectory. One step beyond piloting with new tools and approaches would be the broad institutionalization of newly acquired knowledge and the use of new tools and approaches that have been successfully piloted and tested. This not only embraces awareness creation about their relevance and lobbying aimed at their broader use and implementation, it also embraces their acceptance by decision makers, development actors, the ultimate users or those affected and the multi-stakeholder collaboration required for their institutionalization within a dynamic institutional context (see Section 6.2.2). The latter will be easier in democratic, transparent societies with relative free markets than in more authoritarian, more corrupt, and/or command-and-control driven societies. As partly discussed in Chapter 3 (Sections 3.4.1 and 3.5), stakeholder collaboration and concerted multi-level R&D efforts are challenged by the following – partly interrelated – factors:

i. Lack of donor coordination and long-term donor commitments to structural development needs

Donor coordination for concerted multi-stakeholder and multi-scale efforts, i.e. the macro- and meso-linkages with the micro, i.e. community, level, and vice versa, are often weak. In part, this can be explained by the fact that decision makers at donor level in their ‘ivory towers’ are positioned too far away from the poverty reality and often insufficiently informed about local realities and the challenges at the intermediary and local levels, while local communities because of institutional constraints and marginalization lack the voice and leverage to influence decisions and funding for their own development. Donors, because of their decision-making power for the allocation of development budgets, are in a powerful position and, although somehow accountable to political elites in developing countries that, in their turn, may be under pressure from international accountability, donors are not directly downward accountable to the majority of local development actors and the communities at large. Instead, local development actors may have to dance to the whims of the donor community and their host governments. Short-term or inconsistent funding can also be caused by the fast rotation of staff of donor agencies, as well as by the fact that bilateral donor policies may be influenced by political developments in the donor countries and similarly multilateral donor policies by international political developments.

ii. Lack of shared views about causes/strategies among stakeholders (including the internalization of relevant and innovative concepts)

This can refer to different insights at one level, but often even more obvious between levels and sectors, also with respect to the internalization of relevant and
innovative concepts. It points at the weak linkages among different development actors at the same or different levels, which may be due to lack of access to information, but also politically driven, due to different views and interests. The different development actors include donors, government organizations, civil society organizations, a wide range of international and local non-governmental organizations (NGOs), other international organizations and the private sector. Many of these actors, in one way or another, have, at least partial, R&D mandates, or should have them.

iii. Overlapping disciplinary mandates and responsibilities
This refers to the existence of overlapping disciplinary and decision-making mandates and responsibilities between different groups involved in the research, development, and implementation continuum scales, both within and between institutions and countries. This either may contribute to a lack of mutual – disciplinary – recognition or to competition in shared mandate areas or scale interfaces.

iv. Isolated mandates and weak micro-macro linkages; lack of integrated and harmonized efforts
On the other hand, rather than constraints caused by overlapping mandates and scale interfaces, the existence of isolated and introvert mandates including weak micro-macro linkages may be equally constraining to concerted efforts. Different views and priorities within different sectors, such as the agricultural sector, the health sector, the educational sector, etc., often involve disciplinary biases towards the own sector and a lack of framing sector priorities and challenges into a holistic, ‘trans-disciplinary’, development vision and framework (Chapters 1 and 3).

v. Competition for financial and human resources and ideas
Not all organizations/stakeholders are always happy to fully open themselves for the engagement in collaborative efforts, which may also expose their weaknesses and comfort zones and affect the latter. For organizations with development mandates, both national and international, their work is also their business and sustains the livelihoods of their staff, in particular their leaders, explaining why they may wish to either hide or protect their vested interest or to go into competition with similar organizations for their survival. Within a context of high diplomacy there is fierce competition, but at the expense of the interests of the poor; i.e. food security and poverty alleviation.
All such factors contribute to a lack of demand-driven, development/client-oriented collaborative (participatory) R&D efforts, based on clear partnerships between communities on one hand and NGOs and public entities, each having its own interest and comfort zones, on the other.
vi. Lack of development commitment by a development industry

Due to the presence of the African Union (AU) headquarters and the United Nations Economic Commission for Africa (ECA) and therefore diplomatic representations from all over the world, Addis Ababa is known as the ‘talk’ and ‘development tourism’ capital of Africa. It is impossible to estimate how much money and time is consumed in discussing food security and poverty alleviation by ‘experts’ that rarely visit the rural areas themselves; not even the poor in urban slums (Chambers, 2006), let alone that they are really familiar with grass root realities of food insecurity, or have been confronted with famine themselves (Mesfin Woldemariam, 2003).

Moreover, there is a tendency of protected organizational domains. In general, whatever the vision and mission, for organizational survival or that of individual staff, each organization – large or small; national or international – will give priority to its own interests, controversially including personal satisfaction of rural development tourism, personal enrichment of NGO directors, often without genuine commitment and willingness to spend some more time, learn from and be with, showing solidarity and commitment to the ‘poor’ (Chambers, 2006).

Improvements could be brought about by awareness creation about existing challenges and root-causes of limited or sub-optimal collaboration in and coordination of development efforts, in which donors and their constituencies also have their roles to play. Solutions may be found in the spheres of improved governance and organizational and institutional development efforts, including those trying to pursue harmonized development efforts across the sectors and based on improved micro-macro linkages (Ubels et al., 2005), rather bottom-up instead of top-down (Section 3.4.3), on the basis of scale equality and genuine participation and empowerment (see Section 6.2.11).

Lobby and advocacy may contribute to the promotion of partnership development and more concerted multi-scale efforts, such as for bringing identical, including donor, initiatives together and in order to strengthen the research linkages of development efforts through action learning and action research, aimed at improved research back-up of development initiatives (Chapter 3; see Section 6.2.11).

6.2.4. Capacity development

Capacity development is the process by which individuals, organizations, institutions and societies develop abilities (individually and collectively) to perform functions, solve problems and set and achieve objectives (UNDP, 1997). Joint efforts aimed at the sustainable development of individuals, organizations, including their self-learning abilities, and institutions (see Section 6.2.2) and their subsequent effects (sustainable
impact) are referred to as capacity development (Fukuda-Parr et al., 2002; SNV, 2002b). According to Liebl er and Ferri (2004), capacity development involves the following four dimensions:

- **External capacity areas** – needed for effective interactions with the wider institutional and societal contexts;
- **Internal capacity areas** – relevant for the internal functioning of the system;
- **Technical capacity areas** – essential to the work, area of specialization, profession, etc., of the organization or network;
- **Generative, or ‘soft’, capacities** – needed to enable the organization or network to continuously develop, adapt and innovate.

As an example, the Netherlands Development Organization (SNV), provides a mix of technical-thematic and change expertise (SNV, 2002b), which may cover the following four capacity development services (CDS) (adapted from Wijnhoud, 2005):

- Diagnosis and learning: this can be at different levels, *i.e.* individual, team, organizational and even inter-organizational (forums, network organizations) or institutional level (for instance feeding into lobby and advocacy strategies based on diagnosis of ground-truth). Awareness creation and advocacy are relevant, but often underestimated aspects.
- Organizational development; (see Section 6.2.1)
- Partnership building: this refers to brokering and facilitation of relevant institutional linkages (see Sections 6.2.1, 6.2.3)
- Facilitation for contributions to institutional change (see Sections 6.2.2, 6.2.3); this may refer to capacity development for lobby and policy advocacy.

CDS can be provided in the following ways (adapted from: Wijnhoud, 2005):

- Process and change facilitation;
- Provision of technical-specialist advice (also on-the-job);
- Capacity gap/opportunity-oriented training courses;
- Coaching;
- Knowledge development, based on action learning and action research (see Section 6.2.11) and knowledge dissemination (learning and sharing);
- Networking, linking and brokering (facilitation) for information, knowledge, expertise, funds and institutional linkages in general (see Section 6.2.1);
- Support to mechanisms for lobby and policy advocacy (see Section 6.2.2).

Although the capacity development paradigm in part emerged due to the ownership requirements, it cannot substitute and should not ignore, but rather draw on, the
principles of participatory approaches and the relevance of empowering participation and self-mobilization (Sanginga and Chitsike, 2005; see Section 6.2.11).

6.2.5. Good governance and the relevance of decentralization
Governance can be defined as the way government, in partnership with the private sector and civil society and in dialogue with its citizens, both women and men, apply and use authority and resources for development. The term ‘local’ is used to refer to the lowest representative structures to which tasks and functions essential for societal development can be decentralized. Indicators for good (local) governance include democracy, transparency, responsiveness, accountability, inclusiveness and civil participation, but also efficiency and effectiveness (Wijnhoud, 2005).

Decentralization reforms are promoted based on the following proposition: “If institutional arrangements include local authorities who represent and are accountable to the local population and who hold discretionary powers over public resources, then the decisions they make will lead to more efficient and equitable outcomes than if central authorities make those decisions” (Ribot, 2004). Downwardly accountable or representative local actors with significant discretionary power constitute the necessary infrastructure for effective decentralization. Decentralization advocates, such as donors, NGOs, and (democratic) governments, aim to ‘get the institutions right’, i.e. to influence power and decision making structures and (downward) accountability for inclusive development and environmental sustainability (Ribot, 2004; Shackleton et al., 2002). It should be emphasized that decentralization is not a panacea for all local development requirements, nor a sufficient guarantee for good (local) governance. Such a positive outcome may be constrained by existing local power structures, local inequalities and low capacity of local organizations. The latter is usually the case in the initial stages. Capacity development of local organizations (see Sections 6.2.1, 6.2.4) is one way to enhance the chances of gradually successful, efficient and effective, decentralization efforts (Wijnhoud, 2005), but there may always be areas and sectors that could most efficiently and successfully be addressed and governed by the central state. Chabal (2005) elaborates on the limits of decentralization and outlines that the success of decentralization in Africa, both devolution and de-concentration, ultimately rests on the quality of overall state governance. This also points at one of the failures of international development policies in the 1990s, when the critical role of government entities was downplayed too much (Chabal, 2005).

6.2.6. Local realities: Illiteracy, gender, socio-cultural inequalities, HIV-AIDS, political agendas
This points at some of the dilemmas and constraints in the reality of smallholders that
are easily overlooked in efforts aimed at integrated rural development. This particularly holds for those women and men living on much less than 1 US$ per day, such as the millions of food insecure women and men in LDCs, many of whom are in one way or another also constrained by the HIV-AIDS pandemic, in particular in sub-Saharan Africa (ECA, 2005; see Section 6.2.10), and other chronic or regular shocks. Poor people in developing countries must cope with droughts, floods, illnesses, recession and civil unrest. Much of their energy goes into coping with these shocks and into day-to-day survival, which condemns many to persistent poverty and excludes them from economic growth (Dercon, 2003).

In this perspective, it may be relevant to get insight in how decisions are being made at household level, such as whether to produce for subsistence and/or for the market, inclusiveness or exclusiveness with respect to decision making, and ultimate benefits at intra-household and community levels, with gender (see Section 6.2.9) and HIV-AIDS challenges (see Section 6.2.10) being relevant factors as well. From a technological perspective, high post-harvest losses represent another less tangible local factor to be taken into account (ILEIA, 2004).

Many international agencies, governments and NGOs have developed programmes for more widespread social protection. Most of these programmes take the form of safety nets, ways of providing some protection from the worst effects of shocks, like the ‘Food for Work’ (FFW) programmes in Ethiopia (Section 6.3.1; Gedion Asfaw, 2003). The arguments in favour of such programmes are often largely cast in humanitarian or equity terms. They are considered part of social programmes without much economic rationale (Dercon, 2003), at least not for alternative livelihood strategies and sustainable livelihood development out of perpetuated poverty. With the prioritization of poverty reduction, such as through the launch of the Millennium Development Project (United Nations, 2000), and with accelerating change in many dimensions, up-to-date and realistically informed perceptions of the lives and conditions of people living in poverty have come to matter more than ever (Chambers, 2006).

6.2.7. Rural and livelihood transitions

Earlier in this thesis (in particular in the Chapters 1, 2 and 5; Section 6.1), it was concluded that innovative rural development strategies should anticipate on livelihood and rural transitions as triggered by economic diversification and diversified livelihood development. Instead of perpetuating peasantry (Section 6.3.1), it points at the relevance to anticipate on processes of occupational change and agrarian and rural reform, including an often needed land policy reform (Section 6.3.1; Ellis, 2005). Although the situation may not be fully comparable, countries in sub-Saharan Africa could learn from processes of occupational change, de-agrarianization and rural reform
that took place in Europe and the US in the late 19th and the early 20th century, and even more so from more or less identical processes, albeit following alternative pathways, in the 1980s and early 1990s in a number of Asian Tigers like South Korea, Malaysia and Thailand. Notwithstanding similar tendencies, Satterthwaite and Tacoli (2003) emphasize the risk of too much generalization, as local factors underlying rural transitions may vary significantly among nations (e.g. Section 6.3). Moreover, the historical context and driving factors may have been changing, complicating comparison between trends in rural transition in different countries and continents at different times, including current trends in sub-Saharan Africa in a contemporary context of ‘globalization’, which, based on differences in local factors, often economic, institutional and political factors, results in diverging trends in different countries of sub-Saharan Africa (e.g. Section 6.3).

6.2.8. Rural-urban linkages

The relevance of rural-urban linkages was partly dealt with implicitly in foregoing chapters when discussing rural and livelihood transitions (see Section 6.2.7), for instance when pointing to the relevance of off-farm income (Chapter 5) in livelihood transitions out of peasantry (Chapters 1, 2, 5 and Section 6.1). Transitions towards SNRM and sustainable economic and livelihood development in general are characterized by ‘de-agrarianization’ and, more specifically, ‘de-peasantization’ (Bryceson, 2000). Urban centres, including small and intermediate agglomerations of economic activity, potentially play important roles in regional and rural development and in poverty reduction (Satterthwaite and Tacoli, 2003). Therefore, it is argued that integrated rural development strategies should not ignore rural-urban linkages. On the contrary, rural development strategies should explicitly draw on and influence rural-urban linkages for the benefit of SNRM and livelihood development as part of societal transitions. Some relevant aspects include:

- Absorption of rural migrants in urban centres. Migration is a fundamental part of rural livelihood strategies and rural transformation, not simply a way to escape rural areas (IFPRI, 2005).
- Concentration of value-adding functions in agro-product chains, business development services and off-farm employment in general, in larger or smaller urban centres (DFID/BuZa, 2002).
- Emergence and development of (clusters of) economic activity and regional business systems, involving rural as well as urban stakeholders (DFID/BuZa, 2002).
- The role of small population centres in supplying services to rural areas (Satterthwaite and Tacoli, 2003).
- Prevailing production, consumption and investment patterns based on rural-urban
linkages, as well as their changing nature based on economic growth and development in general.

