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Heidhues · Herrmann · Neef · Neidhart
Pape · Sruamsiri · Thu · Valle Zárate (Eds.)

Sustainable Land Use in Mountainous Regions of Southeast Asia

Meeting the Challenges of Ecological, Socio-Economic and Cultural Diversity

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D. C. Thu, A. Valle Zárate
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Meeting the Challenges of Ecological, Socio-Economic and Cultural Diversity

With 78 Figures

Springer

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Preface

Mountainous regions are vitally important ecosystems. They are an important storage of fresh water and energy, a rich source of biodiversity and a significant provider of food for the people living there. They are ecologically highly variable, complex and vulnerable and ethnically, socio-culturally and economically extremely heterogeneous. At the same time they are under severe and increasing pressures caused by higher population growth, inmigration, resource exploitation and rising demands and expectations. They also account for a major share of poverty and food insecurity in rural areas.

Given their importance, complexity and vulnerability mountainous regions pose a demanding and new challenge for agricultural research, particularly for research that is addressing environmental sustainability, poverty and food insecurity.

The University of Hohenheim's long-term research program "Sustainable Land Use and Rural Development in Mountainous Regions of Southeast Asia" (Sonderforschungsbereich (SFB) 564 der Deutschen Forschungsgemeinschaft, also known as "The Uplands Program") is taking on that challenge. It is an integrated interdisciplinary research program where sustainable innovations for agricultural production systems, combining fruit trees, crops, livestock and aquacultural production in their interaction with soil, water and agrochemical use are analysed, as well as their impact on landscape diversity and population dynamics of pests and beneficial insects. Further along the value added chain of agricultural production, potentials of product conservation, processing and marketing are studied. Land use and innovation acceptance by farmers are determined by their economic profitability within the farming system and by the institutional and policy framework that shapes the range of options farmers have. A decisive factor in the design and successful acceptance of innovations is the integration of local knowledge, brought into the process by adopting participatory research approaches across the entire research program.

The book is organized into seven chapters. The introduction discusses the rationale and concept of the long-term research program and its key concerns: sustainability, participation and interdisciplinary. Chapter 2, **Sustainable Research Management in the Highlands,** presents the findings of research on soil-water interactions, agrochemical flows and the impact of land use and land management on biodiversity. Chapter 3, **Sustainable Fruit Production and Processing Systems** addresses issues of stabilizing fruit production through plant nutrition and flower inducing techniques, water saving irrigation and fertigation technologies and control of post harvest ripening processes and their implications for fruit processing. **Livestock Production**, discussed in Chapter 4, is often a central part of farmers' activities in the uplands. Its contribution to sustainable mountain farming, efficiency constraints and potentials of livestock production systems, their local genetic resource base and diversity as well as parasitic pressures are presented in this chapter.

Chapter 5, **Farm Economics and Marketing Dynamics in Support of Sustainability,** summarizes research on the economics and sustainability of mountain farming systems using different research approaches. Economic viability of innovations is heavily influenced by market potential, stability and market integration studied for specific markets in Thailand.

The **Institutional Framework for Sustainable Land Use** is addressed in Chapter 6, focusing on participatory research and technology development, rural financial markets, land and water tenure and management studies and on an analysis of the political structure and its relations to local networks. Chapter 7 summarizes key aspects of the research and presents first conclusions.

In presenting first results of The Uplands Program research the editors hope to encourage further scientific work on the challenging issues of sustainable land use systems and rural development in mountainous regions, and to trigger feedback from scholars, extensionists and development practioners with an interest in Southeast Asia that can improve efficiency and impact of The Uplands Program.

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1.0 Introduction

1 Introduction

Sustainable Land Use and Sustainable Rural Livelihoods in Mountainous Regions of Southeast Asia – Meeting the Challenges of Ecological, Socio-Economic and Cultural Diversity

Franz Heidhues and Jens Pape

The Setting: Mountainous Regions under Pressure

High population growth, resettlement programs and migration have increased the pressure on the fragile natural resources in many marginal mountainous areas in Southeast Asia. As a result, we observe vicious circles of natural resource degradation of a distinctly different nature: in the more subsistence oriented areas as they can be found in the remote areas of northern Vietnam (one location of The Uplands Program) farmers react to increasing pressure by shortening fallow periods and cultivating steep hillsides resulting in erosion, loss of soil fertility and leading to decreasing agricultural productivity.

In regions that are already closer linked to markets, such as many mountainous areas in northern Thailand (the second research location of The Uplands Program), farmers try to maintain agricultural productivity by intensifying land use, employing increasing amounts of fertilizer and pesticides, often resulting in a loss of biodiversity and contamination of water resources.

These processes often take on self-accelerating speed and result in a downward spiral of poverty, unemployment and food insecurity particularly in regions that are ecologically fragile and economically and socio-culturally extremely heterogeneous and where complex interactions between determining factors, causes and effects dominate. Ethnic diversity with politically, economically and socially marginalized minorities is an additional characteristic of these regions. At the same time, we observe that the urban centers with dynamic trade and manufacturing sectors develop dynamically, thus increasing the gap in living conditions between rural and urban areas. A more detailed description of the research locations in northern Thailand and northern Vietnam is provided at the end of this chapter.

Objectives of Research

For this setting, research under the special research program 564 (Sonderforschungsbereich (SFB) 564) - also called “The Uplands Program” - aims at creating the scientific base for

1. the development and testing of sustainable production and land use systems with increased productivity in ecologically fragile and economically disadvantaged and socio-culturally complex mountainous regions in Southeast Asia;
2. the development of concepts for rural institutions that can contribute to a sustainable reduction of rural poverty, food insecurity and to an improvement of livelihoods in mountainous regions in Southeast Asia; and
3. advancing methods for analyzing complex eco-systems and their interactions with the socio-cultural, economic and institutional environment.

With these objectives in mind, the concept of The Uplands Program is based on the hypotheses that

- scientific research can decisively contribute to conserving natural resources and biodiversity in production systems in the mountainous regions and can, at the same time, provide effective tools to raise productivity and efficiency in the use of natural resources;
- to attain sustainable improvements, research needs to include and work with farmers and all stakeholders concerned with natural resource use;
- innovations will only have a chance to be accepted by farmers on a wide scale if they are addressing their needs and are economically advantageous, well integrated into the existing farm household systems and provide adequate incentives to be accepted within the institutional and political framework.

Basic Concepts of the Uplands Research

With these objectives and fundamental hypotheses of The Uplands Program the concept of **sustainability** moves into centre stage. It is the 'leitmotiv' of all research work of The Uplands Program. Thus the creation of knowledge that leads to sustainable innovations guides the uplands research in the natural science, economic and socio-cultural fields.

The term sustainability has a colorful history and is now a widely used term with different meanings in economic, social and environmental policy discussions. Sustainability of economic growth was first challenged by MEADOWS (1972) in his book 'The Limits of Growth'. He pointed out that unrestricted economic growth could not be sustainable given the serious ecological constraints imposed by a limited amount of natural resources and enormous social problems caused by inequities in economic development.

The conflicts between ecological, economic and social sustainability have continued to dominate scientific and socio-political discussions until today. The intergenerational dimension of sustainability was added in the work of the Brundtland Commission which then provided a widely accepted definition of the concept of sustainability in stating:

"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" *(WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT, 1989).*

The UN Conference on Environment and Development in Rio de Janeiro in June 1992, in its Agenda 21, 'Sustainable Development', focused in article 14 on *sustainable agriculture and rural development.* It emphasized that the following program areas had to be integrated into a sustainability concept for agriculture and rural development: agricultural policy review; people's participation and human resource development; diversification of farm and non-farm employment; land resource planning; land conservation and rehabilitation; water for sustainable food production and rural development; conservation and sustainable utilization of plant and animal genetic resources.

Also the Consultative Group for International Agricultural Research (CGIAR) focused on sustainable agriculture and defined it as:

"the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources" (TAC/CGIAR, 1989).

This definition considers the ecological, economic and social dimension of sustainability and addresses at the same time the dynamics of human needs. In many agricultural research programs, the emphasis is now placed firmly on the conservation of natural resources in land use systems and production processes. These ecological aspects of sustainability in the long term can only be achieved if at the same time such use of natural resources is economical for the users and socially acceptable to all stakeholders involved. In other words, sustainability of land use requires the integration of three aspects of sustainability: ecological, economic and social sustainability.