- The impact of decentralization policies on local economic development (DFID/BuZa, 2002; Wijnhoud, 2005)

Development experts may disagree on the relevance of targeting urban development as compared to rural development. International donors appear to favour urban projects, whereas on average 75% of the population in LDCs live in rural areas (Ruben, 2006). Ruben (2006), argues that increased investment in rural infrastructures will be critical and may contribute to development synergies among infrastructural development, basic service delivery, but also local economic development (Hassam and Wijnhoud, 2005; Wijnhoud, 2005). On the other hand, the relevance for rural development of economic growth and available services, in both, small and larger urban centres, should not be underestimated. For remote rural areas, both the role and functions of the largest ‘urban’ or population centres and out-migration by part of the population may be important for the development of such areas (Satterthwaite and Tacoli, 2003; IFPRI, 2005).

6.2.9. Gender equality and mainstreaming gender

‘Gender equality’ implies that conditions for women and men are equal for realizing their full human rights and their potential to contribute to national, political, economic, social and cultural development and that they benefit equally from the results (KoopUG/SCC, 2004). Gender equity is the process of being fair to women and men. Provisions for equal opportunities may not take into account the unique challenges that different individuals and groups face. Equity measures are necessary to ensure fairness to compensate for historical and social disadvantages that prevent women and men from otherwise operating on a level playing field (KoopUG/SCC, 2004).

Historically, two concepts have dominated the ‘gender’ debate. From the 1970s onwards, ‘Women in Development’ (WID) that emphasized the need for economic empowerment of women, but ignoring the nature of relational sub-ordination of women and unequal gender power relations (Mukhopadhyay et al., 2006). WID was characterized by the emergence of stand-alone women projects, but with women remaining at the periphery of development. On the contrary, ‘Gender and Development’ (GAD) offered an alternative to WID with its focus on social gender relations and a critique of dominant development paradigms (Miller and Razawi, 1998; Mukhopadhyay et al., 2006). While the introduction and popularization of GAD signifies a conceptual change, mainly in academic circles and among gender practitioners themselves, the degree to which GAD was adopted, in rhetoric or in practice, varies considerably. Some organizations simply adopted the term ‘gender’ without
changing their WID focus (Mukhopadhyay et al., 2006), while others mainly included the term ‘gender’ to decorate their proposals to donors with gender appeal, but with little attention being paid to it in practice.

For those that are genuinely concerned, gender has become an increasingly important development issue, not only because of the human rights aspect, but also from the economic efficiency and sustainability point of view (KoopUG/SCC, 2004). Increased gender equality improves pre-conditions for both economically and socially sustainable development and for increased growth. Gender equality is crucial for a fair distribution of resources and benefits the entire development of society. The main concern regarding gender equality is how resources and power are divided between men and women (KoopUG/SCC, 2004). Development programmes and projects have different implications for men and women. Gender-sensitive approaches are being advocated (Chapter 1), which incorporates gender analysis, and for which the minimum requirement that gender is mainstreamed, in planning, monitoring and evaluation in a systematic way to identify whether women – and men – will not be negatively affected and whether the gender inequality gap will narrow rather than widen as a result of development activities (KoopUG/SCC, 2004). When gender mainstreaming is ignored in situations of gender inequality, gender inequality often tends to increase, which may have disastrous effects on the sustainability of the development intervention, both in general and in particular for women that will become ever more marginalized.

It should be noted that apart from the boundary conditions and initial technical character of the collaborative R&D programme in Northeast Thailand (Chapters 2–5), another reason, although not an excuse, that gender was not explicitly mainstreamed was the fact that gender inequality gaps in Thailand appeared to be much smaller than in sub-Saharan Africa or other parts of Asia. In fact, many female farmers were involved in the collaborative R&D programme in Northeast Thailand, even though no explicit reference has been made to it, such as for Ethiopia (Wijnhoud and Solomon Abate, 2004; Section 6.3.1).

6.2.10. Mainstreaming HIV-AIDS

The impact of the HIV/AIDS pandemic on the agricultural sector, rural development and development in general is strong, in particular in sub-Saharan Africa (ECA, 2005; SCC, 2005; SLU, 2005). HIV/AIDS has added significantly to problems for smallholder agriculture, where production is labour intensive. AIDS causes severe labour and economic constraints that disrupt agricultural and other economic activities, aggravate food insecurity, and undermine the prospects of rural development (ECA, 2005; SCC, 2005; SLU, 2005). Some of the most important effects of HIV-AIDS on
agricultural and rural development are (partly adapted from SCC, 2005):

- Less time available for cultivation;
- Reduction in area of land under cultivation;
- Declining yields;
- Decline in crop varieties and changes in cropping patterns;
- Decline in livestock production;
- Loss of skills and knowledge (both indigenous and in general), negatively affecting the family/community learning environment;
- Increase in juvenile- or elderly-headed households;
- Reduced access to relevant business development services, such as micro-credit;
- Reduced access to or opportunities for alternative employment and education;
- Increased food insecurity;
- Increased malnutrition;
- Increased gender inequality;
- Increased poverty.

It is essential to emphasize that women are more strongly affected by HIV-AIDS than men and that the pandemic thus contributes to increased gender inequality and the ‘feminization’ of the HIV-AIDS crisis. In large parts of the African continent, women are largely responsible for labour-intensive tasks such as weeding, harvesting, post-harvest processing, fuel wood and water provision, and household maintenance, including the care and burden for those that are ill or orphaned as a result of the disease (ECA, 2005). Due to the existent gender inequality, women themselves are less able to prevent infection than men.

HIV-AIDS may only be effectively combated if, as for gender, mainstreamed, in all development efforts, including rural and agricultural development initiatives. Stigmatization, ignorance, lack of awareness about the magnitude of the problem, as well as the misperception of dealing with HIV-AIDS as a medical problem alone, all are challenges to be dealt with. Moreover, there are serious doubts about the efficiency and effectiveness of the HIV-AIDS ‘development business’, as established over the last decade and a half. Parallel structures and new ‘specialist’ organizations may consume large budgets, but may not always be most efficient for mainstreaming purposes to deal with the particularities of the pandemic within different sectors.

Gender inequality, the feminization of the HIV-AIDS crisis, as well as the stigmatization and denial surrounding it, are among the most critical challenges to be addressed. Instead of being subjected to discrimination and marginalization, those infected and affected need full support and care, including the provision of antiretroviral (ARV) or other medical treatments (e.g. SLU, 2005).
6.2.11. Participatory approaches: Action learning and action research

Earlier, as in Sections 2.2.1 and 3.4.3, the relevance of participatory approaches has been indicated for the ownership and increased adoption of technologies and for the promotion of agricultural and rural innovation in general. Moreover, some of the challenges of participatory and integrated approaches have been discussed as well (Section 2.2.1). It may be relevant to add that perceptions and interpretations of participation have changed over time, with ‘genuine participation’ evolving around ‘empowering participation’ and ‘self-mobilization’ (Sanginga and Chitsike, 2005; Sanginga et al., 2005), rather than ‘passive participation and the extraction of information as in Participatory Rural Appraisal (e.g. Bechstedt, 2000), one of the most applied participatory approaches in recent decades.

Participatory Learning and Action Research (Defoer and Budelman, 2000; Chapters 2 and 3), emphasize the relevance of action-orientation such as based on action learning and/or action research (Hassam and Wijnhoud, 2005; Section 6.3.2, Table 6.2).

6.2.12. Private sector development – farming as a business

Over the last decades, development interventions in the LDCs have mainly focussed on social aspects, the delivery of basic services, such as health care, primary education and potable water and the provision of extension services and agricultural inputs to smallholders. It is argued that basic service delivery and poverty reduction cannot be sustainable without private sector development, the engine of economic growth and well-being (see Section 6.3.2).

Smallholder farming for too long has been considered from the perspective of subsistence and survival, rather than as a micro-enterprise or business. This may explain that most support to smallholders for a long time has been socially motivated, with the objective to alleviate their main problems and to survive during the most difficult periods, instead of thinking of growing businesses. It is argued that a process out of poverty should be based on in-depth integration of smallholders into national economies (Hassam and Wijnhoud, 2005), based on farm innovation and commercialization as a first step towards farm intensification/diversification, resulting in a ‘growing’ farm enterprise or livelihood diversification out of smallholder farming (see Section 6.2.7; Section 2.2.1 and Section 6.1). Recognition of smallholder farming as a business, even if vulnerable and challenged by food insecurity and other threats, is a first key condition for the socio-economic empowerment of smallholders (see Section 6.2.13), as a first step in moving out of smallholder farming (see Section 6.2.7). As such, producer associations are part of an emerging private sector with income/asset generation being the main incentive, objective at the same time for the
strengthening of business associations, including producer, processing and trading associations.

6.2.13. Business associations and market access

There may be many advantages for smallholders to form and operate in groups. Farmers may participate in farmer groups for the following, partly interrelated reasons:

- Improved negotiation position and increased bargaining power;
- Saving costs through bulk/joint purchase of inputs;
- Sharing and reducing production and marketing costs in general;
- Achieving production and economies of scale;
- Facilitating marketing, including access to new markets;
- Improving access to and sharing of information;
- Facilitating creation of relevant partnerships and institutional linkages (see Sections 6.2.1, 6.2.2, 6.2.3);
- Joint learning and institutionalized capacity development;
- Improving access to relevant – including new – services, such as financial and other business development services;
- Improving access to and more favourable savings and credit options;
- Improving opportunities for agro-processing and value-addition, for instance through development of new products;
- Reducing risks in general;
- Lobbying and policy advocacy for smallholder interests (economic and socio-political).

The ultimate goal, and main incentive at the same time, will be to guarantee increased and sustainable income (Hassam and Wijnhoud, 2005).

The recognition of smallholder farming as a business, or, if in survival and subsistence mode, the realization that it has to become a business in the medium term, is essential. In this perspective, speaking about business associations or cooperative businesses instead of farmer associations or cooperatives, may contribute to the advocacy for such recognition of the economic objective and incentive at the same time (Hassam and Wijnhoud, 2005). Many of the failures of smallholder associations or cooperative groups were due to the fact that governments forced farmers into such associations or cooperatives for other reasons than to meet their economic objectives or to function as a business. Whereas the economic incentive and objective should be a precondition, the World Bank (2002) acknowledges that farmers’ organizations might contribute to amplifying the political voice of smallholders. This is an important step forward in thinking about the complementarities between political power and markets (Bingen et al., 2003).
The following two conceptual tools may be important for the socio-economic empowerment of smallholders and their – emerging – business associations:

*The Ansoff growth strategy matrix (Figure 6.2):*  
The Ansoff growth strategy matrix (Ansoff, 1957) has the following four quadrants with risks and challenges for farmer associations increasing when proceeding from one to four:  
1. *Market penetration;* Farmer associations market existing products at existing markets. The products remain unchanged but they launch promotions or otherwise try to increase their market share in order to increase revenues.  
2. *Market development;* Farmer associations attempt to sell existing products at new markets. New markets either refer to new market segments or markets with a different geographical location.  
3. *Product development;* Farmer associations market new products to existent costumers / at existent markets. Often this is done through innovation while gradually replacing old products with new ones.  
4. *Diversification;* Farmer associations produce and market new products to new costumers at new markets.

It is argued that for immature business associations it is important to sequence innovations for increased market access and in the initial years to focus more on the low risk quadrants than on diversification (e.g. Ferris et al., 2006; KIT/Faida MaLi/IIRR, 2006). It needs to be emphasized that the risks and time required for diversification may vary per product and is especially high when value-adding activities (grading, packing, labelling or even processing) are taken on board. Diversification, however, may be part of a longer term vision and could come into the picture after having matured, as part of a longer term strategy, most appropriately after having been successful in respectively market penetration, market and/or product development.

<table>
<thead>
<tr>
<th></th>
<th>Existing products</th>
<th>New products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing markets</td>
<td>1. Market penetration</td>
<td>3. Product development</td>
</tr>
</tbody>
</table>

Figure 6.2: Ansoff matrix (Source: Ansoff, 1957).
Farmer groups involved in a number of chain activities

2. CHAIN ACTIVITY INTEGRATOR
   - Specialized in production and some value adding activities (grading, packing, processing)

4. CHAIN (CO-) OWNER
   - Involved in production, value adding activities and being a chain partner at the same time

1. CHAIN ACTOR (SEGMENT)
   - Specialized in production and without concrete chain relationships

3. CHAIN PARTNER
   - Specialized in production but with established (value) chain links (more or less guaranteed business linkages)

Farmer groups do not participate in chain management

Vertical Integration

Farmer groups specialized in production

Horizontal Integration (Management)

---

Figure 6.3: The chain empowerment framework (adapted from: KIT/Faida MaLi/IIRR, 2006; Peppelenbos, 2005). Farmer groups that are only involved in production (1) can be empowered by finding reliable market outlets for their produce (moving to 3), getting involved in value-adding activities, such as grading, packing, etc. (moving to 2) or a combination of both (moving to 4) which will be most challenging (KIT/Faida MaLi/IIRR, 2006).

The chain empowerment framework (Figure 6.3)

Chain empowerment can be achieved either by:
1. Co-ownership/horizontal integration: strengthening of the negotiation position as depending on reliable market outlets; and/or
2. Vertical integration: value-adding activities at local level.

In general, these frameworks proceed from a modality of gradual development of autonomous business associations or cooperative businesses. There may be other formats, such as contract farming (e.g. Eaton and Shepherd, 2001; KIT/Faida MaLi/IIRR, 2006), that may accelerate technology development and may provide the associations with intensive extension support and the required inputs. Although case-specific, contract farming may also create dependence and go against empowerment and business development transitions. In particular, it may be risky for smallholders when the large contractors are trying to spread their political and geographical risks
over a number of LDCs and/or are piloting contract farming based on subsidy programmes for risky investments in LDCs as an incentive, i.e. with the livelihoods of smallholders at stake. On a more positive note, contract farming can accelerate technology development and innovation, and after learning, but having depended on the contractor, smallholders may decide to run similar production activities on their own. However, formation of farmer and business associations should not always be considered as an end in itself for livelihood development. In fact, at a certain stage and upon learning and growth, members, the most entrepreneurial ones first, may decide that they could perform better on their own and move out of the association to run their own businesses, or often more gradually, be only partly relying on some favourable services provided by the associations or cooperatives, such as input supply, storage and/or marketing, as is the case in OECD countries these days (see Section 6.2.7).

It is argued that chain empowerment and socio-economic development of smallholders should not ignore the relevance of the production side, as without environmentally sustainable market-oriented production systems, market access and business development cannot be sustainable. Apart from environmental sustainability, development interventions aimed at market access should mainstream gender (see Section 6.2.9), HIV-AIDS (see Section 6.2.10) and food security (Sanginga and Chitsike, 2005; Sanginga et al., 2005; Ferris et al., 2006). It should be assured that increased returns will not only end up in the pockets of male heads of households. This means that livelihood strategies aimed at chain empowerment and more market-orientation should not compromise with increased gender inequality and food insecurity, of which women and children are often the first and main victims.

6.2.14. Translation of international and national development policies into local strategies and action (PRSP and MDGs)

The Millennium Development Goals and Targets (Table 6.1) come from the Millennium Declaration signed by 189 countries, including 147 heads of state, in September 2000 (United Nations, 2000). The goals and targets are related and should be seen as a whole. They represent a partnership of countries determined, as the Declaration states, “to create an environment – at the national and global levels alike – which is conducive to development and the elimination of poverty” (United Nations, 2000, 2001; World Bank, 2005).

In many LDCs, the national poverty reduction strategy is embodied in a poverty reduction strategy paper (PRSP), used as a basis for programmes with IMF and the World Bank (UN Millennium Project, 2005). Those PRSPs urgently require revision to align them to the Millennium Development Goals. Very few PRSPs are ambitious enough to achieve the goals, largely because they have been prepared in a context of
insufficient donor assistance. Even when the PRSPs claim to aim for the goals, they rarely identify the path of public investments that would be needed to achieve them (World Bank, 2005).

The World Bank (2005) states that poverty reduction in sub-Saharan Africa has been disappointing, primarily because of its slow growth and low sensitivity of poverty to growth (holding constant the distribution of income). This low sensitivity can be traced to the region’s low incomes and high inequality levels.

A challenging argument may be that the lack of progress towards the MDGs is due to the fact that MDGs were launched as goals without being accompanied by well-developed strategies. As a consequence, the implementation process has resulted in comprehensive and expensive planning exercises, endless debates and workshop trajectories, often far away from those that suffer the consequences of poverty (Chambers, 2006). Partly due to lack of clarity about institutional mandates that are often overlapping or contested, but also due to issues of scale, a myriad of strategies and initiatives were launched coming in at different levels. In sub-Saharan Africa during 2000–2005, poverty alleviation returns to invested development money remained far below anticipated targets, although some progress has been made and islands of success may be dis-aggregated from what have been partly non-concerted efforts with limited sustainable impact.

A recent report on the MDGs (UN Millennium Project, 2005) appears to argue that an international fund-raising campaign and large amounts of money in the end will buy the goals. The counter-argument is that investment may be largely fruitless or unsustainable if certain criteria or less tangible prerequisites for sustainable poverty alleviation are not satisfied, such as good governance, market liberalization and substantial investment in human capital and broad-based capacity development. Moreover, there may be a conflict between on one hand quick results, and on the other hand the relevance of sequenced efforts and realistic time plans for empowerment in order to reach sustainable impact. This does not invalidate the argument that development may require substantial financial investments, but the main focus on financing would be more efficient under more optimal contextual conditions, whereas learning, capacity development and institutional change should be addressed in a realistic time frame.

As far as strategy development and anticipated impact is concerned, individual MDGs may require a closer look, but, even more importantly, it is recommended to look for synergism among the MDGs (see Section 6.2.12). For example, the single target for environmental sustainability under MDG7, may make the goal powerful, but with the risk that environmental sustainability mistakenly will be considered from a sector-wide perspective, instead of being closely linked with social and economic
Table 6.1: Millennium Development Goals (MDGs): Goals and targets from the Millennium Declaration (Source: World Bank, 2005).

<table>
<thead>
<tr>
<th>GOAL 1: ERADICATE EXTREME POVERTY AND HUNGER</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARGET 1: Halve, between 1990 and 2015, the proportion of people whose income is less than $1 a day</td>
</tr>
<tr>
<td>TARGET 2: Halve, between 1990 and 2015, the proportion of people who suffer from hunger</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GOAL 2: ACHIEVE UNIVERSAL PRIMARY EDUCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARGET 3: Ensure that by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GOAL 3: PROMOTE GENDER EQUALITY AND EMPOWER WOMEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARGET 4: Eliminate gender disparity in primary and secondary education, preferably by 2005, and at all levels of education no later than 2015</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GOAL 4: REDUCE CHILD MORTALITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARGET 5: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GOAL 5: IMPROVE MATERNAL HEALTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARGET 6: Reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GOAL 6: COMBAT HIV/AIDS, MALARIA, AND OTHER DISEASES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARGET 7: Have halted by 2015 and begun to reverse the spread of HIV/AIDS</td>
</tr>
<tr>
<td>TARGET 8: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GOAL 7: ENSURE ENVIRONMENTAL SUSTAINABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARGET 9: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources</td>
</tr>
<tr>
<td>TARGET 10: Halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation</td>
</tr>
<tr>
<td>TARGET 11: Have achieved a significant improvement by 2020 in the lives of at least 100 million slum dwellers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GOAL 8: DEVELOP A GLOBAL PARTNERSHIP FOR DEVELOPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARGET 12: Develop further an open, rule-based, predictable, non-discriminatory trading and financial system (including a commitment to good governance, development, and poverty reduction, nationally and internationally)</td>
</tr>
<tr>
<td>TARGET 13: Address the special needs of the least developed countries (including tariff- and quota-free access for exports of the least developed countries; enhanced debt relief for heavily indebted poor countries and cancellation of official bilateral debt; and more generous official development assistance for countries committed to reducing poverty)</td>
</tr>
<tr>
<td>TARGET 14: Address the special needs of landlocked countries and small island developing states (through the Programme of Action for the Sustainable Development of Small Island Developing States and the outcome of the 22nd special session of the General Assembly)</td>
</tr>
<tr>
<td>TARGET 15: Deal comprehensively with the debt problems of developing countries through national and international measures to make debt sustainable in the long term</td>
</tr>
<tr>
<td>TARGET 16: In cooperation with developing countries, develop and implement strategies for decent and productive work for youth</td>
</tr>
<tr>
<td>TARGET 17: In cooperation with pharmaceutical companies, provide access to affordable, essential drugs in developing countries</td>
</tr>
<tr>
<td>TARGET 18: In cooperation with the private sector, make available the benefits of new technologies, especially information and communication.</td>
</tr>
</tbody>
</table>
welfare (and incentives), and vice versa. Notwithstanding the relevance of looking for development synergies among the efforts aimed at individual targets and goals, the rather diverse set of targets under MDG7 is not very clear. The way forward either may be to come up with a revised and coherent set of goals and clear integrated strategies for their achievement, which appears unlikely, or to move ahead with the existing MDGs, but improving considerably on more coherent and integrated strategies and concerted action for MDG localization and achievement, such as efforts pivoted around action-learning and action-research, involving action beyond planning (see Section 6.2.11).

6.2.15. Learning, education and human capital
One of the key factors influencing the success of farm enterprises, business association development and improved livelihoods is the effectiveness of learning mechanisms and the build up of human capital (Chapter 1). Investment in farmer education and quality child education, for both girls and boys, and other learning mechanisms will be critical and partly explain the relative success of some of the Asian Tigers, such as Thailand (Rigg, 1997; see Section 6.2.7).

In Section 6.2, we have presented a number of the most relevant considerations for the development of innovative rural development strategies. Of course, a number of other highly divergent aspects and factors are of high importance as well, such as result-orientation, participatory planning, monitoring and evaluation (PME), micro and rural finance and policy research, advocacy and development. Some of these are partly touched on or implicitly dealt with in this thesis, such as policy research and advocacy in Section 6.3, but their detailed analyses and elaborations are beyond the scope of this thesis.

6.3. Elaborations on developments, challenges and opportunities in two sub-Saharan African countries

6.3.1. Ethiopia: Perpetuating environmental degradation, food insecurity and poverty?

Situation sketch
Ethiopia is a country of extremely diverse biophysical features. Besides some comprehensive areas of relatively fertile arable land, often used for cash crops such as coffee, in the West and South, the country predominantly consists of rugged mountain areas of which large parts are used for mixed peasant farming systems, drought-prone semi-arid arable land with mixed farming systems and extensive areas of arid and
Conclusions, broader considerations and general discussion

Semi-arid grazing land. Forest areas, although rapidly declining, are found predominantly in the South and West, with some protected areas in the Central, Northern and Eastern highlands. About 85% of the population of 70 million almost fully depends on natural resources for their livelihoods. Most of these depend on peasant agriculture and some groups on pastoralism, with livestock production being a key component within the farming production systems of the peasants in the highlands (Abegaz, 2005; Alemneh Dejene, 2003), although not for the ever growing number of ‘destitute’ and land-less people relying on common property resources or being day labourers (Sharp et al., 2002). Both, peasants and pastoralists predominantly depend on the direct or indirect use of biomass for their energy needs (Mengistu Teferra, 2002). The environment-poverty nexus is dramatic and has resulted in extreme forms of soil erosion, overgrazing, deforestation, loss of biodiversity and other forms of natural resource degradation, with the consequences of extreme economic losses, extreme poverty with food shortages and famine, the latter being more severe during prolonged periods of drought. This development has not been brought to a standstill yet, let alone counteracted significantly at a large scale. Access to land and livestock ownership are considered as relative important indicators of wealth. Particularly livestock ownership is telling in this respect, with land distribution being rather egalitarian among households, although with little access to and control over land by women and rapidly increasing land fragmentation (Taye Assefa, 1999). Droughts often lead to partial or complete yield loss, starvation of livestock and the general loss of livelihood assets, resulting in increased vulnerability, poverty and famines. Many rural development efforts failed or had limited impact, because of ignoring the need for participatory approaches, the empowerment of marginalized groups, such as rural women and pastoralists, and ignoring the need for gender mainstreaming by addressing gender roles aiming at gender equity and empowerment of women and other marginalized groups in general. Although women rights are guaranteed by the national constitution, due to continued socio-cultural obstruction and gender-blind policies, women find themselves in a very weak position with limited decision-making power at different levels. Moreover, too often the holistic context, including the socio-economic, policy and institutional environment at different scale levels, is insufficiently considered.

Policy context and institutional constraints

Because of its multiple dimensions, a wide range of sector and cross-sector policies touch on or have interfaces with the SNRM ‘sector’, such as sector-wide water and food security policies, a draft ‘agricultural’ policy, covering NRM, land-use, forestry and research components and the policy based on the conservation strategy of Ethiopia
Chapter 6

(CSE) that addresses environmental issues in a cross-cutting way. The most important elements of these policies have been incorporated in the sustainable development and poverty reduction programme (SDPRP) for Ethiopia (MOFED, 2002), the key framework for donor support to Ethiopia. One of four interrelated pillars of SDPRP is the agriculture-development led industrialization (ADLI) policy, whereas the other three pillars deal with the justice system and civil reform, decentralization and local empowerment and capacity building (MOFED, 2002). ADLI was adopted in 1993 as Ethiopia’s long-term strategic policy for general socio-economic development. Its agricultural- and rural-centred emphasis justifies a closer look at its potential for SNRM and livelihood development in Ethiopia.

The ADLI strategy concentrates on three priority areas:

1. Accelerated growth in the agricultural sector with a key focus on the supply of fertilizers, improved seeds and other inputs, but on a credit basis;
2. Expansion of small-scale industries to interact with agriculture;
3. Expansion of (agricultural and agro-industrial) exports to pay for capital goods imports.

The main argument for the introduction of ADLI was the predominantly agrarian nature of the country’s economy, the development potential that can accrue from this sector and the spill-over effects on the rest of the economy (Van der Loop, 2002).

From the late 1990s onwards, arguments have been gaining ground that the rather one-sided ADLI approach has major weaknesses:

- Like most national policies, ADLI was developed and implemented in a rather top-down and gender-blind way (five-year master plans). However, ongoing decentralization efforts are expected to slightly but steadily improve local and gender-equal participation and policy advocacy with associated reformulations.
- It only appeared to have impact in high potential areas, and blanket extension recommendations failed in low potential, semi-arid and erosion-prone areas (Eyasu Elias, 2002), which resulted in millions of resource-poor farmers becoming highly indebted to the State.
- Lack of attention for land tenure reform. Limited land tenure security (Dessalegn Rahmato, 2003) does not provide the required incentives for peasants to invest in the land, nor does it provide sufficient collateral to get access to sufficient and favourable loans. Others advocate private land ownership, arguing that more land tenure security and a market of official land certificates will not be sufficient to embark on commercial agriculture, rural innovation, including livelihood and economic diversification.
- Neglect of requirements for rural transport infrastructure and marketing arrangements (Gedion Asfaw, 2003).
• Making peasants vulnerable to extortion by corrupt officials (Gedion Asfaw, 2003).
• It considers urban development and non agro-industrial private sector development (PSD) within a follow-up stage after agricultural based rural development has been taken of. In this, ADLI ignores development trends in other countries, like Thailand (Chapter 3), where poverty is less severe and development far ahead of Ethiopia. Moreover ADLI ignores the relevance of PSD in general, positive effects of economic/ income diversification, the establishment of local markets and infrastructures through urban development and the rural-urban development interfaces (Van der Loop, 2002; Berhanu Nega, 2003).
• A narrow focus on agriculture per se all too often leads to policies and development interventions that undervalue or even undermine the values of the wider local food/cash crop system for agricultural production, markets, livelihood security, well-being and local culture (Pimbert, 1999).
• Given the country’s agriculture-centred economy, it is particularly vulnerable to the adverse effects of fluctuations in commodity prices (especially coffee) and drought (Van der Loop, 2002). The need for and benefits of farm and agricultural diversification, and certainly those of intensification and commercialization, are not adequately addressed (Berhanu Nega, 2003).
• The advocacy of labour-intensive agricultural development may become an additional burden for women and is constrained by the ongoing HIV-AIDS pandemic (ECA, 2005; SLU, 2005). Moreover, it may delay or block part of the much-needed innovative efforts aimed at sustainable land use (Section 6.2).

Parts of these insights triggered moderate policy reforms when ADLI was reformulated in a somewhat more balanced format within the SDPRP (MOFED, 2002). In line with the SDPRP, the EPDRF (ruling party) 5-year plan (EPDRF, 2000) emphasizes the need to deviate from a completely agricultural-development centred approach to a more balanced approach that takes into account the relevance of PSD and urban development as equally important for concerted interrelated sector-parallel development efforts.

In addition to agricultural development as one of the key objectives, the SDPRP has key interrelated objectives with respect to increased water resource utilization, small-scale irrigation, food security and agricultural research. Although the SDPRP appears to be more balanced than ADLI, due to the sector-wide approaches (SWAPS), cross-sector policies and SNRM-related issues are addressed in a rather fragmented way, with the policy segments being partly overlapping, rather than integrated in a coherent way. In this perspective, it lacks emphasis on the need for integrated and coordinated development efforts, and, given the degraded status of natural resources in the country, the limited attention for SNRM is remarkable.
Chapter 6

Breaking the cycle of poverty and famine: two schools of thought

Poverty and food security issues are highly politicized and opinions very much polarized in Ethiopia. At the extreme ends, two schools of thought can be distinguished:

1. The one that is fully ascribing poverty and recurrent famines to recurrent drought and increasing environmental degradation. It believes that technical/biophysical attempts will be most important to combat poverty and vulnerability and reverse the trend of recurrent famines. Proposed interventions, such as ‘Food For Work’ (FFW)-based environmental regeneration may not reduce dependence and provide sustainable solutions, let alone that they are based on a vision and are ultimately aimed at alternative livelihood strategies beyond peasantry (see Section 2.2.1). Many of its proponents do not consider the current land tenure system as a hurdle to rural development.