Figure 1.1 illustrates the comprehensive sustainability concept in the shaded area where the three components of sustainability overlap. The objective is to enlarge the overlapped (shaded) area through research and innovation development in all three areas and to focus on those processes that move the three components of sustainability into the direction of maximal overlaps.

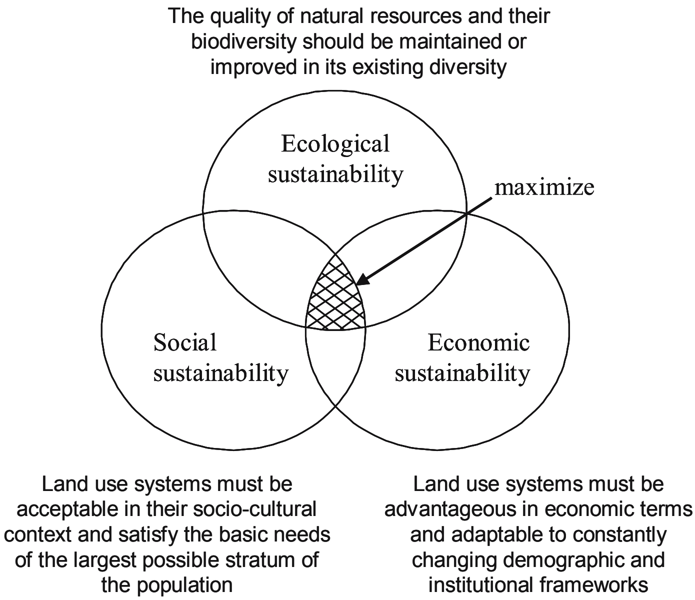

Figure 1.1: Components of land use sustainability.

The potential of agricultural research for improving *land use sustainability* lies especially in two areas: first, to *identify through research determining factors of sustainability.* This incorporates both the natural science and socioeconomic-institutional contexts. The second fundamental contribution of agricultural research is in *producing know-how for developing technological and institutional innovations that can bring about an increase in the efficiency of resource use and thus improve sustainability.* Over and above this, The Uplands Program provides a third important contribution to the sustainability question in that it integrates the local population and their knowledge into the research process and simultaneously tries to ascertain the potential, constraints, costs and usefulness of participatory research.

A sustainability-oriented research program is directed towards the most efficient use of scarce resources (land, water, trees, capital). An analysis of the specific problem situation in Thailand and Vietnam shows the ranking order of scarce resources, which is presented in simplified form in Table 1. In northern Thailand, above all, water availability, in addition to land, has become a pressing problem in recent years in many watershed regions, hindering an increase in agricultural production. In market-oriented regions, in contrast, labor and capital are not especially scarce resources.

Therefore, technological improvements in the agricultural sector in northern Thailand must work, above all, towards increasing efficiency in the application of the production factors “water” and “land”. Improved fruit production with a reduced application of agro-chemicals, stabilized by erosion-diminishing cover crops and water-saving irrigation systems can best meet these requirements.

Table 1.1: Ranking order of scarce resources in northern Thailand and Vietnam (simplified).

	Rank 1	Rank 2	Rank 3	Rank 4
northern Thailand	land	water	labor	capital
northern Vietnam	land	capital	water	labor

In northern Vietnam, land is by far the scarcest resource compared to other factors. Secondly, small farms lack capital. Water availability throughout the year is only limited in some regions and, in general, labor is available. Consequently, technological improvements in northern Vietnam must concentrate on integrated production systems with nutrient cycles that utilize land optimally and call for low levels of capital and external inputs. As long as the mountainous regions in northern Vietnam are still less accessible and farmers continue to produce their products mainly for subsistence and local markets, high priority is to be given to livestock, which supports subsistence, is marketed locally and which can contribute to improving the soil nutrient situation by providing organic fertilizers.

Simultaneously, from a longer-term perspective, conditions for opening up the market economy and for creating a stronger connection to economic centers are to be investigated. Also water constraints in quantity and quality may become increasingly relevant. In this context, the experiences of Thailand are especially useful. The future development of the agricultural sector in Southeast Asia is likely to be driven by dynamic economic developments in urban centers bringing about an increase in the demand for high-value agricultural products, like fruits and livestock products. In the mountainous regions of northern Thailand and Vietnam, such high-value agricultural products, with higher productivity in terms of land and labor, will have the best chance of competing with opium production and ensuring food security for farm families, even on small farms, by providing adequate agricultural incomes.

Both development reality and research findings have shown that the agricultural sector alone in a dynamic national economy with high population growth is no longer able to satisfy the needs of an ever growing rural population and secure rural incomes in the long term. Sustainable agricultural development can only be ensured if non-farm employment opportunities and incomes are generated in rural areas. Agriculture can be an important base for off-farm employment development. Methods are to be found for processing raw agricultural products into high-value products using simple processes in order to retain the highest possible value added in the regions and to generate income alternatives for the agricultural labor force.

Like 'sustainability', the concept of '**participation**' has also moved to the centre of both development policy discussions and scientific discourses in international agricultural research. Participatory approaches in development policy and in agricultural extension are well established and their importance for sustainable innovation acceptance is undisputed. However, the usefulness of participatory approaches in agricultural research is still controversial. From the policy point of view, participatory approaches in development-oriented international agricultural research are increasingly gaining support. In the science community, however, considerable caution is expressed regarding the use of participatory approaches in agricultural research, which is predominantly geared towards the interests and priorities of farmers.

The SFB 564 pays special attention to participatory approaches. It addresses 'participatory approaches' as a research subject. The advantages and limitations of participatory approaches are investigated independently of scientific discipline, research topic and research phase. At the same time, the participatory research activities are set up to support other sub-projects in applying participatory methods. The participatory research sub-project is intended to initiate a common reflection on the comparative advantages and disadvantages of participatory approaches in other sub-projects. As there are costs involved in participatory research, the goal is optimization of participatory research, not maximization in the respective research contexts. In order to achieve optimization of participation, a new analytical framework was developed. This framework consists of various ‘dimensions’ each characterized by ‘attributes’ that enable a differentiated assessment of the integration of participatory elements in agricultural research projects.

By applying participatory approaches, a continuing process of combining scientific and farmers’ knowledge is ensured. The integration of the priorities of farmers, local scientists and experts was investigated in Thailand and Vietnam using different approaches; the results are discussed below.

Interdisciplinarity is a key feature for integrating the components of sustainability into a comprehensive sustainability concept. It is also a precondition for all special research programs (SFBs) funded by DFG. Interdisciplinary research helps to assess complex situations and can contribute to solving complex problems. Soil, water, vegetation, animals, marketing and other factors of agriculture and rural development are closely linked with each other and should not be regarded as single factors. Several scientific disciplines need each other in order to find solutions for sustainable development. Besides the scientific necessity there are synergies of interdisciplinary research: researchers can work at the same research sites and share resources. The projects can support each other and learn from each other.

However, interdisciplinary research has costs: it raises the demands on researchers` time and efforts to understand the “other” discipline. While interdisciplinarity may be beneficial for the whole research program, it may not be attractive for a single researcher. The publication of interdisciplinary research results might be problematic as few scientific journals give space for broad discussions of problems; most are still specialized and discipline oriented and do not accept papers leaving the narrow boundaries of a journal's subject. Other constraints may originate in personal chemistry and relationship.

The interdisciplinarity in The Uplands Program covers different disciplines within the agricultural sciences, food technology and economic and social sciences. It thus includes key disciplines relevant for sustainability research in rural areas.

This book records and discusses the results of research carried out within the SFB 564. It has addressed questions and issues of all three dimensions of the sustainability concept outlined above. Thus, it covers research on the ecology and sustainable management of fruit production and fruit processing systems in northern Thailand and on local livestock production systems in northern Vietnam, and it addresses market dynamics and farm economics issues and issues of the rural institutional framework for sustainable land use.