2. The one that advocates that drought and degrading natural resources are not the main causes of famine, but that the reasons are socio-economic, policy-related and politically perpetuated. They are calling for policy reform and democratization to dismantle policies, practices and institutions designed to perpetuate poverty and recurrent famine as a conspiracy to hold on to power. Many of its proponents advocate access to resources for food security for the poor and an end to land tenure insecurities by reviewing and revising the current land tenure policy and ongoing population resettlement programmes (Dessalegn Rahmato, 2003; Ellis, 2005), to avoid that the rural population has no other alternative than relying on policies that oblige them to stick to land-bound livelihoods (Berhanu Nega, 2003; Ellis, 2005). Based on statistical analysis, Berhanu Nega (2003) claims that food aid dependence will continue to grow as long as rural and overall population growth is outpacing the growth in food production, as well as overall agricultural and economic growth. He also argues that the perpetuation of peasantry and an ever increasing number of peasants, stand in the way of economic diversification and livelihood transitions that have to go hand in hand with increased urbanization (Berhanu Nega, 2003; Section 6.2).

Mesfin Woldemariam (2003) advocates the need to ‘liberate’ the farmers, especially the small peasant producers, from exploitation by the state, the market and religious forces. The first is in the national political arena and partly refers to land policies, failing the poor, tax regulations and widespread indebtedness due failed credit-based agricultural programmes. The second refers to both the national and the international political arenas with the poor losing out on vested interests of local political elites, including economic gains from the relief and food aid industry, and unfair trade at international level. The last refers to disproportional time and
financial investment in (cultural) religious ceremonies, including high investments in funeral ceremonies by those whose livelihoods themselves are at stake.

Discussion
It is argued that (increased) vulnerability and deteriorating livelihoods of Ethiopian peasants only can be addressed by long-term structural efforts, following a sustainable livelihood approach (SLA) (Chapter 1). Large groups of peasants, but also pastoralists, gradually lose or no longer own the (livelihood) assets that could give them resilience to cope with drought and avoid famines and the need for relief aid. They have reached the point at which they have ‘nothing to fall back on’ (Robinson, 2003).

Another key indicator of the prevailing crisis is the perpetuated import of huge amounts of relief food, produced by subsidized farmers in OECD countries, but with high transport cost involved for shipment through Djibouti and the long distribution lines spread out over Ethiopia. Local para-statal transport companies, middlemen and other businesses profit, but it very negatively affects local markets, without considering alternative options, such as the provision of cash and/or ‘local’ purchase of food in surplus areas.

In Ethiopia, so far, R&D efforts aimed at environmental reconstruction and SNRM, have almost exclusively been initiated from technical and biophysical angles, ignoring the socio-economic, cultural (including gender), policy and political aspects. As such, they are rather old-fashioned and their significance may be questioned, as long as the ‘environmental’ issues are isolated from their overall (integrated and holistic) context. There is a large development gap and a substantial potential towards poverty eradication and food security, if rural R&D could be based on a more holistic and integrated (pivoted around the need for sustainable livelihoods out of peasantry) approach, that is more participatory, community-based and empowering, more gender-sensitive, more policy-focused and more relying on effective partnerships and the involvement of socio-economic R&D institutions and big international (non-profit) R&D institutions.

6.3.2. Localization of the Millennium Development Goals (MDGs) in Mozambique based on capacity development for local economic development (LED)

Situation sketch: Poverty and policy context
Mozambique, a country with a population of 19 million, is still challenged by its legacy of colonialism and civil war that came to an end in 1992, and was followed by the first parliamentary and presidential elections in 1994, when the country consolidated the transformation from a socialist system into a market-oriented
democracy. The historical legacy was one of low skills, weak institutions, and poor coverage of essential basic services, let alone major and widespread economic activity. Gender inequality, the growing impact of the HIV-AIDS pandemic, continuing corruption challenges, poor infrastructure, a weak financial services sector and complex or unclear property rights legislation compound the overall development challenge (UNDP, 2002; DFID, 2004).

Notwithstanding a steady economic growth, albeit from a very low basis, Mozambique’s per capita annual income of $ 229 remains among the lowest in the world (AfDB/OECD, 2005), with the country also remaining among the eight poorest countries in the world, based on its human development index (UNDP, 2004). A few mega-projects have largely accounted for significant economic growth in recent years, but there are questions about the distributional effects of this growth and its effect on poverty reduction, as it may have contributed to rising income and wealth inequalities in general and geographically (AfDB/OECD, 2005). Local entrepreneurs still face the bureaucratic hurdles that were largely waived for the mega-projects (DFID, 2004). In this perspective, the major challenge remains to create an enabling business climate for broad-based economic growth and competitive productive capacities, beyond the mega-projects (AfDB/OECD, 2005).

The country’s poverty reduction strategy plan (PRSP) for 2001–2005 identifies the following six priority areas of action: education; health; infrastructure (roads, energy and water); agriculture and rural development; good governance, legality and justice; and macro-economic and financial policies (GoM, 2001). Whereas public sector support for economic development is still being covered under the ‘other areas of action’ in the PRSP (GoM, 2001) it has emerged as a key pillar in the latest five-year (2004–2009) government plan (GoM, 2005). Where the country’s poverty reduction strategy plan (PRSP) for 2001–2005 (GoM, 2001) lays the basis for ‘socio-economic growth’ and identifies ‘good governance’ as a priority area of action, it does not make an explicit link between the two or anticipates on the coherence between good governance, including local governance, and economic growth. Moreover, it does not elaborate the role of private sector and civil society actors in key areas (DFID, 2004).

The in-depth integration of Mozambican rural farmers into the national economy is a vital component of the agricultural and rural development strategy for which a public expenditure programme (PROAGRI) with broad-based donor support has been put in place since 1999 (Saasa, 2004). The first 5-year phase of PROAGRI had the objective to address the need for increased production through strengthening of rural services and civil sector reforms, the second phase aims at linking increased production, and increasing marketed surpluses, to marketing and processing activities, while promoting producer organizations – although not elaborating on formats and institutional
arrangements – and developing an efficient commercial sector (GoM, 2001, 2005). As PROAGRI is implemented by and partly targeting the Ministry of Agriculture and its line offices at provincial and district level, the interdisciplinary dimensions of such rural development needs and the role of other actors and their institutional arrangements are not always clear (Saasa, 2004). The current situation of isolated, overlapping and unclear mandates appears to be a major challenge for the implementation of the five-year (2004–2009) government plan (GoM, 2005), which also does not elaborate, as yet, on institutional (re-)arrangements and organizational requirements for the various action points.

Ongoing decentralization efforts (Faria and Chichava, 1999), central to the good governance component within the PRSP (GoM, 2001), have created opportunities for local initiatives. The country has embarked on a gradual introduction of elected local governments for 33 municipalities, predominantly urban, but also a few with a largely rural character. This may provide a basis for initiating local initiatives, directly linking local governance and local economic development, which is among the seven municipal mandate areas (GoM, 1997).

Notwithstanding the fact that District Administrations remain non-elected, the latest amendment to the law on local public organs of the government of Mozambique (LOLE) gives a new impetus to participatory planning processes and decision making at district level (GoM/Council of Ministers, 2005), as such broadening the scope for local initiatives at district level.

In order to halt ‘development’ efforts that often remain restricted to planning and paper exercises far above the local level and without concrete follow-up and local action, measures were announced that would better guarantee the concentration of development efforts at district level and that would turn districts into ‘poles of development’, based on concrete action (Notícias, 2005).

Notwithstanding the relevance of national strategies and strong national institutions, the need for efficient decentralization efforts is also emphasized; both political decentralization (devolution or devolved governance) and administrative decentralization (de-concentration) will be required. The degree and usefulness of decentralization may vary per sector and is only possible through considerable reallocation (de-concentration) of funds, material and human resources (Notícias, 2005), and, in parallel, will require considerable capacity development efforts. Its success ultimately depends on the quality of state governance in general (Chabal, 2005).

A rather large policy shift was made by the second Poverty Reduction Strategy Plan (PRSP-II) for 2006–2009 (GoM, 2006) that together with governance and human capital has economic development among its three fundamental areas of action. The combination of the 5-year plan (2005–2009) of the government of Mozambique (GoM
2005), PRSP-II (GoM, 2006), legislation for municipalities (Alves and Cossa, 1999) and the latest legislation on local authorities, LOLE, (GoM/Council of Ministers, 2005) is largely filling some of the identified policy gaps. In combination, they provide a strengthened policy framework for:

1. Efforts aimed at a more integrated and balanced national economy with municipalities and districts being transformed into ‘poles of development’;
2. An improved business climate, apart from capacity development efforts targeted at public entities with relevant mandates, it is aimed at strengthening the public-private-civil dialogue and public-private partnerships;
3. Improved financial systems; public, through the public financial administration system (SISTAFE) and allocated district development funds, and private, such as a growing micro-finance sector and attraction of local and foreign direct investment;
4. Development of small and medium enterprises, including producer and other business associations;
5. Good governance, including efficient decentralization efforts, for i, ii, iii and iv.

**Breaking the cycle of poverty and aid dependence: The relevance of local economic development (LED)**

It is the strong believe that private sector development (PSD), the engine of economic growth and well-being, will be the key to poverty reduction in a sustainable way. Local economic growth entails an increase in income, jobs and business transactions. Local economic growth is essential for creating a local and national tax base, relevant for basic service delivery and the development of public infrastructures, in turn contributing to a more favourable business climate and, therefore, stimulating economic growth. Moreover, higher incomes and more employment will result in increased purchasing power for basic goods and services. This will also create required conditions for viable public private partnerships (PPP) for service delivery.

Pro-poor PSD and inclusive economic growth may benefit from responsive and accountable (good) governance, but at the same time represent essential conditions for it. The latter is less often acknowledged to be essential in order to ultimately escape a vicious circle of aid and donor dependence, but it explains the relevance of PSD for improved and sustainable – *i.e.* ultimately not on aid depending – basic service delivery and infrastructural development, important components of the business climate.

In sub-Saharan Africa and Mozambique, ongoing decentralization processes and the latest poverty reduction strategy papers (PRSPs), stress the importance of broad-based economic growth. Local public entities are increasingly mandated to promote and coordinate local economic development (LED) and are held accountable for meeting
development targets, including those related to investment, job creation, the business environment and local economic growth in general.

However, local capacity to create the enabling conditions for local economic development tends to be weak. Therefore, the LED process aims at addressing these weaknesses through capacity development. The success of LED trajectories and their sustainable impact depends on the organizational capacity of local stakeholders and an appropriate institutional framework. Part of the rationale for starting capacity development for LED is that substantial development leverage can be derived from a simultaneous focus on improved local governance and pro-poor private sector development, such as chain empowerment for local producer associations and small and medium enterprises (KIT/Faida MaLi/IIRR, 2006; Ferris et al., 2006), including commercial business development service providers, and/or significant job creation by larger enterprises.

The ultimate goal of a LED process is to build the economic capacity of a local area in order to sustainably improve its economic future and the quality of life of its citizens (jobs, income, and increased access to basic services).

The primary objective of a LED process is identification of competitive local economic advantages and opportunities, as well as local and non-local constraints which are then addressed through concrete action to trigger high-potential local economic activities and create an enabling environment for these activities and LED in general.

Deliberate facilitation of a LED process is expected to boost economic development and growth at local level, partly through capacity development targeted at the local government to clarify and strengthen its role for the promotion and coordination of LED, and partly through direct capacity development support to a partly still emerging private sector and their local non-governmental and governmental support agencies. For development facilitators, from a strategic point of view, a LED process or framework is potentially a powerful instrument for concrete short-term action, based on local competitive advantages and development opportunities. Development leverage can be obtained by targeting and building the capacity of a group of interrelated actors, including private sector actors as well as local government agencies with a mandate for the coordination and promotion of PSD and LED.

From the perspective of the localization and achievement of the Millennium Development Goals (MDGs), first and foremost capacity development interventions for LED are aimed at contributing to the income and employment driven MDG1 (Table 6.1). As a result of positive impacts on local governance and anticipated synergy among MDGs the process may also make sustainable contributions to other service-oriented MDGs (MDG2 and MDG4-7). Specific targets may be set for the promotion of gender equality and empowerment of women (MDG3) as well as for
promotion of environmental sustainability (MDG7). Global partnerships (MDG8) could be beneficial, provided they do not waste resources for conferences, seminars and perpetuated planning and if navigating on downward accountability and geared towards concrete action at local level.

**Capacity development for LED in Mozambique**

Wijnhoud (2005) provides an overview of a range of comprehensive international frameworks and toolboxes developed by various agencies for stimulating LED (PDM/Club du Sahel, 2001; Van Boekel and Van Logtestijn, 2002; Trousdale 2003; Meyer-Stamer, 2003, 2004; Swinburn et al., 2004; Besong and Foki, 2005). Taking into consideration the local context in Mozambique, SNV has opted for a much lighter and more flexible approach. A number of criteria were identified, assumed to be relevant for the design of a LED framework and launching a LED process at municipal or district level in Mozambique. In part, they cover more general aspects that were identified when anticipating what a LED approach should be about, while others are more related to the specific character and needs of Mozambican municipalities and districts. The following, partly interrelated and overlapping, criteria/aspects were used:

- Emphasis on competitive local economic advantages and the creation of the associated favourable economic/business climate;
- Contextual awareness and relevant horizontal and vertical institutional linkages;
- Sufficient ‘guarantees’ for concrete action, tangible results and sustainable impact;
- Relatively simple and flexible process;
- Action-oriented process and ‘learning by doing’;
- Integrated and coherent approach; linking devolved governance with economic growth;
- The strong belief that private sector development, in particular local economic development (LED), the engine of (local) economic growth and well-being, is the key to sustainable poverty reduction in Mozambique;
- In addition to positive economic impact, social, gender and environmental impacts are anticipated (no negative impacts will be the bottom line);
- Action-oriented and integrated capacity development (see Table 6.2);
- Requirements for financial, material and human resources, at least for the identification phase, should be realistic and tailored towards local realities;
- Clear distinction from approaches for strategic/district planning and community development;
- Participatory principles and sufficient local ownership;
- Flexibility regarding its applicability and system boundaries.
The LED trajectory (framework) for Mozambican municipalities and districts includes the following two phases, with respectively four and two steps (Wijnhoud, 2005):

Phase 1: Appraisal and planning phase (should be dealt with thoroughly but kept as short as possible)
Step 1: Initial explorations, awareness creation and contracting with local government;
Step 2: Establishment of a LED team, preparation of action plan/monitoring and evaluation (M&E) for remainder of phase 1;
Step 3: Deepening of institutional analyses and identification of competitive local economic advantages and constraints;
Step 4: Identification and prioritization of concrete activities; elaboration of concrete bankable proposals; establishment of relevant partnerships, including for financial requirements and additional preparations for implementation.

Phase 2: Implementation phase/monitoring; evaluation and impact assessment
Step 1: Launching of LED plan; start of implementation; assuring M&E and impact assessment mechanisms are in place;
Step 2: Full-fledged implementation based on ‘learning by doing’ and under provision of Capacity Development Services; accomplishment (e.g. elimination of constraints; establishment of infrastructures/services) or auto-sustainability of activities (specific economic activities).

It is emphasized that the LED trajectory should be integrated into the daily routine of its actors and be embedded in or linked to existing, but developing institutional structures, such as municipal or (consultative) development committees – that have a much broader and more formal character – instead of creating parallel ones. This means that the trajectory should directly be linked to the economic mandate of the municipalities and district administrations and may be part of, but not restricted to, the economic component of the municipal and district development strategies and action plans. Similar principles have to be followed when and where other themes (mandate areas) come to the fore and other actors assume a key role. As the ultimate engine for local economic growth, it is essential that the (emerging) private sector itself is involved in LED planning. The LED team is the platform for dialogue between the public and private sector and for the planning and launching of concrete activities, including those navigating on public-private partnerships.

Anticipated results or resulting processes may include the following:
• Increased conceptual awareness about LED and about local competitive advantages and local and non-local constraints for LED;
Chapter 6

- Making more and better use of local resources and requirements for their subsequent development (natural, human, financial, social, organizational);
- Taking advantage of local economic competitive advantages;
- Improvement of the local business (economic) climate;
- Promotion of the municipality or district and its economic potential;
- Attract more local and foreign direct investment;
- Local economic growth (value addition) and the inherent increase in business transactions (number and magnitude);
- Improved partnerships, coordination and collaboration for LED (public-private-civil society-support organizations, both at local level, horizontal linkages, and with provincial, national and international actors, vertical linkages, partly depending on economic activities to be included and business constraints to be addressed in a LED framework);
- Clarification of the emerging role of the Municipal Council or District Administration for the promotion and coordination of LED;
- Improved accountability by the (local) government for LED, to the private sector, civil society and citizens at large;
- Improved emphasis on LED and integration of LED in municipal and district development strategies and support for the identification of existing policy gaps, e.g. for land use, municipal and district planning; interpretation of land legislation;
- Improved (more systematic/constructive) exploration of (and piloting within the boundaries set by) new policy frameworks in practice and regarding the revised government structures at different levels (village, municipality, district, province, national and regional and international);
- Increased awareness about rural-urban linkages and the conditions set by globalization;
- Building the institutional, organizational and individual capacities in Mozambique to accelerate the adoption of participatory approaches for LED;
- Creation of mechanisms to monitor and evaluate a local economic development process and its component activities, as well as the creation of mechanisms for the assessment of ultimate impact;
- Commitment of the (emerging) private sector and their support agencies to the integration of business development efforts within a LED framework at municipal or district level.

Although initially not included within a formal LED framework, the action-oriented and integrated capacity development of pineapple producer associations in the Chibabava District in Sofala Province (Table 6.2; Hassam and Wijnhoud, 2005), could
serve as a prototype for one type of activities embedded within a LED capacity development framework (Wijnhoud, 2005). In fact, identification of the economic opportunity and the capacity development of the associations and their economic activities was very much based on LED principles (Wijnhoud, 2005). The primary objective for strengthening of the farmer associations, incentive at the same time, is increased income generation and economic prosperity at household level. Action on the ground started from local realities and adequate contextual awareness and emphasized the potential for synergies with efforts aimed at more efficient service delivery and based on broader stakeholder involvement and collaboration. Efforts aimed at LED and service delivery are mutually enhancing (e.g. Ruben, 2006). For the pineapple producers in Chibabava, this link is emphasized where their lobby to get

Table 6.2: The action-oriented and integrated capacity development of pineapple producer associations in the Chibabava District in Sofala Province (adapted from Hassam and Wijnhoud, 2005).

<table>
<thead>
<tr>
<th>The action-oriented and integrated capacity development approach includes the following elements:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Action-learning/action-research: Action-learning means ‘learning by doing’. It is reactive. Objectives are set, activities undertaken and, based on reflections, adaptations are being made continuously. Action research is different, in that it follows a more deliberate process of actions based on clearer strategies and targets. Local realities and the needs and multi-level challenges and opportunities of farmer associations are set at the centre. A gradual approach of exploring and learning together with farmers is followed to minimize the risks, and guarantee sustainability of the efforts.</td>
</tr>
<tr>
<td>- Integrated and incentive-based efforts (organizational perspective): The approach draws on synergism by simultaneously targeting economic performance and its required basic organizational development and institutional linkages. Strengthening associations without strengthening their core commercial business, incentive for their existence, would be of little value. In turn, business interventions may not be sustainable if not embedded in and owned by strong associations.</td>
</tr>
<tr>
<td>- Contextual analysis: The approach aims at linking local poverty and development constraints to some of its root causes beyond the local level and identifying opportunities (f.i. alternative markets), requiring information about and exposure to the broader multi-sector regional, national and international context, f.i. weak national institutions, market opportunities, best practices at local, national and international level.</td>
</tr>
<tr>
<td>- Partnership building and development synergism (local and broader development perspective): Emphasizing the relevance of strengthened institutional linkages (f.i. for market access and agro-processing opportunities, but also organizational development) and promoting synergism among development interventions and concerted efforts by its involved actors (f.i. the successful lobby for rural electrification). In this perspective, one could also speak about the competitive advantages of a ‘pole of development’ (Notícias, 2005), where demand-driven efforts, aimed at business and economic development, contribute to those aimed at more efficient (basic) service delivery, and vice versa.</td>
</tr>
</tbody>
</table>
access to the electric grid, required for local processing of their pineapples, at the same time is relevant for power supply requirements in the health, education and potable water sectors, in turn influencing the local business climate (Hassam and Wijnhoud, 2005).

Conclusions
In Mozambique, as elsewhere in sub-Saharan Africa, the first five years of the Millennium Development Goals (MDGs) trajectory have been dominated by strategy development, with concrete initiatives and results towards the achievement of the MDGs having remained below expectations (World Bank, 2005; UNDP, 2004). Poverty alleviation returns to invested development money have been very low, which also holds for Mozambique, where many ‘development’ efforts remained restricted to planning and paper exercises without or with limited follow-up and concrete action (Notícias, 2005). There is a need for approaches and mechanisms navigating on concrete action and the localization of the MDGs, where a capacity development approach for LED matches well with ongoing policy reforms.

Efficient decentralization efforts, both devolved decision-making and de-concentration of financial, material and human resources, including those with higher educational degrees, as well as pro-poor private sector development at local level are thought to be essential (Notícias, 2005). Although the LED-based capacity development approach at municipal and district level may not be a panacea for all development requirements, the approach has a lot to offer for mobilizing local capacities for the MDGs and MDG localization (Van Klinken, 2005).

For the specific case of the pineapple producer associations, the primary objective for its strengthening is increased income generation and economic prosperity. However, it reveals that, also from the perspective of efficiency and effectiveness, this cannot be considered in isolation from requirements for and efforts aimed at more efficient service delivery. In this perspective, based on local realities, this case touches on how the economically driven MDG1 cuts across some of the targets set by other MDGs. Synergism among strategies for individual MDGs may become obvious, based on local realities and is valuable input for MDG localization strategies. This case also shows that strong local demand for development (electrification) and confronting non-local stakeholders with local realities, including (potential) synergism, is very powerful in bringing stakeholders and strategies for individual MDGs together and in making progress towards the sustainable achievement of the MDGs (Hassam and Wijnhoud, 2005). The local-level action-oriented and integrated capacity development experience (Table 6.2), starting from an economic perspective, may provide essential inputs for rethinking strategies aimed at MDG localization that will be better tailored
Conclusions, broader considerations and general discussion

Towards the sustainable achievement of the MDGs by 2015 (UN Millennium Project, 2005).

The description of this case was brought into this thesis as part of a discussion on innovative rural development strategies. First experiences appear to be promising (Hassam and Wijnhoud, 2005; Wijnhoud, 2005), but insight in its effectiveness in the medium and longer term, is lacking as yet.

6.3.3. Synthesis

These case descriptions from Ethiopia and Mozambique reveal that due to very different historical and policy factors, development challenges may vary strongly among the LDCs in sub-Saharan Africa, and even more so at global level. Notwithstanding the existence of similarities, the differences are equally striking. Vulnerability of the rural poor and development challenges and opportunities are highly country-specific. Whereas in the Ethiopian context most bottlenecks already start at the policy level, in the Mozambican context, recent policy developments appear to have created more options for inclusive socio-economic development, in particular for adopting a LED approach to integrated rural development. In Mozambique, land degradation and land policy issues appear to be less pertinent than in Ethiopia, at least in the short term. In Mozambique, food insecurity exists, but is less widespread. For both countries the HIV-AIDS pandemic and gender inequality pose huge challenges and the requirements with respect to human and social capital development are equally challenging in both countries.

6.4. Final discussion: Contemporary insights for SNRM and livelihood development

6.4.1. Introduction

Many rural development efforts have failed or have had limited impact, because of ignoring the need for participatory approaches due to a lack of ownership by local actors, including the ultimate target groups (Van Paassen et al., 2007). Inherently, this touches on the relevance of the empowerment of marginalized groups, such as rural women, the need for gender mainstreaming and empowerment of women, and inclusiveness of other marginalized groups, such as those infected or affected by the HIV-AIDS pandemic, which, over the last two decades, has gradually become one of the main development challenges in sub-Saharan Africa (ECA, 2005; Section 6.3).

The environment-poverty downward spiral is also at the heart of the relation between poverty alleviation and the (cross-cutting) Sustainable Natural Resource Management (SNRM) theme, with emphasis on management. Instead of a single focus
on natural resources and their conservation through biophysical and technical measures, achieving SNRM and improved livelihoods in a complex reality, needs broader interdisciplinary, participatory and gender-sensitive efforts taking into account the holistic multi-scale context in order to breach the vicious circle of unsustainability (Section 1.1; Wijnhoud and Solomon Abate, 2004).

Policy and economic incentives, as well as human, organizational and institutional capital assets have often received insufficient attention, which is at the basis of a lack of sustainable impact of large numbers of projects and programmes (Lundy et al., 2005; Hassam and Wijnhoud, 2005). Overall livelihood security, including access to and control over (1) land and other natural resources, (2) viable and appropriate technologies, (3) financial resources, including favourable (micro-) savings and credit systems, and (4) markets, is a pre-condition for investment in SNRM (Boyd and Slaymaker, 2000). To realize that, appropriate policies, aimed at socio-economic empowerment and gender equity, good (local) governance, pro-poor private sector development (PSD), with guarantees for value addition, income generation and job creation at the grass root level, e.g. through pro-poor market access and local (agri-)industrial and business development, as well as human, organizational and institutional development at different levels, are essential. For efforts aimed at SNRM, the holistic context, including the dynamic socio-economic, political, policy and institutional environments at different scales, often does not receive sufficient attention, which requires ‘out-of-the-box’ thinking and acting, beyond the one-sided focus on technical interventions from a biophysical perspective. The same holds for any interventions aimed at sustainable development in general, often predominantly addressed from an economic or, sometimes, socio-economic angle, underestimating or neglecting environmental sustainability as a key condition, and the general relevance of natural resources (management) and biophysical aspects, including technical dimensions, for the development of sustainable rural production systems. This is often due to disciplinary bias, and misperceptions about the multiple dimensions of SNRM, particularly its interfaces with a wide range of socio-economic disciplines (Chapter 1).

Paradoxically, the relevance of (socio-economically viable) sustainable rural production systems for SNRM in developing societies, due to their direct or indirect impact on sustainable income generation and economic growth, in turn affecting SNRM, is often not well understood in the biophysical and environmental sectors.

The majority of rural production systems make direct use of natural resources for production and livelihood development, while the remainder, to a varying degree, has an impact on the natural environment and/or eco-system dynamics. Environmental sustainability is the bottom line to guarantee socio-economic sustainability, with sustainable socio-economic development being a key condition for SNRM and
environmental sustainability at large.

From an institutional perspective, there are certainly different ‘schools of thought’ that somehow may need to be reconciled. Some organizations have or come from an environmentalist (green) background; others are more people- and pro-poor oriented, and a last category may be merely interested in short- and medium-term economic gains for which environmental impact analysis (EIA) may be a legislative burden. The risk of conflicts and the need for assessment of the trade-offs between conservation and economic development perspectives are always there. As programmes that, at least in name, are ‘conservation’/’NRM’ programmes often tend to isolate environmental sustainability and natural resource management from mainstream development efforts, they often are doomed to fail. Moreover, they are often not sustainable once the money flows are cut off, as long as income, economic, livelihood, policy and/or governance incentives are ignored in efforts to break the poverty-environment downward spiral.

6.4.2. Towards a sustainable livelihood approach to SNRM

By addressing SNRM from a livelihood perspective, much more emphasis is given to the multiple dimensions of SNRM, particularly the human and poverty dimensions in their broadest sense. This may result in higher success rates of innovative R&D efforts, if realistically planned and implemented accordingly (see Sections 2.2.1 and 3.4.1).

Within the sustainable livelihood approach (SLA) (Chapter 1, Section 1.3), natural resources are directly accounted for in the natural capital assets; however, the differences between ownership of, access to and/or control over natural resources already highlight the obvious linkages with other types of capital assets. In this perspective, the role of common property resources (CPRs), such as communal land, forests and forest products, irrigation water, hunting areas, fishing waters, etc. may be critical for the poor. In general, the poorer sections of society are more dependent on communally owned resources for their survival than the better-endowed sections (Beck and Nesmith, 2000). A clear example is the encroachment of agriculture by landless communities into public forest areas in Northeast Thailand, partly under pressure of the economic crisis in the late 1990s (Chapter 3). However, the risk exists that under the influence of increasing land pressure CPRs will become more monopolized by elites (Johnson, 1997). In developing countries, in general, these practices will proceed as long as they are legitimised by prevailing policies, legislature and governance structures, favourable to specific political elites, while insufficiently protecting the poorest in society. However, this may be a more serious challenge in many of the LDCs, many of them in sub-Saharan Africa (SSA), than in emerging economies, such as Thailand, that, in general, are more stable with better-developed
democratic and governance standards. This issue underlines the relevance of power relations, inclusiveness and exclusiveness, political economics, institutional and governance structures and social capital in general. It also emphasizes the importance for the poorest groups in society to increase their social, institutional and political capital, relevant for their access to and control over natural resources (natural capital assets), as well as for their sustainable management (Payne, 2001), as social sustainability may be a key pre-requisite for SNRM is in its broadest sense (Smyth and Dumanski, 1993), and environmental protection (or sustainability), though necessary, is not a sufficient condition for SNRM (Smyth and Dumanski, 1993; Johnson, 1997).