Research Areas

Pang Ma Pha

The District of Pang Ma Pha covers a total area of 443 km^2. The mountainous landscape is characterized by limestone, sandstone and volcanic rocks. The altitude ranges from 300 to 1,900 meter above sea level (masl). The area is mainly covered with mixed deciduous forest and only small patches of dry evergreen forest. The average temperature ranges from 20-28°C and the annual rainfall averages 1,300 mm. The eastern and southern parts of the district belong to the Pai Wildlife Sanctuary and the western parts to the San Pan Daen Wildlife Sanctuary.

The total population of the district is 15,382 (2003) in 38 villages and comprises diverse ethnic groups. Black and Red Lahu (majority), Lisu, Karen, Hmong and Lawa live in the upland areas, while the mountain valleys are populated by Shan and Thai. Most upland farmers still practice swidden cultivation mainly for subsistence. Major crops grown are upland rice, corn and chilli. Cash crops are produced on a minor scale and include red kidney beans, garlic, mango and other fruit trees. The main cash income is derived from raising cattle, buffaloes and pigs.

The main focus of The Uplands Program's research is on the villages Bor Krai and Jabo (both Black Lahu), Mae Lana (Shan) and Muang Phaem (Karen)

Mae Sa Watershed

The Mae Sa watershed covers an area of 142.2 km² and extends from 20 to 45 kilometers northwest of Chiang Mai, in Mae Rim district, Chiang Mai province. Major parts of the watershed are included in the Doi Suthep Pui National Park. It covers the three subdistricts (Tambon) Mae Sa, Pong Yang and Mae Ram. The main stream, the Mae Sa, has a length of 24 kilometers, with about 20 creeks as tributaries. The watershed is an upland area with mountainous terrain and altitudes ranging from 300 to 1400 masl. Precipitation differs in the watershed among locations and years; the average rainfall is at 1,160 mm, with about 85% concentrated in the rainy season.

The watershed is inhabited by 15,426 people (2003) with 52% belonging to the ethnic minority group of the Hmong and 48% being northern Thais. In the past people grew predominantly rice, corn, and poppy for opium production. Since the prohibition of opium production in the late 1950s the Thai government – with support of international donors and the Royal Project Foundation – has put an enormous effort into replacing poppy by other crops under a range of opium substitution programs. Today, farmers in the area cultivate a variety of cash crops, such as vegetables like sweet pepper, eggplant and cabbage, cut flowers and fruits (mainly litchi).

Son La Province

Son La is a mountainous province in the Northwest of Vietnam. It borders Lao Cai Province and Yen Bai Province to the north, Phu Tho and Hoa Binh Provinces to the east, Lai Chau Province to the west and Thanh Hoa Province and Laos to the south.

The area of Son La province covers 14.055 km² and has a population of about 942.000 people (2002), consisting of 12 ethnic groups, including Thai (54%), Kinh (Vietnamese, 18%), H'Mong

(12%), Muong (8.4%), Dao (2.5%) and others (5.1%). The average population density is 67 persons per km². The number of total working people is 430,000, of which 85% live in rural areas.

Son La Province consists of 10 districts of which Son La town and Yen Chau are the main research areas of The Uplands Program. Son La town is the provincial center, which is 320 km away from Hanoi capital and connected through highway no. 6.

Son La Province is characterized by two large plateaus: Moc Chau and Na San. Moc Chau plateau in the average height of 1,050 masl, with tropical climate, average temperatures of 18°C and fertile soil has good conditions for developing industrial crops, such as tea and fruit trees and raising livestock. Na San plateau with an average height of 800 masl with fertile soil is suitable for industrial plants such as sugar cane, coffee and mulberries and fruit trees (mango, longan, pineapple, banana and litchi).

Son La's climate can be divided into two main seasons, a dry season (November-April) and a rainy season (May-October). The yearly average temperature is 21.4°C, with 27°C in the hottest and 16°C in the coldest month. It receives a yearly average rainfall of 1200-1600mm. The average humidity is 81%. Lime- and sandstone cover volcanic stones giving the basis for mainly ferralitic soils. Two main rivers, Da and Ma, collect the water of 35 major and hundreds of small streams running on the sloping terrain with many waterfalls. Intensive agricultural use of the fertile alluvial soils is found in the river basins, especially for paddy rice.

Agriculture and forestry are the main economic sectors, followed by trade and services. The industry and construction sector is small. Through the extension of agricultural land, the slopes have largely been cleaned from deciduous forest through slash-and-burn agriculture and are now often used for the cultivation of maize.

This volume presents research results of The Uplands Program`s first three-year phase. It is structured as follows: Chapter 2 analyzes constraints to sustainable use of soil and water resources in the highlands of northern Thailand. In chapter 3 research in fruit production and processing, food quality and environmental concerns is presented. Chapter 4 discusses livestock's present contribution and future potential for the sustainable development of mountainous farming systems in northern Vietnam. Chapter 5 addresses the economic constraints, influencing factors and future potential of rural households in their use of natural resources in mountainous regions of northern Thailand and northern Vietnam. Chapter 6 investigates institutional constraints hindering sustainable development in the mountainous regions of the two study countries. Conclusions and an outlook to further research are presented in the final chapter 7.

2.0 Sustainable Resource Management in the Highlands

2.1 Introduction

Mattiga Panomtaranichagul and Ludger Herrmann

Approximately 80 % of the land surface area in northern Southeast Asia (Thailand, Laos, Vietnam, Myanmar, Cambodia, South China) is covered by mountainous and hilly highlands, with relatively long valley and inter-mountain depressions. These countries have a monsoon climate with high rainfall during the rainy season which can vary by several hundred millimetres from year to year. These highlands (with altitudes of > 500 m, and slope gradients of <20 to >100 %) are inhabited by more than 2 million hill-tribe people mostly from ethnic minorities. Population growth has put increasing pressure on the *natural resources* (soil, water, biodiversity). Consequently, environmental and political problems have emerged which are as yet unresolved. With respect to the environment, deforestation and agricultural intensification have led to overuse and deterioration of soil and water resources and a decline in biodiversity. In addition, the application of inappropriate land and water rights, insufficient technical knowledge and inadequate technology transfer have all resulted in inefficient management of natural resources.

Evergreen and deciduous forests are the natural vegetation in the highlands. Under these original conditions the highland sites have a high capacity for absorbing and storing rainfall, and regulating stream-flow (RUNGROJWANICH et al., 1998). But deforestation and the establishment of permanent agricultural land has profoundly affected the natural balance of the hydrological system by reducing the natural buffering capacity of the forest. Furthermore, removal of forest and land covers by slash and burn or swidden may cause a significant increase in bulk density and a decrease in infiltration capacity, hydraulic conductivity, and aeration porosity of the soil. Consequently, surface run-off is increased leading to higher peaks in surface water flow and flooding.

Forest removal also results in significant changes in air and *soil* temperatures and relative humidity of the air. Enhanced decomposition of organic matter in the soil and associated nitrification lead to soil acidification and promote an excessive loss of basic cations (LAL and CUMMINGS, 1979). In principle, the organic pool can be restored if a site is left fallow for several years. However, the long fallow periods characteristic of traditional shifting cultivation have been shortened (from 7-10 to 1-2 years) and replaced by intensive cultivation. Under land pressure and a difficult economic and legislative environment, recent cropping practices like mono-cropping, intensive cultivation without fertilizer input and excess pesticide use have caused severe problems like soil erosion, accumulation of sediment/toxic substances along the streams, and toxification of drinking and irrigation water. These developments result in a deterioration of the physical, chemical and hydrological properties of the soil, a decline in soil productivity and crop yields, decreased viability of the agro-ecosystem, decreased storage capacity of water reservoirs, and decreased stream and river depth. These trends call for counteraction.

At least with respect to anti-erosive cultural practices several options like alley cropping, hillside ditches, surface mulching, strip cropping, agro-forestry and grass-strip barriers were developed and validated by the national researchers on station and in farmers' fields. Results showed that these improved technologies can effectively reduce runoff and soil loss to an acceptable level (CHANDRAPATYA, 2003). However, to be effective these measures must be introduced to and accepted by the farmers. Whether and under which conditions this may be accomplished will be a future research task.

Increasing population and cropping area also lead to higher pressure on *water* resources. On the one hand household consumption is increasing and on the other tourism and dryland irrigation are new sources of water use. Together with increasing pesticide use, these trends lead to conflicts with respect to water distribution and quality between the population uphill vs. downhill and upstream vs. downstream, respectively (subchapter 2.3 and 2.4).