Remarkably, it is not uncommon that resource-poor groups may be victimized in protecting resources and their management in an environmentally sustainable way, if only or mainly for the benefit of and with profits for other groups, often those that are already better off (Payne, 2001).

At global scale, such inequalities at the expense of direct benefits for the poor may exist as well, in relation to such issues as climate treaties, carbon sequestration, protection of tropical (rain) forests, and global biodiversity. Long-term benefits for the better off, at local, national and international levels, may be at the expense of direct benefits for the poor that have to survive through exploitation of resources. This situation can only be changed by developing more sustainable alternative livelihood strategies, requiring the build-up of critical capital assets and, already for the objective of environmental sustainability, requiring attention for factors beyond biophysical and technical aspects alone.

Access to and control over natural resources nor their full ownership is a sufficient condition for their appropriate and sustainable management, which may require access to other capital assets such as finances, knowledge and skills (human capital) and/or viable market linkages (Chapter 1, Section 1.2; Boyd and Slaymaker, 2000; KIT/Faida MaLi/IIRR, 2006). Boyd and Slaymaker (2000) indicate the lack of a direct correlation between the importance of agriculture and investments in SNRM; in certain locations and at certain stages in a developmental process, positive correlations are found, but negative correlations in other situations, e.g. where access to finances, knowledge and skills and/or pro-poor market access is not guaranteed (Section 1.2). This is also the case where natural resources are being degraded and depleted, in societies were livelihoods fully depend on ‘survival’ rather than ‘subsistence’ agriculture, i.e. in situations of severe poverty with high land pressure and recurrent shocks and stresses, such as in traditional systems with unfavourable conditions for alternative livelihood strategies, as in large parts of Ethiopia (Wijnhoud and Solomon Abate, 2004; Section 6.3). However, survival at the cost of resource degradation also happens in countries that are relatively much better off, most obvious when affected by unexpected shocks,
like Thailand during the economic crisis in the late 1990s (Chapter 3), less obvious when soils are gradually mined (Drechsel and Gyiele, 1999; Chapters 2–5). This means that the relation between the importance of agriculture and SNRM is affected by a large number of other factors, that may come to the fore through SLA that will quickly reveal that overall socio-economic development, including socio-political stability and sustainable economic growth, are key requirements for SNRM, although up to a certain degree conflicts about CPRs along gender, age and socio-ethnic lines may always exist (Nzamujo, 1999).

The institutional context and institutional development are essential for environmental entitlements in a rural context (Leach et al., 1999). In fact, the same may hold for accumulation of all capital assets and livelihood development in general, implying that sustainable pro-poor institutional development is essential to realize the twin-objectives of SNRM and improved and sustainable livelihoods. Although institutional development is increasingly considered in SLA, it has been one of the key missing aspects in many integrated rural development projects (IRDP) in the past, and still remains one of the most undervalued and neglected aspects in integrated R&D efforts. This may be due to a combination of limited understanding, outright resistance, in situations where vested interests exist to maintain the status quo, and/or fear for repercussions when touching on sensitive institutional issues with a highly political character. Therefore, multi-scale sustainable institutional development, directly relying on efforts aimed at good governance, remains among the most challenging requirements for successful R&D efforts. Concerted, multi-scale and integrated R&D agendas should be pursued. They should leave sufficient room for action learning, lobby and policy advocacy, such as for improved governance and institutional change with improved policies and strategies and their concerted implementation being inherent to the R&D agenda and its objectives.
References


References

International Board for Soil Research and Management, Bangkok, Thailand. 56 pp.
Buresh, R.J., Sanchez, P.A., Calhoun, F. (Eds.) (1997). Replenishing soil fertility in
References


References


EPDRF (2000). The second five years peace, democracy and development program and evaluation of the first five years program. Ethiopian People’s Revolutionary Democratic Front. Addis Ababa, Ethiopia. (in Amharic)


References


IDS, UK. (consulted 2001-2005).


References


References


SWNM, Bangkok, Thailand. 43 pp.


Satterthwaite, D., Tacoli, C. (2003). The urban part of rural development: The role of small and intermediate urban centers in rural and regional development and poverty
References

Sharma, P.K. (1993). In situ water conservation in sandy soil for rainfed lowland rice. 5th annual meeting Ubon Ratchathani Rice Research Center, Ubon Ratchathani, Thailand.
References

Ecosystems and Environment 71. 346 pp.
References


174
Regional and Local Development Studies (RLDS), UN-HABITAT and Addis Ababa University, Addis Ababa, Ethiopia. 111 pp.


References


Summary

In Northeast Thailand, the sustainability of rainfed lowland rice-based systems, the dominant land-use system (LUS) in the region, is a concern for livelihood development in this relatively poor area of the country. Poor soil fertility and low inputs are considered major causes of the sustainability problems. Similar problems exist for a wide range of LUS in the developing world. Reversal of such developments requires integrated rural development strategies aimed at breaking the environment-poverty downward spiral.

The key hypothesis for this thesis is, that efficient and effective rural-development strategies, aimed at the twin-objectives of sustainable natural resource management (SNRM) and improved and sustainable livelihood development, require ‘innovative’, i.e. more participatory, integrated and holistic approaches, while following a strict priority setting by combining holistic concepts and a small selected set of participatory, integrated and/or complementary analyses to keep efforts manageable and result-oriented. The challenge therefore, is to find the appropriate balance between on one hand the demand for more comprehensive contextual and integrated analyses and on the other hand the requirement to keep such efforts manageable in terms of human, material and financial resources. The key hypothesis was partly tested in a collaborative research and development (R&D) programme in Northeast Thailand. The R&D programme explicitly examined the relevance of integrated nutrient budget, soil fertility management and livelihood analyses. It serves as an exemplary and paradigmatic case for innovative approaches and contributes to the advocacy for their broad adoption.

As a back-up, based on literature study and later experiences, including work in sub-Saharan Africa, the introductory chapter elaborates relevant concepts, principles and approaches, such as the multiple dimensions of SNRM, the sustainable livelihood concept and approach (SLC/A) and nutrient balance analyses (NBA), that are useful for the work in Northeast Thailand, but also – often even more essential – for development strategies in the least developed countries (LDCs) of the world. Brief reference is made to other relevant aspects, including less tangible ones such as governance, decentralization, organizational and institutional development, and capacity development, that partly surface in the collaborative R&D programme in Northeast Thailand and are further discussed in the final chapter.

NBS-NET (nutrient balance studies in Northeast Thailand), a collaborative research and development (R&D) programme in Northeast Thailand, explicitly examined the relevance of integrated nutrient budget, soil fertility management and livelihood
analyses. It is concluded that partial nutrient balance analyses (PNBA) are useful for interdisciplinary and participatory R&D activities in Northeast Thailand, especially those primarily aimed at designing improved and sustainable nutrient and land management systems, and improved and sustainable livelihoods. Because of the relatively simple logic utilized, nutrient balance analyses are useful for training farmers and extension workers in appropriate nutrient management practices. In addition, NBA can serve as a template for economic accounting and financial assessment of nutrient depletion and surpluses.

One direct aim of NBS-NET was sustainability assessment of rainfed lowland rice-based systems. A first objective was the characterization of the dynamic resource management domain (DRMD), both with respect to general aspects and developments and with respect to bottlenecks and challenges for R&D aimed at sustainable natural resource management (SNRM), emphasizing soil fertility management, and improved livelihoods. A second set of core objectives related to assessment of some biophysical aspects of SNRM through multi-scale assessment and interpretation of partial nutrient balances. A third set of objectives dealt with the relation between farm performance, livelihood development and SNRM, which was investigated by studying the relationships between agricultural production, biophysical and socio-economic factors. A fourth objective was to investigate the possibilities for integrated environmental and socio-economic accounting, starting from nutrient management, partial nutrient balances and the valuation or costing of nutrients and partial nutrient balances. By drawing on this set of objectives and methods, a fifth objective was to identify and develop some of the basic elements of a decision support tool (DST), aimed at dynamic and site-specific decision support for improved soil fertility management, SNRM and improved and sustainable livelihoods.

The relevance and bottlenecks of participatory and integrated approaches to rural R&D are discussed in the framework of the NBS-NET methodology. R&D efforts are advocated that anticipate on and contribute to diverse options for economic diversification, agricultural innovation, SNRM and livelihood transitions and development. Data collection in the NBS-NET pilot and main surveys and data analyses are discussed. A relational database system (RDBS) was designed for data storage, data management and part of the data analyses. For the bulk of the analyses, a two-scale, or sometimes multi-scale approach has been followed, with analyses proceeding from lower to higher spatial scale, i.e. from land utilization type (LUT) to field, farm, (sub-)district and provincial level, respectively. Methodological aspects of PNBA are discussed, including a critical assessment of their interpretation. The nutrient balance study of the 30 farms, covered by the main survey, served as the basis for further, more integrated biophysical and socio-economic analyses. Analyses of
organic and inorganic nutrient inputs, partial nutrient budgets and relationships between on- and off-farm income, were followed by integrated environmental and socio-economic accounting at district, farm, field and LUT levels.

NBS-NET served as an exemplary and paradigmatic case, including prototyping elements, for innovative approaches to integrated rural development strategies and advocates their broad adoption in Northeast Thailand and developing countries in general.

Many of the bottlenecks that constrain rural research and development (R&D) can only be addressed through innovative approaches, particularly participatory and interdisciplinary activities within the context of dynamic resource management domains (DRMD). The degree of adoption of such innovative approaches and the detail in DRMD characterization, *i.e.* the contextual analysis, should be based on strict priority setting, considering existing information with a focus on the R&D objectives, available capacity (resources), easily available information, expected bottlenecks and the objectives of the overall R&D effort.

A broad DRMD characterization for Northeast Thailand took place, both with respect to general aspects and developments in the region and with respect to bottlenecks and challenges for R&D aimed at sustainable land management, emphasizing both soil fertility management and livelihood development in rainfed lowland rice-based DRMDs. Within the complex reality, attaining sustainable land management and improved livelihoods needs broader participatory and interdisciplinary efforts to break the vicious circle of unsustainability and resource degradation and to escape from the environment-poverty downward spiral that is due to interrelated unfavourable biophysical and socio-economic conditions and their associated constraints. Moreover, it requires partnership building, based on genuine multi-level and multi-stakeholder collaboration, a key requirement that is confronted with many challenges itself.

Nutrient balance analyses (NBA) are powerful tools for assessing some aspects of sustainability of the dominant LUS in Northeast Thailand. Partial nutrient balances are useful indicators for some critical components of sustainability and important for decision support on soil fertility management, when seriously considering the additional factors that are required for quantifying full nutrient balances.

A pilot study was carried out at 10 farms in one district of Ubon Ratchathani Province, Northeast Thailand. More comprehensive biophysical, socio-economic and management-related data on the farming systems were collected, down to the sub-farm level for 30 additional farms located in two sub-districts in the same province. The RDBS includes a utility to semi-automatically generate partial nutrient balances. Partial nutrient balances were assessed per land utilization type (LUTs), distinct
cropping system-management combinations at sub-farm level, and aggregated to the farm and sub-district levels.

Mean partial N, P and K farm balances for the rice-based systems of the 30 farms were 12, 8 and 7 kg ha\(^{-1}\) y\(^{-1}\), respectively, with very large variations among and within farms, especially at LUT level. Although mean values were positive, many negative partial balances were observed, especially at LUT level. The relatively high lower-scale variability in partial nutrient balances was about similar for the two sub-districts of the main survey and the district of the pilot-study. The results confirm the high inter-farm and intra-farm variability for partial N, P and K balances of preliminary studies and were re-confirmed in the analysis of a broader data set of 80 farms spread over six districts. Similar tendencies appear to exist in large parts of Ubon Ratchathani Province and in major parts of Northeast Thailand with similar LUS.

The large variations in partial nutrient balances are the result of the fact that farmers manage nutrients for similar parcels of land in very different ways, even for LUTs with identical cropping systems within the same farm. Recognition of biophysical variability, combined with constraints in financial and labour resources, is at the basis of this unequal resource allocation, and thus the variable management, between and within farms. A serious risk exists that short-distance variability is hidden as a result of inappropriate scaling up of data. Policy makers and other users will make far better use of data at broader scales, if they are supplemented by indications of the variability at lower scales. Results are discussed with specific emphasis on biophysical aspects, in line with a discussion on methodological aspects.

Partial NBA can be made useful for decision support, for both policy development and the development of a DST for farmers and extension workers aimed at participatory, dynamic and site-specific nutrient and land management.

In combination with socio-economic data, nutrient budgets can indicate factors that are important for sustainable management of soils and that can be used to develop improved recommendations, aimed at both biophysical and socio-economic aspects of sustainability. Multi-scale nutrient balance assessments were used in more integrated environmental and socio-economic analyses, which involved livelihood and correlation analyses, as well as integrated environmental and socio-economic accounting. In part, a two-scale approach was followed with outcomes of analyses and insights at the district level serving as input for analyses at the farm and field levels, and vice versa.

Diversification of income sources, through off-farm employment, non-agricultural on-farm income, such as weaving, and diversification of the agricultural system beyond rice, has a large impact on household wealth. This in turn, can affect the capacity of the household to manage the natural resources of the farm. For the 30 households included in the study, off-farm employment had the strongest impact on
household income (P < 0.001), in particular for higher income households. At the lower income-end, rice provided the main income, but in absolute terms rice provided significantly more at the higher income-end. No significant correlation was found between total income or non-rice income and nutrient inputs; however, this does not mean that they are unrelated. Additional information from farmers indicated strong, but opposing, relationships for different households. Where some households improved management of rice production with increased access to capital from non-rice activities, others did not or even reduced their efforts. No factors were identified to statistically separate these groups.

Based on fertilizer use and price, mean elemental N, P and K retail prices were calculated as 12.4, 60.0 and 13.1 THB (Thai baht; US$ 1 ≈ THB 42) kg\(^{-1}\), respectively. These values were used for integrated environmental and economic accounting to calculate partial N, P and K balances in monetary terms. The results followed the average positive partial balances for rice-based systems of 30 farms, with large variability among farms and, even more so among LUTs, however, for each nutrient to a degree depending on its price. Partial nutrient balances were most extreme for N and K. In contrast, in monetary terms P balances were most extreme. These analyses revealed that, due to the common use of N-P or N-P-K compound fertilizers, investments in P that is generally non-limiting and rather expensive, are too high. Although information on mean district balances can be useful for policy makers, fertilizer retailers and the fertilizer industry, improved nutrient application must rely on additional farm-level data. Outcomes at the farm level may be used for correction of on-farm fertilizer allocation, from both the agronomic and economic points of view.

Economic viability, one of the five pillars of sustainability, may be assessed for rainfed lowland rice cultivation on the basis of a set of cost-benefit related economic analyses. As an illustration of some of the complications that may arise with respect to data needs, some alternative (prototype) cost benefit analyses (CBA) have been carried out for rice cultivation in 1999 on one of the farms included in the main survey. Complementary and integrated biophysical and socio-economic analyses are relevant for decision support for SNRM and livelihood development, including the development of decision support tools for farmers and extension workers. The collaborative R&D programme served as an exemplary and paradigmatic case for innovative approaches and contributes to the advocacy for their broad adoption.

The final chapter starts with the synthesized conclusions of the first five chapters. Apart from the relevance of its direct outcomes for SNRM and livelihood development in the region itself, the collaborative research programme in Northeast Thailand yielded practical applications of prototype analysis methods, such as multi-scale
PNBA and integrated environmental and socio-economic accounting within a DRMD context. The programme set a paradigm for integrated development studies elsewhere, but recommendations are given for inclusion of additional aspects. These were based on a summary overview of missing links, broader perspectives, and issues that require additional attention, in the design of more successful integrated rural development strategies. The hiatus and issues are often relevant for both Asian ‘Tigers’, such as Thailand, and the least developed countries (LDCs) in the world, characterized by the biggest capacity and development gaps. Some of the aspects and broader considerations are highlighted as part of a summary overview of major challenges and opportunities for rural development in two of the least developed countries (LDCs) in sub-Saharan Africa, i.e. Ethiopia and Mozambique. Challenges and opportunities vary considerably between these two sub-Saharan African countries. Starting from a policy perspective for both countries, different requirements to overcome the different challenges are identified. Some concrete elements for innovative rural development strategies are discussed, most in particular for Mozambique. This is followed by a general discussion on rural development strategies and the integrated requirements of sustainable natural resource management (SNRM) and improved and sustainable livelihoods. It is advocated that SNRM can only be achieved by following a livelihood approach, including a strong emphasis on socio-economic incentives. In addition, major challenges are identified for multi-scale sustainable institutional development, which requires efforts aimed at good governance.
Samenvatting

In Noordoost Thailand is de duurzaamheid van de dominante, regenafhankelijke, op laaglandrijst gebaseerde landgebruikssystemen een zorg geworden met het oog op de bestaanszekerheid van de bevolking in dit relatief arme deel van het land. De belangrijkste oorzaken van de duurzaamheidsproblemen houden verband met de lage bodemvruchtbaarheid, gecombineerd met lage niveaus van externe inputs. Dergelijke problemen zijn kenmerkend voor veel landgebruikssystemen in ontwikkelingslanden. Oplossingen voor dit soort problemen vragen een aanpak gebaseerd op geïntegreerde strategieën voor plattelandsontwikkeling die de neerwaartse landdegradatie-armoede spiraal kunnen doorbreken.

De belangrijkste hypothese die aan dit proefschrift ten grondslag ligt is dat efficiënte en effectieve rurale ontwikkelingsstrategieën, gericht op het gelijktijdig verwezenlijken van twee doelstellingen, i.e. duurzaam beheer van natuurlijke hulpbronnen (DBNH) en duurzame bestaanszekerheid (DB), dienen uit te gaan van een innovatieve benadering, gebaseerd op participatieve, geïntegreerde en holistische methoden. Daarbij moeten strikte prioriteiten gesteld worden bij het combineren van holistische concepten en een beperkt aantal nauwkeurig geselecteerde participatieve, geïntegreerde en/of elkaar aanvullende analyses, met het oog op de beheersbaarheid en resultaatgerichtheid van de inspanningen. De uitdaging is daarom de juiste balans te vinden tussen aan de ene kant de behoefte aan meer uitgebreide contextuele en geïntegreerde analyses en aan de andere kant de eis om een dergelijke aanpak uitvoerbaar en beheersbaar te houden in termen van beschikbare personele, materiële en financiële middelen. De belangrijkste hypothese is deels getest binnen een in een samenwerkingsverband uitgevoerd onderzoeks- en ontwikkelingsprogramma in Noordoost Thailand (het O&O programma NBS-NET, Onderzoek naar nutriëntenbalansen in Noordoost Thailand). Binnen dit O&O programma is onderzoek gedaan naar de relevantie van een geïntegreerde analyse van nutriëntenbalansen, bodemvruchtbaarheidsbeheer en bestaanszekerheid. Binnen dit proefschrift dient het programma als een voorbeeld en paradigma voor de voorgestelde innovatieve benadering en draagt als zodanig bij aan de bevordering van die benadering ten behoeve van een brede invoering.

Ter ondersteuning worden in het inleidende hoofdstuk, op basis van literatuurstudie en meer recent eigen werk, inclusief activiteiten in Afrika ten zuiden van de Sahara, relevante concepten, principes en benaderingen uitgewerkt. Dit betreft de meervoudige dimensies van DBNH, het concept en de benadering van duurzame bestaanszekerheid (DBC/A), en analyses van nutriëntenbalansen (NBA), die relevant zijn voor het werk
in Noordoost Thailand, maar ook – en meestal zelfs in sterkere mate – voor ontwikkelingsstrategieën in de minst ontwikkelde landen (MOLs) van de wereld. Er wordt hier ook kort verwezen naar andere relevante aspecten, inclusief minder tastbare begrippen, zoals bestuur, decentralisatie, organisatorische en institutionele ontwikkeling en capaciteitsversterking, die deels ook naar voren komen in het gezamenlijke O&O programma in Noordoost Thailand en die verder worden behandeld in het laatste hoofdstuk.

Op grond van de resultaten van NBS-NET wordt geconcludeerd dat analyses van partiële nutriëntenbalansen (PNBAs) bruikbaar zijn binnen interdisciplinaire en participatieve O&O activiteiten in Noordoost Thailand, speciaal voor activiteiten die gericht zijn op het ontwikkelen van zowel verbeterde, duurzame nutriënten- en landbeheersystemen, alsmede verbeterde, duurzame bestaanszekerheden. Vanwege de relatief simpele logica die erin wordt toegepast, zijn (P)NBAs bruikbaar bij het trainen van boeren en voorlichters in aangepast nutriëntenbeheer. Daarnaast kunnen NBAs dienen als een breder kader voor economische berekeningen en voor financiële analyses met betrekking tot verliezen van en overschotten aan nutriënten.

Een directe doelstelling van NBS-NET was een beoordeling van de duurzaamheid van de regenafhankelijke, op laaglandrijst gebaseerde landgebruiksystemen. Een eerste doelstelling was het karakteriseren van het Dynamic Resource Management Domain (DRMD), zowel met betrekking tot de algemene kenmerken en ontwikkelingen, als met betrekking tot de knelpunten en uitdagingen voor O&O gericht op DBNH, met de nadruk op bodemvruchtbaarheidsbeheer en betere bestaanszekerheden. Een tweede groep doelstellingen had betrekking op de analyse van enkele biofysische aspecten van DBNH door middel van analyse en interpretatie van partiële nutriëntenbalansen op verschillende schaalniveaus. Een derde groep doelstellingen had betrekking op de relaties tussen de bedrijfsvoering en de bedrijfsresultaten, ontwikkeling van betere bestaanszekerheden en DBNH. Dit werd onderzocht via het bestuderen van de verbanden tussen landbouwproductie aan de ene kant en biofysische en sociaal-economische factoren aan de andere kant. Een vierde doelstelling was het doen van onderzoek naar de mogelijkheden voor ontwikkeling van een geïntegreerd milieu-kundig en sociaal-economisch boekhoudsysteem, te beginnen bij nutriëntenbeheer, partiële nutriëntenbalansen en de financiële waarde of de kosten van nutriënten. Afgeleid van deze doelstellingen en methoden, werd een vijfde doelstelling geformuleerd, *i.e.* het identifieren en ontwikkelen van basiselementen voor een beslissingsondersteunend systeem (BOS) ten behoeve van dynamische en lokatie-specifieke beslissingen voor verbeterd bodemvruchtbaarheidsbeheer, DBNH en grotere en duurzame bestaanszekerheid.

De relevantie en de beperkingen van participatieve en geïntegreerde benaderingen
voor ruraal O&O worden behandeld in het kader van de in NBS-NET gebruikte methodologie. Er wordt gepleit voor het gebruik van O&O activiteiten die anticiperen op en bijdragen aan het identificeren van verschillende opties voor economische verscheidenheid, innovaties op landbouwgebied, DBNH en overgangen naar alternatieve bronnen van levensonderhoud. Het verzamelen en analyseren van gegevens binnen de NBS-NET pilot- en hoofdstudies worden besproken. Er is een relationele databasesysteem (RDBS) ontworpen voor de opslag en het beheer van gegevens, alsmede ten behoeve van een deel van de analyses. Voor het merendeel van de analyses is een benadering gevolgd op twee ruimtelijke schaalniveaus, of soms op meervoudige schaalniveaus, in de volgorde van kleine naar grote schaal, *i.e.* startend van landgebruikstype (LGT) via perceel, bedrijf en (deel)district naar provinciaal niveau. Er wordt eveneens aandacht besteed aan methodologische aspecten van PNBA, inclusief een kritische analyse van de interpretatie van de uitkomsten. Een studie van de nutriëntenbalansen voor de 30 bedrijven die betrokken waren bij het hoofdonderzoek, diende eveneens als basis voor meer geïntegreerde biofysische en sociaal-economische analyses. Analyses met betrekking tot de aanvoer van nutriënten in organisch materiaal en kunstmest, partiële nutriëntenbalansen, en (cor)relaties tussen bedrijfs- en extern inkomen, werden gevolgd door geïntegreerde milieu- en sociaal-economische berekeningen op districts-, bedrijfs-, perceels- en LGT-niveau.

Op deze manier werden binnen NBS-NET prototype elementen ontwikkeld voor innovatieve benaderingen, die tevens dienen om het gebruik van dergelijke benaderingen in Noordoost Thailand en ontwikkelingslanden in het algemeen, te bevorderen.

Veel van de knelpunten bij ruraal O&O kunnen alleen worden opgeheven door innovatieve benaderingen, in het bijzonder participatieve en interdisciplinaire activiteiten binnen de context van DRMDs. De mate waarin dergelijke innovatieve benaderingen worden toegepast en de mate van detail waarmee een DRMD wordt gekarakteriseerd, *i.e.* het niveau van detail in de contextuele analyse, dient gebaseerd te zijn op een strikte prioriteitsstelling, waarbij rekening gehouden wordt met al bestaande informatie die van belang is voor realisatie van de O&O doelstellingen, de beschikbare middelen, informatie die eventueel makkelijk gegenereerd kan worden, verwachte knelpunten en de uiteindelijke doelstellingen van het O&O programma.

Een uitgebreide DRMD karakterisering van Noordoost Thailand is uitgevoerd, zowel met betrekking tot algemene aspecten en ontwikkelingen in deze regio, alsmede met betrekking tot knelpunten en uitdagingen voor O&O gericht op duurzaam landbeheer en met de nadruk op bodemvruchtbaarheidsbeheer en de ontwikkeling van verbeterde en duurzame bestaanszekerheden in de (vooralsnog) regenafhankelijke, op laaglandrijst gebaseerde DRMDs. Binnen de complexe realiteit van de regio vraagt het
Samenvatting
gelijkwijzig realiseren van de met elkaar samenhangende doelstellingen van duurzaam landbeheer en verbeterde en duurzame bestaanszekerheden, een bredere, participatieve en interdisciplinaire aanpak. Deze is nodig om de vicieuze cirkel van landdegradatie en armoede te doorbreken en te ontsnappen aan deze neerwaartse spiraal die veroorzaakt wordt door de met elkaar samenhangende ongunstige biofysische en sociaal-economische omstandigheden en de daarmee gepaard gaande belemmeringen. Bovendien vergt dit het aangaan van echte samenwerkingsverbanden tussen de verschillende belanghebbende partijen op verschillende niveaus, hetgeen op zichzelf al een grote uitdaging is.

NBAs zijn krachtige hulpmiddelen bij het analyseren van specifieke aspecten van de duurzaamheid van de dominante landgebruiksystemen in Noordoost Thailand. Partiële nutriëntenbalansen zijn bruikbare indicatoren voor enkele kritische duurzaamheidsaspecten en belangrijk bij het ondersteunen van beslissingen met betrekking tot bodemvuchtbaarheidsbeheer, waarbij het essentieel is dat factoren die van belang zijn voor kwantificering van volledige nutriëntenbalansen, serieus in de beschouwing betrokken worden.


Gemiddelde partiele N-, P- en K-bedrijfsbalansen voor de op rijst gebaseerde systemen van de 30 bedrijven waren respectievelijk 12, 8 and 7 kg ha\(^{-1}\) j\(^{-1}\), met zeer grote variatie tussen en binnen de bedrijven, in het bijzonder op het niveau van LGTs. Ondanks het feit dat de gemiddelde waarden voor de balansen voor alle drie macro-nutriënten positief waren, werden er veel negatieve waarden waargenomen, in het bijzonder op het niveau van de LGTs. De variabiliteit in partiele nutriëntenbalansen op het laagste schaalniveau was vrijwel gelijk in de twee deeldistricten van het hoofdonderzoek en in het district van de pilot studie. Deze resultaten bevestigen de grote variabiliteit in partiele N-, P- en K-balansen tussen en binnen bedrijven, zoals waargenomen in eerdere inleidende en minder gedetailleerde studies, en nogmaals herbevestigd in analyses van een uitgebreidere set gegevens van 80 bedrijven verspreid over zes districten in de provincie. Soortgelijke tendensen lijken daarom kenmerkend te zijn voor deze landgebruiksystemen in grote delen van Ubon
Ratchathani en Noordoost Thailand in het algemeen.

De grote variabiliteit in partiële nutriëntenbalansen is het resultaat van het feit dat het nutriëntenbeheer door de boeren zeer verschillend is voor gelijksoortige percelen, zelfs voor LGTs met identieke gewassystemen binnen hetzelfde bedrijf. Inzicht in de variatie in biofysische omstandigheden, in combinatie met beperkingen qua financiële middelen en beschikbare arbeid, liggen aan de basis van verschillen in allocatie van beschikbare middelen en daarom van verschillen in landbeheer, zowel tussen bedrijven als binnen een enkel bedrijf, met directe effecten op het nutriëntenbeheer. Er bestaat een wezenlijk risico dat variabiliteit over korte afstanden niet tot uiting komt indien gegevens op een onjuiste manier of onterecht worden geaggregeerd, gegeneraliseerd en/of geëxtrapoleerd, hetgeen tot onjuiste conclusies en onjuiste aanbevelingen zou kunnen leiden. Beleidsmakers en andere gebruikers zullen veel beter gebruik kunnen maken van gegeneraliseerde gegevens op een hoog schaalniveau indien tegelijkertijd indicaties gegeven worden met betrekking tot de variabiliteit op lagere, meer gedetailleerde schaalniveaus. De resultaten worden besproken met specifieke aandacht voor biofysische aspecten en in relatie tot de discussie over de methodologische aspecten.