A typical problem with respect to water availability and use in the regional cropping systems is that heavy rainfall predominates in the early part of the growing season (May to August) when water consumption by crops is low and decreases during the latter part of the season (October to November) as the crops reach maturity. Consequently, strategies are needed to optimise soil water storage and use. Soil structure has a major impact on soil water balance via infiltration, storage capacity and drainage characteristics particularly in the steeper slopes of the highlands. Therefore, new strategies should include measures to sustain soil structure like mulching etc.

Natural forest in the mountainous regions of Southeast Asia is dwindling at an alarming rate mainly due to its conversion into agricultural land. Cultivated and degraded land now covers a far greater area than natural ecosystems. This process is accompanied by a loss of natural *biodiversity* in plant, animal and microorganism species and also adversely affects the biodiversity of agro-ecosystems (subchapter 2.5). Species diversity and functions, such as the interactions between pests and beneficials, are influenced by species originating from the surrounding habitats of the agricultural site. Therefore, the structure of the landscape in terms of fragmentation, heterogeneity, and proportion of unmanaged areas, is related to the diversity of native species (e.g. predators) as well as introduced species (e.g. specific pests of crops). This, in turn, affects their interactions and the role and effectiveness of natural biological pest control. Finally, these conditions provide important criteria for determining whether it is necessary to apply other pest management strategies.

In general, the increasing shortage of natural resources demands regional land development strategies. But these strategies are hindered by a lack of information on available resources. There is not enough information on climatic variability, surface water flows, or soil distribution. For instance the "Soil Map of Thailand" with a scale of 1:600.000 (VIJARNSORN and ESWARAN, 2002) treats most of the highland soils as one undifferentiated unit called "slope complex". However, geological diversity including rock types like granite, sandstone, marls, limestone etc. will also result in pedological diversity, which has in fact been observed in a number of local studies (i.e. HANSEN, 1991; WELTNER , 1996; KUBINIOK ,1999). This situation calls for a more detailed resource survey in the highlands of Southeast Asia (subchapter 2.2). In addition, future land development plans should consider market access, cultural differences and history in order to result in sustainable development. Consequently, an interdisciplinary and cross-cultural approach is necessary.

This chapter gives an overview of research results from the literature and gathered within the framework of SFB 564 with respect to the institutional environment, and the inventory and management of natural resources of northern Thailand (subchapters 2.2 to 2.5). Finally key constraints and consequences for a future research strategy are discussed (subchapter 2.6).

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2.2 Variability of Soil Resources in Northern Thailand

Ludger Herrmann, Klaus Spohrer, Ulrich Schuler, Karl Stahr, Niwat Anongrak, Thanun Hongsak and Dusit Manajuti

2.2.1 Introduction

There is still much of great value to discover about soil variability in the highlands of northern Thailand. Part of this chapter tries to review the state of knowledge of the highland soils and part presents results which have been produced within subproject B1 of SFB 564. This project follows a long-term strategy in which the variability of soil and water balance is researched beginning at a field scale and ending at a regional level. The same approach is also followed here.

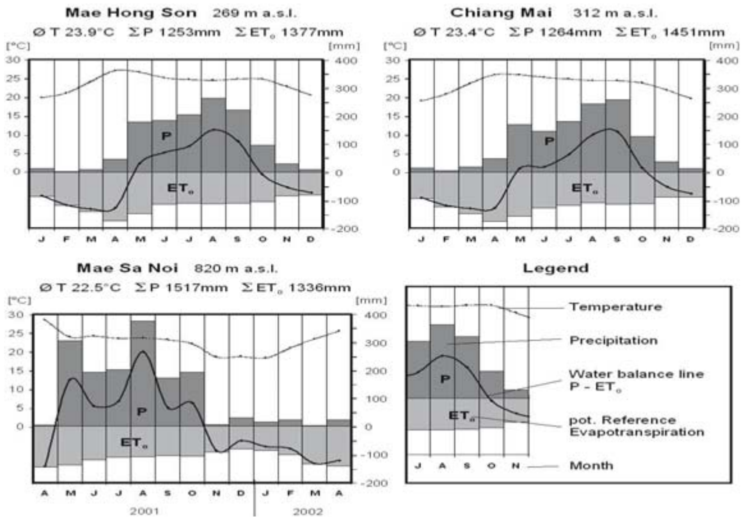


Figure 2.1: Climate diagrams of Mae Hong Son and Chiang Mai (averaged annual data from FAO, 1994) and own climate data of 2001/2002 from the Mae Sa Noi research plot.

2.2.2 The Regional Environment

Long-term average climate data (Figure 1) indicate quite homogeneous conditions for northern Thailand, with a seasonal tropical monsoon climate (Köppen: Aw). However, sound long-term data exist only for the major towns situated in valleys (approx. 300 m a.s.l.). Our own short term measurements indicate that with increasing elevation one can expect to find increased rainfall, and decreases in temperature and potential evapotranspiration. Consequently, relief should be the major determinant of climate/weather variability in the highlands, further modified by exposition.

The geology of the region is diverse as highlighted in Table 2.1, which shows the existence of geological formations from the Quaternary to the Cambrian epoch. In the Pang Ma Pha district of Mae Hong Son province, these include magmatic as well as sedimentary and partly metamorphic rocks.

Table 2.1: Spatial extent of geological and petrographical formations in the Pang Ma Pha district, Mae Hong Son province.

Geological formation	Petrography	Area [km^2]
Quaternary	Gravel, Sand	12.2
Tertiary-Quaternary	Gravel, Sand, Sandstone, Shale	0.6
Permian	Limestone	36.0
Carboniferous-Permian	Conglomerate, Sandstone, Shale	43.5
Carboniferous-Permian	Sandstone, Shale, Chert, Greywacke	398.1
Carboniferous-Permian	Basic volcanics	0.2
Carboniferous-Permian	Granite, stressed	15.8
Devonian-Permian	Sandstone, Shale, Chert, Greywacke	<0.1
Silurian-Permian	Shale, Chert, Limestone, Sandstone	7.2
Ordovician-Permian	Limestone, Shale	0.2
Cambrian-Permian	Sandstone	5.2

According to HAWORTH (1966) formations from the pre-Cambrian up to the Quaternary are present in northern Thailand. Limestone is prominent to the west and towards the east, red sandstone covers wider areas. The main mountain chain generally running north-south consists of granites and other magmatites and is characterised by strong relief. The valleys are filled with Quaternary to Tertiary river sediments (BGR, 1975). The whole area has to be considered as heterogeneous with regard to geomorphology and mineralogy.

The existing information (scale 1:250.000) on spatial variability of parent rocks is not sufficient especially as a background for soil studies at the watershed scale. I.e. for the Bor Krai watershed (Pang Ma Pha district) limestone is reported (BGR, 1975) to cover the whole area. But according to our own observations silt- and claystone seem to be associated major rock types (SCHULER et al, 2004) as parent material for soil formation. Tectonics seem to be the source of further small scale variation. I.e. a basaltic intrusion could be detected as an abnormal feature in the Bor Krai area and freshwater carbonate appears locally in the Mae Sa granite/gneiss catchment (approx. 35 km NW of Chang Mai).