PNBAs zijn nuttig ter ondersteuning van beleidsontwikkeling, alsmede voor de ontwikkeling van een BOS voor boeren en voorlichters ten behoeve van participatief, dynamisch en locatiespecifiek nutriënten- en landbeheer.

In combinatie met sociaal-economische gegevens, kunnen nutriëntenbalansen gebruikt worden voor het identificeren van voor duurzaam landbeheer belangrijke factoren. Deze factoren kunnen vervolgens gebruikt worden voor het formuleren van verbeterde aanbevelingen met betrekking tot zowel biofysische als sociaal-economische duurzaamheidsaspecten. De analyse van nutriëntenbalansen op meerdere schaalniveaus werd vervolgens gebruikt in toepassingen voor geïntegreerde milieukundige en sociaal-economische analyses, waaronder analyses met betrekking tot bestaanszekerheden en correlatieanalyses, en geïntegreerde milieukundige en sociaal-economische financiële analyses. Voor een deel werd een benadering op twee schaalniveaus gevolgd, waarbij de uitkomsten en inzichten op districtsniveau fungeren als input voor de analyses op bedrijfs- en perceelsniveau, en omgekeerd.

Diversificatie van inkomstenbronnen, via arbeid buiten de landbouwsector, niet-agrarische inkomsten gegenereerd op het bedrijf, bijvoorbeeld via weven, en diversificatie van het bedrijfssysteem door het introduceren van activiteiten buiten de rijstverbouw, heeft een grote invloed op de financiële positie van huishoudens. Deze beïnvloedt op zijn beurt de mogelijkheden van het huishouden met betrekking tot het beheer van de beschikbare natuurlijke hulpbronnen. Inkomsten van buiten het bedrijf droeg het meest bij aan het totale inkomen van de 30 huishoudens, in het bijzonder van
Samenvatting

dehuishoudens met de hogere inkomens. Rijst leverde de grootste bijdrage aan het totale inkomen van de huishoudens met de lagere inkomens, maar in absolute zin droeg rijst juist significant meer bij aan de hogere inkomens. Er werd geen significante correlatie gevonden tussen het totale inkomen of de niet van rijst afkomstige inkomsten en de externe nutriëntenaanvoer; dit betekent echter niet dat er geen relatie zou bestaan. Integendeel, aanvullende informatie vanuit de huishoudens wees op het bestaan van sterke, maar tegengestelde, relaties voor verschillende huishoudens. Waar sommige huishoudens bij toenemende inkomsten uit niet-rijst activiteiten rijstproductie intensificeerden, inclusief de toevoeging van nutriënten van buiten het bedrijf, gold dit niet voor andere huishoudens of ze bleken juist te extensiveren. Het bleek niet mogelijk factoren te identificeren op basis waarvan beide groepen statistisch zouden kunnen worden onderscheiden.

Op grond van gegevens betreffende het gebruik en de prijs van diverse typen kunstmest werden gemiddelde detailhandelsprijzen voor elementair N, P en K berekend: respectievelijk 12.4, 60.0 en 13.1 THB (Thai Baht; US$ 1 ≈ THB 42 in Oktober 2000) per kg. Deze waarden werden gebruikt voor geïntegreerde milieukundige en sociaal-economische financiële berekeningen, waarbij partiële N-, P- en K-balansen werden berekend in financiële termen. De resultaten zijn min of meer gelijk aan de gemiddeld positieve (fysieke) partiële nutriëntenbalansen voor de op rijst gebaseerde bedrijfssystemen op de 30 bedrijven, met grote variabiliteit tussen bedrijven en nog meer tussen LGTs, echter elementspecifiek, als bepaald door de verschillen in prijs. Fysieke partiële nutriëntenbalansen toonden de hoogste waarden voor N en K, maar in financiële termen voor P. Deze analyses toonden aan dat, als gevolg van het wijdverbreide gebruik van N-P en N-P-K mengmeststoffen, de investeringen in P, dat in het algemeen niet beperkend is voor de productie en nogal duur, veel te hoog zijn. Hoewel informatie over gemiddelde nutriëntenbalansen op districtsniveau bruikbaar kan zijn voor beleidsmakers, kunstmesthandelaren en de kunstmestindustrie, zijn aanvullende gegevens op bedrijfsniveau nodig om te komen tot een verbeterd bodemvruchtbaarheidsbeheer. Uitkomsten van analyses op bedrijfsniveau kunnen worden gebruikt voor het formuleren van bemestingsadviezen, zowel vanuit een agronomisch als economisch perspectief.

Economische levensvatbaarheid is één van de vijf duurzaamheidszuilen, en kan voor regenafhankelijke, op laaglandrijst gebaseerde landgebruiks- systemen worden beoordeeld op basis van kosten-baten analyses. Ter illustratie van de moeilijkheden die zich hierbij kunnen voordoen worden een aantal (prototype) analyses gepresenteerd voor rijstverbouw in 1999 op één van de bedrijven uit het hoofdonderzoek. Aanvullende, geïntegreerde biofysische en sociaal-economische analyses zijn relevant ter ondersteuning van beslissingen met betrekking tot DBNH en de ontwikkeling van
Samenvatting

betere bestaanszekerheden, alsmede voor ontwikkeling van een BOS voor boeren en voorlichters. Het gezamenlijke O&O programma dient als voorbeeld voor het ontwikkelen van innovatieve benaderingen en helpt bij het bevorderen van een brede invoering van dergelijke benaderingen.

Het laatste hoofdstuk begint met de conclusies die kunnen worden getrokken naar aanleiding van de eerste vijf hoofdstukken. De directe uitkomsten zijn van belang voor DBNH en voor de ontwikkeling van betere bestaanszekerheden in de regio. Het gezamenlijke O&O programma in Noordoost Thailand leverde daarnaast een aantal praktische toepassingen en prototype analysemethoden op, zoals PNBA op verschillende schaalniveaus en geïntegreerde milieu- en sociaal-economische berekeningswijzen binnen de context van een DRMD. Het programma dient als voorbeeld voor geïntegreerde ontwikkelingsstudies elders, maar er worden aanbevelingen gedaan voor uitbreiding met aanvullende aspecten. Er wordt daarom verder ingegaan op ontbrekende schakels en bredere perspectieven, in eerste instantie door middel van een samenvattend overzicht van aanvullende aandachtspunten bij het ontwerpen van succesvolle geïntegreerde ontwikkelingsstrategieën. De ontbrekende schakels en aandachtspunten zijn vrijwel allemaal van belang voor Aziatische ‘Tijgers’, zoals Thailand, maar ook voor de MOLs van de wereld die worden gekenmerkt door de grootste capaciteitsproblemen en ontwikkelingsachterstanden. Een aantal van die aandachtspunten wordt aan de orde gesteld aan de hand van een overzicht van de belangrijkste uitdagingen en mogelijkheden voor rurale ontwikkeling in twee MOLs in Afrika ten zuiden van de Sahara, Ethiopië en Mozambique. De uitdagingen en mogelijkheden verschillen nogal tussen deze twee landen. Met voor beide landen een beleidsperspectief als ingang, worden voor beide landen verschillende vereisten en behoeften vastgesteld voor het aangaan van de bestaande uitdagingen. Eveneens worden nieuwe bruikbare elementen voor het ontwikkelen van innovatieve rurale ontwikkelingsstrategieën bediscussieerd, in het bijzonder voor Mozambique. Dit wordt gevolgd door een algemene discussie over rurale ontwikkelingsstrategieën en de geïntegreerde vereisten voor DBNH in samenhang met verbeterde en duurzame bestaanszekerheden. Er wordt gesteld dat DBNH alleen kan worden verwezenlijkt indien gebruik wordt gemaakt van een benadering gebaseerd op analyse van de bestaanszekerheden (‘livelihood approach’), met een sterke nadruk op het belang van sociaal-economische drijfveren. Tot slot worden de belangrijkste uitdagingen geïdentificeerd voor de benodigde duurzame institutionele ontwikkeling op verschillende niveaus, waarvoor inspanningen gericht op goed bestuur essentieel zijn.
List of selected papers of the author

Papers / monographs:


* Original title; the title that appears in the final Compendium is not correct.


Reports / Documents:


Wijnhoud, J.D. (ed.) (1997). INIA-DTA manual of methods and procedures for physical and chemical laboratory analysis; presentation and interpretation of laboratory analyses. Série Terra e Água Comunicação 89, INIA-DTA, Maputo, Mozambique. (Portuguese)


Significant (acknowledged) contributions to the following books:

http://www.kit.nl/frameset.asp?/development/html/publications.asp&frnr=1&

MSc theses:


PE&RC PhD Education Statement Form

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 22 credits (= 32 ECTS = 22 weeks of activities)

Review of Literature (4 credits)
- Nutrient balance studies and livelihood development (PE&RC 2001)
- Comprehensive literature study (1999-2006)

Writing of Project Proposal (5 credits)
- NBS-NET (IBSRAM project) proposal (1999)
- Related PhD proposals (summary overview of provisional thesis contents) (PE&RC 2001)

Post-Graduate Courses (5 credits)
- Capacity development / organizational & institutional development (SNV/KIT 2002)
- Enabling rural innovation: participatory diagnosis, market research, farmer part. research (CIAT 2006)
- Chain empowerment (write shop KIT/IIRR 2005)

Deficiency, Refresh, Brush-up and General Courses (4 credits)
- GIS and relational database systems (ITC-Enschede 1999)
- Proposal writing (IBSRAM 2000)
- Gender auditing. Gender and development (SNV 2003)
- Many small courses like project management, GIS (DGIS/IBSRAM/SNV 1996-2006) and subject courses like advocacy, action learning, food security, leadership (BBO/SNV/CRDA 2002-2004)

PhD Discussion Groups (4 credits)
- Various sessions, presentation at PE&RC (2001, 2007)
- Participation in a number of international internet D-groups (e.g. CGIAR-Market Africa 2003-2006)
- Participation in a wide range of seminars/discussion days etc. (1999-2006)

PE&RC Annual Meetings, Seminars and Introduction Days (1 credit)
- Outside PE&RC like IBSRAM, SNV, CRDA-Ethiopia: internal programme review & development, annual meetings seminars etc. (1999-2006)

International Symposia, Workshops and Conferences (6 credits)
- Conference on paddy soil fertility (Manila, Philippines) (IUSS/BSWM 2000)
- Balanced nutrient management systems (Cotonou, Benin) (KUL/IITA 2000)
- Management of acid soils in the tropics (Bogor, Indonesia) (IBSRAM/CSAR 2000)
- Nutrient balances for sustainable agriculture production (Bangkok, Thailand) (IBSRAM/DOA 2001)
- Breaking the cycle of recurrent famine in Ethiopia (Addis Ababa, Ethiopia) (CRDA/CA 2003)
- Towards MDG localisation in Africa: Options and experiences (Kampala, Uganda) (SNV/UNDP/MDP 2005)

Laboratory Training and Working Visits (2 credits)
- Laboratory work: soil analyses (INIA-DTA (now IIAM))/ Mozambique (1996-1998)
- Several laboratory work related publications (INIA-DTA (now IIAM))/ Mozambique (1997-1998)
Curriculum vitae

Jan Derk (Danny) Wijnhoud was born on the 10th of July, 1969 in the village of Hattemerbroek, Oldebroek municipality, The Netherlands. Around his seventh birthday, he moved to the neighbouring small town of Hattem where he continued his primary education at the Van Heemstra School. He attended high school (Athenaeum) at the Carolus Clusius College in Zwolle where he graduated in 1988. In 1994, he graduated from the University of Utrecht (Faculty of Geographical Sciences) with an MSc (with honours) in Physical Geography with majors in Tropical Land Evaluation and Soil & Water Conservation. As part of his MSc programme he did field research in Botswana (7 months), Burkina Faso (6 months) and France (2 months). His major thesis dealt with soil mapping and land evaluation in North Kgalagadi sub-District of Botswana. Under supervision of Wageningen Agricultural University (WAU), he wrote two minor theses, on soil and water conservation in the Kaya area of Burkina Faso, and the application of a quantified land evaluation model to land-use systems in Burkina Faso, respectively.

In January 1995, he started his compulsory military service within the ROAG Programme (Programme for Reserve Officers with Academic Education), during which he was detached as a Research Fellow to the Remote Sensing Group at the Physical and Electronic Laboratory of TNO (TNO-FEL) in The Hague, The Netherlands.

In the period January 1996 till September 2001, he worked in several positions on contract with The Netherlands Directorate-General for International Co-operation (DGIS) of The Netherlands Ministry of Foreign Affairs. First, for roughly 2.5 years in Mozambique as an Associate Expert in Soil Survey and Land Evaluation within the Dutch Bilateral ‘Institutional Support for Land Resources Inventory and Assessment Project’ (ISLARIAP) at the Land and Water Department (DTA) of the National Agricultural Research Institute (INIA) in Maputo. From November 1998 till March 2001, he was detached as an Associate Expert in Sustainable Land-Use Planning to the International Board for Soil Research and Management (IBSRAM), based in Bangkok, Thailand. He was the IBSRAM coordinator for the ‘Nutrient Balance Studies in Northeast Thailand (NBS-NET)’ programme in Ubon Ratchathani Province, a collaborative R&D programme with Ubon Ratchathani Rice Research Centre (URRC) under the Thai Department of Agriculture (DOA). Based on the potential for the NBS-NET outcomes to be incorporated in a PhD thesis, still on a DGIS contract, he subsequently spent 5.5 months as a Guest Scientist at the Plant Production Systems (PPS) Group, Department of Plant Sciences (DPW) of Wageningen University and
Research centre (WUR). During this period he elaborated the core chapters of his PhD thesis.

From March 2002 onwards he started working as a capacity development advisor with The Netherlands Development Organization (SNV). First, he was based in, respectively, Dire Dawa and Addis Ababa in Ethiopia from where he worked as an advisor for Natural Resource Management and Alternative Livelihood Strategies with a wide range of organizations on local and national assignments. Subsequently, from January 2005 onwards, he has been working from Beira in Mozambique as a Local Economic Development advisor. So far, the majority of his assignments were with local governments and producer associations in Central Mozambique. Part of his last experiences and new knowledge obtained in sub-Saharan Africa proved to be useful for the finalization of his PhD thesis.