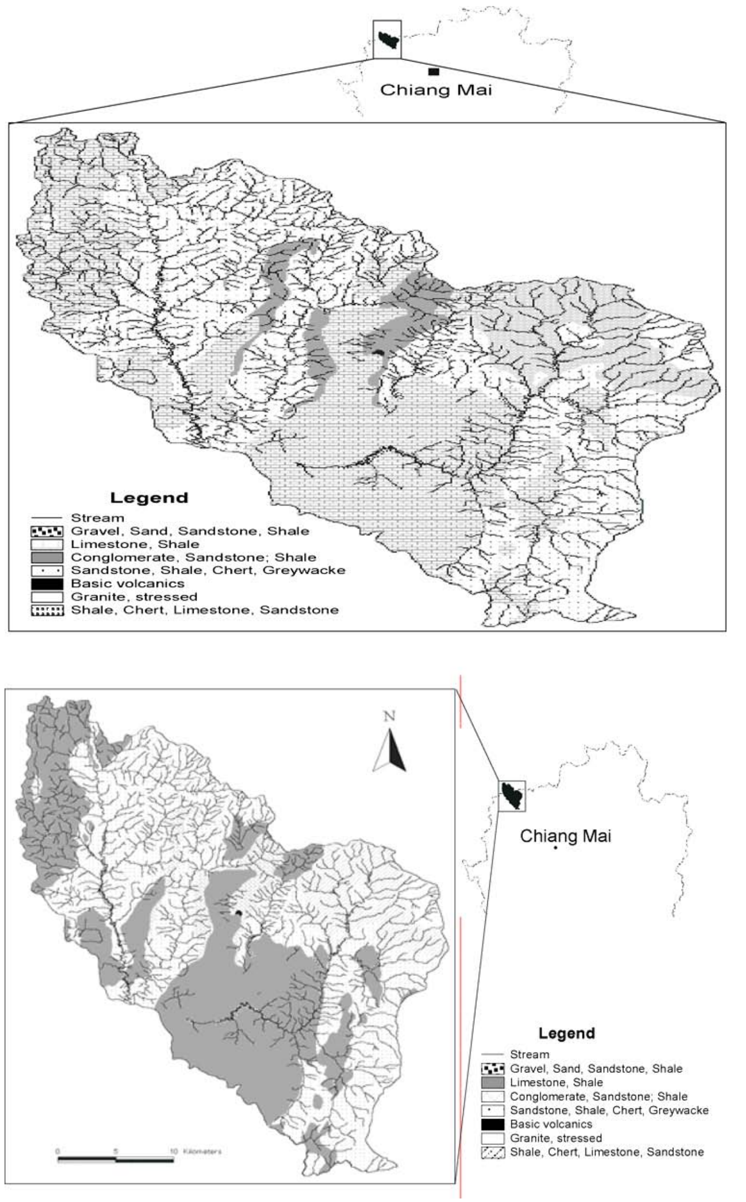


Figure 2.2: Stream density on different rock types in Pang Ma Pha district.

The surface stream density depends on lithology (Fig. 2.2 and Fig. 2.1) which determines subsurface permeability and, via soil distribution, the water storage capacity of the soil cover. For this reason the stream density in areas with magmatites and clastic rocks is obviously higher than in regions which are dominated by limestone. Limestone shows the highest permeability in comparison to all the other rocks, and this feature is expressed in a lot of karst phenomena like caves, shafts, sinkholes, depressions and karst springs. More than 35 % of the area is affected by subsurface discharge into the karstic underground especially in the Pang Ma Pha district

Only small scale information (1:600.000, VIJARNSORN and ESWARAN, 2002) exists on spatial variation of soils in the whole intervention area. Whilst, for the low relief positions, different soil types are mapped, sloping areas with >35% inclination are treated as one undifferentiated so-called "slope complex". There are probably two reasons for this: i. the slopes are accessible only with difficulty and, ii. they are reserved as forest areas by law. However, a number of local studies exist which show the expected variability depending on rock type, relief and land use (i.e. WELTNER 1996; KUBINIOK, 1999). Except for the valley floors, soils with clay illuviation and in some parts Cambisols or Ferralsols are dominant. In granite areas Acrisols are widespread (HANSEN, 1991; KUBINIOK, 1992). In limestone areas Calcic Luvisols appear (FAO, 1973). Although there is a trend of soil depth/development depending on relief (WELTNER, 1996), our own observations indicate that deep soil profiles can also be regularly detected in extremely steep terrain (see also WELTNER, 1996; ANONGRAK, 2003). Meanwhile It seems that there is an increasing awareness within Thai public institutions that the highland soils are a valuable resource which needs to be explored. Consequently an increasing number of initiatives are being launched to describe this resource (i.e. ANONYMOUS, 2002).

2.2.3 Mesoscale Soil Information

Mesoscale soil information is restricted to schematic representation according to the Catena concept. WELTNER (1996) in a report on the granite/gneiss area of the Doi Inthanon National Park states that the predominant soils on biotite gneiss at higher elevations (1600-2560 m a.s.l.) are Cambisols with associated Acrisols and Ferralsols. Between 700-1600 m a.s.l. Acrisols become dominant in the convex slope positions and appear together with Nitisols and Ferralsols. ANONGRAK (2003) investigated in detail 14 soil profiles in the same region on a topographic gradient (620-2460 m a.s.l.). According to his investigation, all profiles belong to the order Ultisol (US Soil Taxonomy). Depending on relief and texture he discovered clay mineralogical differences with dominance of either kaolinite or gibbsite, with gibbsite more prominent at higher elevations. This finding contradicts the statements of WELTNER (1996) whose observations rely mainly on morphological rather than analytical descriptions.

However, KIRSCH (1998) also reports Chromic and Ferralic Cambisols in another granite/granodiorite area in the northern Chiang Rai province (850-1650 m a.s.l.) with associated Leptosols in steep relief positions and additional Acrisols/Alisols below 950 m a.s.l.. Actually, the soils classified as Cambisols show the typical depth distribution of clay as in illuvial profiles and at least some clay cutans could be detected in thin sections. On the other hand, sand fraction ratios indicate layering.

Again in another granite/gneiss area in the SW of northern Thailand KUBINIOK (1999) describes Lithosols and Cambisols in the steepest relief positions. On the Mae Sanan plateau Ferralsols occupy the hilltops, while Acrisols are spread on the slopes. In the mountainous parts of the Phayao area, the same author reports Cambisols on shales, silt- and sandstone with associated Acrisols and Ferralsols, and Rhodochromic Cambisols on limestone.

To sum up, predominantly granite areas have been investigated. So far the descriptions feature only three contrasting major soil groups for the mountainous areas: Cambisols, Acrisols, and Ferralsols.

2.2.4 Watershed Scale

So far two watersheds have been preliminarily investigated within the SFB 564. The Mae Sa Noi granite/gneiss catchment (Chiang Mai Province) and the Bor Krai limestone catchment (Mae Hong Son Province).

The Mae Sa Noi catchment has an approximate area of 10 km^2. It has three streams, namely Nawai, Phunsi and Mae Sa Noi contributing to the perennial Mae Sa stream (Fig. 2.1). In a preliminary survey, 37 augerings were described throughout the watershed. Nine major soil properties were mapped in the terrain (topsoil texture, subsoil texture, surface structure, subsoil colour (moist – value/chroma), subsoil mottles, topsoil reaction, slope class) and these data were clustered according to the weighted average pair group method (RAYNER, 1961; SNEATH and SOKAL, 1973). Clustering revealed 8 groups. For each group at least one soil profile was described and sampled in detail.

In general, the soils show only little variation. Six out of the eight soil groups show high correlation with similarity indices greater than 0.8 (Figure 2.3).

This lack of variation is also reflected in the preliminary soil classification (MANAJUTI et al., 2004). Seven of the pedons were classified as Humi-Profondic Acrisols (1, 4, 5, 6, 7, 8, 9), one as Humi-Hyperdystric Acrisol (2), and one as a Molli-Dystric Cambisol (3). According to the US Soil Taxonomy they are classified as Ultisols, Alfisols, and Inceptisols. The dominant process of soil formation on granite/gneiss is clay illuviation. Variation between the profiles is caused by erosion, colluviation and land use. Eutric Cambisols were only found in the vicinity of freshwater limestone.

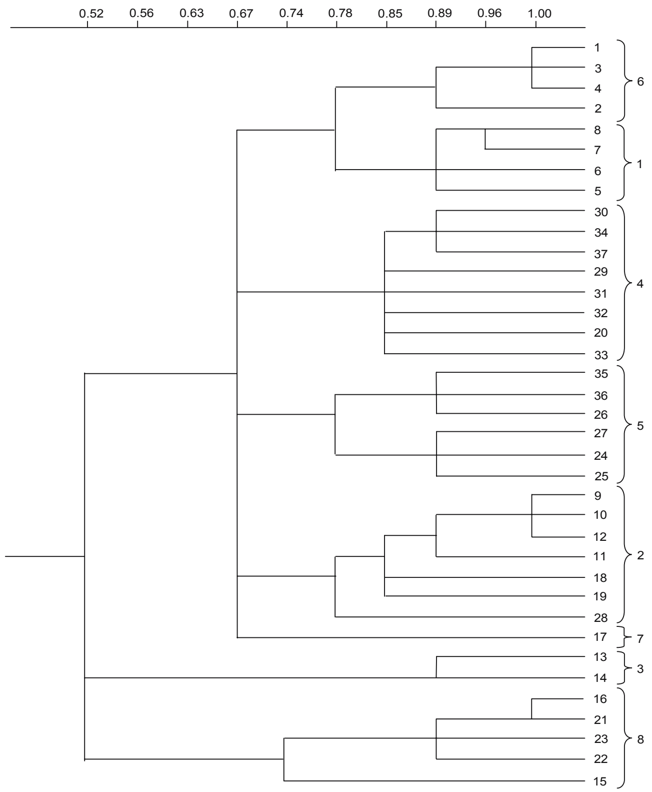


Figure 2.3: Cluster analysis (weighted average pair group method) of soil augerings based on 9 major soil properties for the Mae Sa Noi catchment.

Terrain work revealed the presence of marble lenses within the gneiss. The marble is dissolved by groundwater and then carbonate is precipitated around the springs due to rising water temperature and biotic activity.

In general, the soils are deep to very deep, characterised by a low skeleton content (range: <1-68%, non weighted average over all horizons 5.4%, CV 199%), a clayey texture (14-63% clay, non weighted average over all horizons 47%, CV 26%), and topsoil bulk densities between 0.8-1.2 g cm^{-3}. Only the Molli-Dystric Cambisol shows pH_{H2O} values over 6. Soils on granite/gneiss show little variation in this respect (pH 4.8-5.9). Again with the exception of the Molli-Dystric Cambisol the base saturation is low (<50%). Organic matter content in the topsoil varies between 3.1 and 8.8%, with higher values under forest and lower ones under orchards and arable cropping.

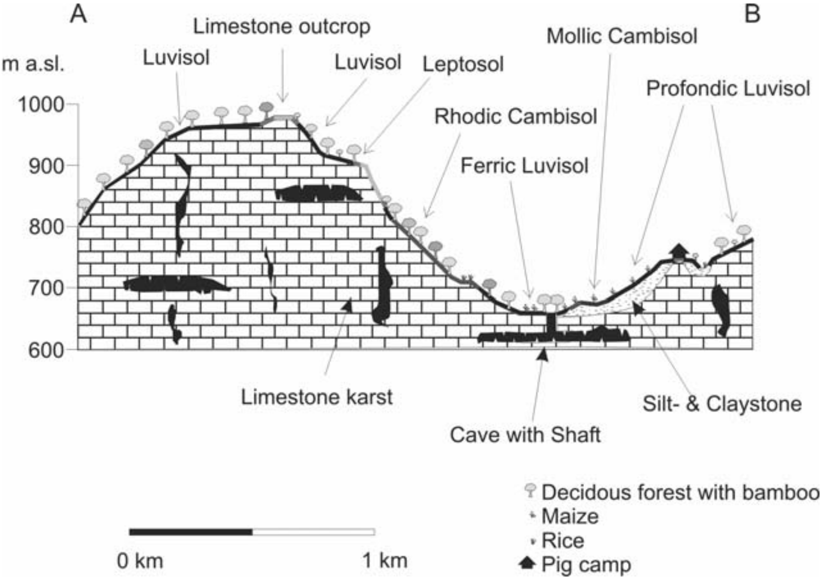


Figure 2.4: Soil catena through the Bor Krai catchment, Pang Ma Pha district, Mae Hong Son province.

The Bor Krai limestone area is approximately 8.5 km^2. Soil mapping reveals that the soil variability there depends to different extents on parent rock, relief, land use and age. The parent materials present are limestone, claystone, siltstone, sandstone, freshwater limestone and probably basic volcanic material (SCHULER et al., 2004).

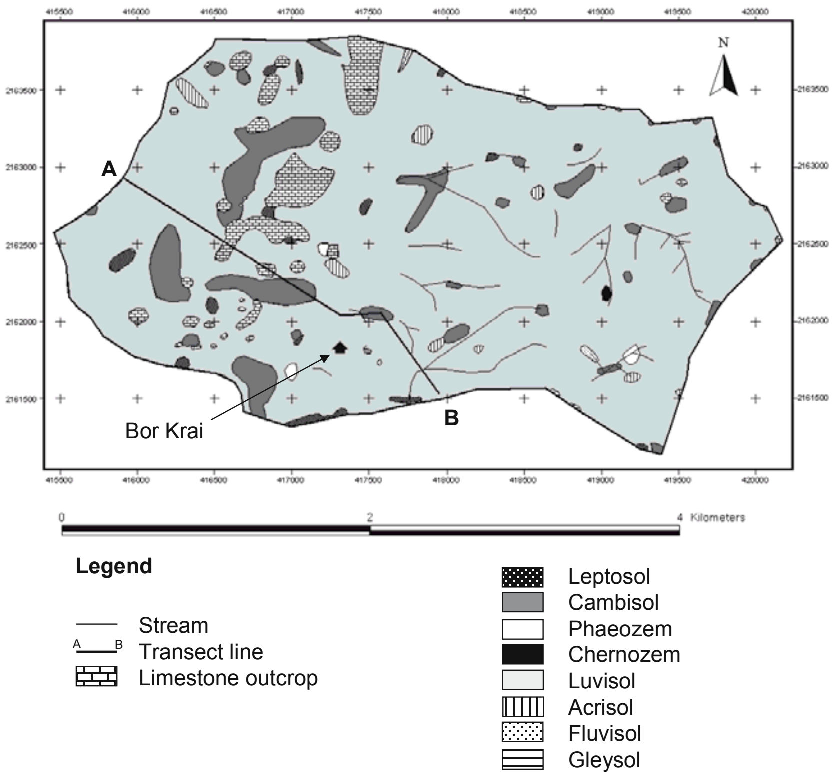


Figure 2.5: Preliminary soil map (WRB - soil group level) of the Bor Krai limestone area, northern Thailand.

According to the preliminary classification, soil variability in this environment is higher than in the granite/gneiss catchment. Luvisols and Acrisols with the WRB-qualifier "rhodic", are widespread on limestone and on its associated dolomite and iron ore, whereas on clastic rocks Luvisols with the WRB-qualifier "chromic" and "ferric" are more common. Around freshwater springs Calcic Chernozems were detected. Soil and nutrient transfer towards karstic depressions is responsible for the formation of Mollic Cambisols and Phaeozems.

The soils on limestone tend to show extreme features like very high clay content (>80% in the subsoil) and gibbsite as the dominant mineral. The latter feature explains the relative low cation exchange capacity despite the extreme clayey texture. Soils on clastic parent materials reveal similar properties to those found in the granite/gneiss catchment, with slight trends towards higher pH and base saturation. Nutrient status is also comparable. However, within the Bor Krai area there is a trend towards higher nutrient concentrations in lower landscape positions. Erosion and colluviation are one explanation for this fact (surface/particulate component). On the other hand hydromorphic features in the subsoil of the silt-/claystone area argue a lateral subsurface flow (subsurface/dissolved component).

The sites investigated are deficient in the following nutrients: B, Zn and P.

2.2.5 Field Scale

So far, there has been one detailed field survey on the major test site (Lychee orchard, 2 ha) in the Mae Sa Noi granite/gneiss catchment. Four soil profiles were described and sampled in detail along the slope. In addition, a variability study that focused on water balance parameters was made with augerings in a 12m grid.

All profiles were classified as Acrisols (if CEC_{clay} corrected for organic matter, LANDON, 1984); the lowermost as Endoleptic, the others as Umbric. The four profiles feature only small textural differences between comparable horizons. Major differences are i. the decreasing depth development down the slope along with ii. parallely increasing inclination (convex slope) and iii. increasing skeleton content (Fig. 2.6).

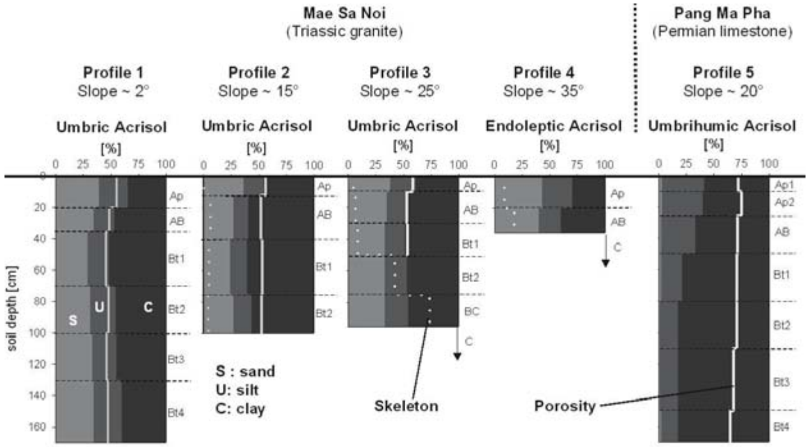


Figure 2.6: Characteristics of soils at the research sites Mae Sa Noi and Pang Ma Pha.

The analytical results fit quite well with results from other studies on granite in northern Thailand (Fig. 2.7). The variability study (Fig. 2.8) reveals quite similar conditions on the plateau. However, downslope, the pattern becomes more heterogeneous, which is mainly as a result of the 3D-relief. Since texture is comparable, the available water capacity is a function of soil depth, which decreases downslope. Irrigation planning has to take into account the trends in inclination (risk of surface run off) and depth distribution (single irrigation amount). However, the expected maximum infiltration rate is optimal at all sites according to the criteria of LANDON (1984). Additional variation with respect to the water balance is created by climatological parameters. Whilst precipitation differences are small between plateau and slope (~2% higher on plateau) larger differences (up to 20 %) occur with respect to ETo which is affected by the lower wind speed and net radiation found in lower topographic positions.

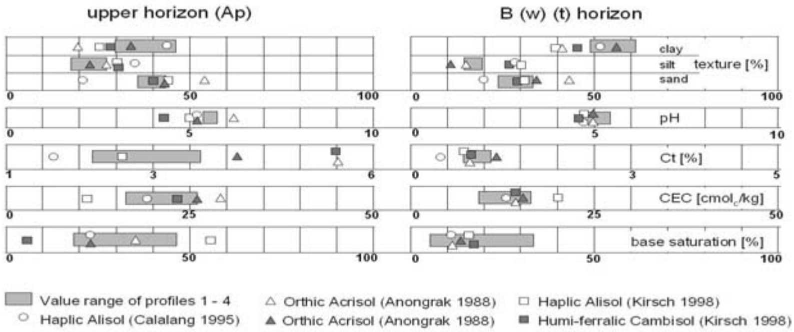
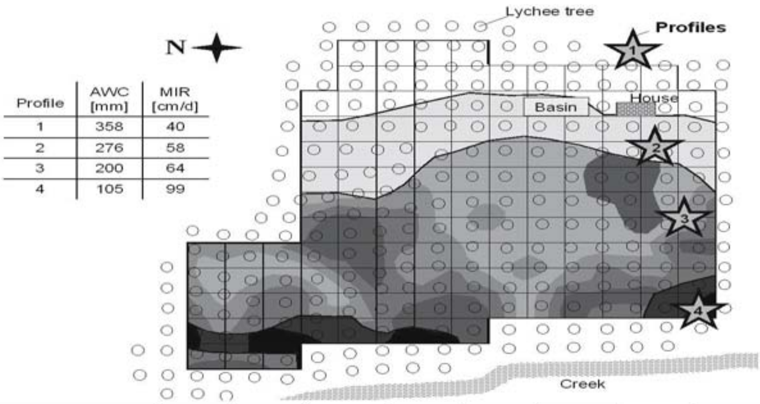


Figure 2.7: Comparison of own analytical results (profiles 1 - 4) with previous soil studies on granite in northern Thailand.



Area unit								
Slope [°]	0-10	10-20	20-30	20-30	20-30	20-30	30-40	30-40
Soil depth [cm]	> 100	> 100	> 100	75-100	50-75	25-50	50-75	25-50
Eff. root space [m³]	11-14	7.5-11	5.6-7.5	5.6-7.5	4.4-6.3	2.7-4.3	2.2-4.4	1.3-2.7
AWC	high	high	high	high	medium	low	medium	Low
MIR	optimal	optimal	optimal	optimal	optimal	optimal	optimal	optimal

Figure 2.8: Spatial variability of parameters influencing the soil water balance.

The ratings for available water content (AWC) and maximum infiltration rate (MIR) are according to LANDON (1984).

2.2.6 Profile Scale

A variability study on the profile scale concentrated on bulk density distribution within one profile. The study revealed a loose topsoil (close to 1 g cm^{-3}) but a compacted horizon underneath (up to 1.4 g cm^{-3}, Table 2.2) at a depth of about 0.3 m, which is probably caused by local tillage practices. The horizon has either been compacted by the routines used during the planting of lychee trees which is combined with topsoil redistribution (small scale local terracing) or by the cropping practices applied between the trees until their cover becomes dominant. Further down the profile, normal values for clayey subsoils are present. The compaction might hinder water infiltration during heavy rain storms which commonly occur at the beginning of the cropping season.

Table 2.2: Variability of soil properties of an Umbric Acrisol at the Mae Sa Mai central plot (Bulk density distribution based on 80 soil cores).

depth [cm]	horizon	bulk density Ø	sand [%]	silt [%]	clay [%]	porosity [%]	C_{org} [%]
15	Ap	1.09	38	21	41	58	2.4
30	AB	1.23	35	19	46	53	1.5
50	Bt1	1.22	31	17	52	51	1.0
75	Bt2	1.20	28	18	54	51	0.7
100	Bt3	1.15	30	19	51	52	0.6

2.2.7 Concluding Remarks

The number of soil groups present in the catchments investigated is lower than expected but higher than previously reported. An important factor which must be considered with regard to variability is the occurrence of very localised rock varieties, i.e.

freshwater limestone in granite and volcanic intrusions in limestone. An important future task is to map soils on other rock types and to produce sufficient statistical data on the variation of their characteristics to enable regional modeling which is a pre-requisite for sound land use planning. Adequate techniques for a sufficiently fast and cost effective survey have still to be developed.

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2.3 Water Allocation and Management in Northern Thailand: The Case of Mae Sa Watershed

Andreas Neef, Chapika Sangkapitux, Wolfram Spreer, Peter Elstner, Liane Chamsai, Anne Bollen and Jirawan Kitchaicharoen

2.3.1 The Socio-Economic, Institutional and Technical Aspects of Water Allocation and Management

Physical availability of water and technical means for water storage and conveyance do not necessarily guarantee access to water for all groups of society. This is particularly true for the highland areas of northern Thailand where water is the object of competition by diverse stakeholders. While agriculture remains the main user of available water resources – the sector accounts for about 80 percent of water use – other sectors, such as tourism, water companies and other industries, are continuously increasing their share of the water used. Downstream residents are becoming increasingly aware of the deleterious effects that upstream water users can have on both water quality and quantity. Hence, intersectoral competition and conflicts between upstream and downstream water users have become a widespread phenomenon in many watersheds of northern Thailand (CHAROENMUANG, 1994). In recent years, highland areas have faced serious problems related to water, particularly water shortages during the dry season.

In this subchapter, we regard water allocation and management as a socio-technical system. Following these introductory remarks, we discuss the legal framework for water in Thailand (section 2). We then describe social and institutional issues of water allocation and management at the farm, household and community level in Hmong and Thai communities in the Mae Sa watershed (section 3). The technical set-up of irrigation technologies and conditions for water-saving irrigation technologies are presented in section 4, followed by a description of the management of water for household consumption (section 5). The subchapter concludes with a discussion of the findings in which the various aspects of water usage are compared (section 6).

2.3.2 National Water Laws and Government Policies

Thailand has more than thirty water-related laws, with responsibilities shared by over thirty departments overseen by nine ministries (SETHAPUTRA et al., 2000; KAOSA-ARD et al., 2001; ONWRC, 2003). Water laws are divided into three categories: water courses in general, irrigation water and groundwater. Surface water in water courses is declared state property but available for the common use of the people, subject to restrictions formulated in Section 1355: "the owner of a piece of land along or through which a water-way passes is not entitled to draw more water than is necessary for his reasonable needs to the detriment of any other piece of land on the waterway." (WONGBANDIT, 1994: 89). The legal framework for irrigation water is regulated in the Royal Irrigation Act of 1942. The use of water from irrigation water courses is under the control of the Royal Irrigation Department which is equipped with the power to decide the allocation and conditions for water use. The extraction and utilization of groundwater, defined as water at a depth of more than 15 meters, is legally based in the Groundwater Act of 1972 (amended in 1992) and requires a license for water extraction from the Mineral Resource Department (HEYD and NEEF, 2005). Due to the lack of an umbrella legislation linking different laws and clarifying particular responsibilities, coordination among all agencies involved in water management is virtually non-existent. A more comprehensive and integrative water bill has still not gone beyond the draft stage. While the draft bill would provide the basis for stakeholder participation through the nation-wide creation of river basin committees (RBCs), it has been criticised for failing to provide a mandate for a single agency to act as the national water manager and coordinating body of the RBCs (ONWRC, 2003). There are also concerns that the draft water bill, which has been developed based on consultations with local residents in 25 river basins, will face opposition by state agencies because it contains strong elements of public participation (HEYD and NEEF, 2005).

In the current situation of legal uncertainty, the perception of water as an open access resource remains widespread among policy makers and technocrats; the existence of diverse forms of control, ownership and use rights of water resources being widely ignored (WUTTISORN, 2002). It is believed that water is overused as a consequence of the inability of local communities to establish viable regulations that would guarantee a more sustainable use of water resources. This perception is often used as an argument for enhanced state control of the management of water resources. Many NGOs, on the other hand, claim that local communities share common values concerning water rights and management, that communal management guarantees equal access to water resources and that all community members act according to locally established rules of water management. The following study presents empirical evidence that both perspectives tend to oversimplify the complexity of water tenure and management in Thailand.

2.3.3 Allocation of Water for Irrigation at the Community and Farm Level

In this section we present research results on water allocation and management from two Hmong and two Thai communities in the Mae Sa watershed (Figure 2.9). The characteristics of the four villages are summarized in Table 1. In all villages, open and semi-structured interviews with key persons (e.g., village headmen, government officials, heads of water management committees and women's groups) were conducted between 2002-2004. In cooperation with local experts, we carried out an inventory of water storage and transport systems and identified water rights, management, use and conflicts. Location of water sources was determined by a mobile Global Positioning System (GPS) and integrated into a Geographic Information System (GIS). Participant observation was applied in the case of conflict mediation, e.g. when water committees made field trips to areas of water conflicts.

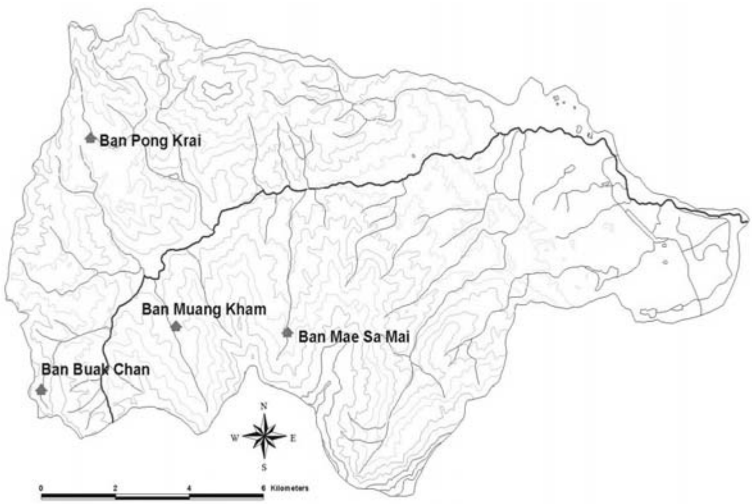

Figure 2.9: Study villages in Mae Sa watershed.

Table 2.3: Characteristics of the survey villages.

	Mae Sa Mai	Buak Chan	Muang Kham	Pong Krai
Ethnic group	Hmong	Hmong	Thai	Thai
Population	1765	893	910	359
Location	Upstream	Upstream	Midstream	Upstream
Altitude [masl]	700-1380	1140-1380	780-920	800-1400
Market access	good	good	very good	good
Main crops	Fruit trees, vegetables	Flowers, vegetables, fruit trees	Vegetables, flowers	Flowers, vegetables

2.3.3.1 Management of Irrigation Water in Hmong Communities

Under the opium replacement policy of the Thai government, land use in Mae Sa Mai and Buak Chan changed from poppy cultivation and upland rice over corn and coffee production to its present land use system, consisting mainly of cash crops such as flowers, vegetables and fruit trees. Today, a major proportion of the agricultural fields are irrigated by conventional sprinklers through gravity irrigation. In Mae Sa Mai, three main water tenure systems have developed over time, (1) individual water use rights, (2) user groups sharing the same pipe or ponds, and (3) user groups sharing the same springs or creeks (HAMMER, 2002). The establishment of user groups follows pragmatic economic considerations. Farmers sharing the same compartment, pond or pipe are owners of neighbouring orchards and belong to different clans in the village. This is in stark contrast to the traditional social structure of Hmong society in which cooperation between members of different clans is not very common (cf. COOPER, 1984).

Water rights are part of a resource tenure system adapted to social, cultural, economic, technical and geographical conditions. The complexity and pluralism of water tenure and use rights is exemplified in Figure 2.10 by four selected cases. Those farmers who were first to build reservoirs and pipes have first priority in water use ("first come, first served" principle), causing an unequal allocation of water. Hence, water use rights strongly reflect local power relations, with members of local elites controlling the water conveyance systems by tapping water directly from the source and by claiming a bigger share than others, since the less powerful would not dare to interfere. Powerful farmers also have the opportunity to take water from different sources and thus are able to use the legal pluralism at community level to their own advantage and to diversify risks in a rapidly changing institutional environment (NEEF et al., 2004a).

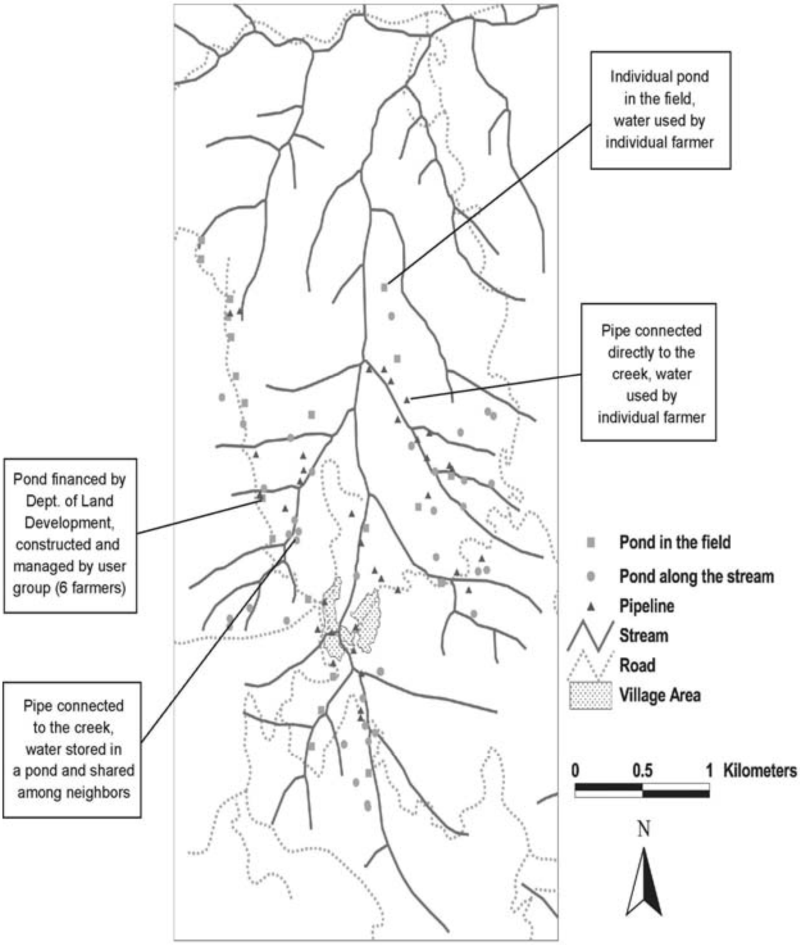

Figure 2.10: Water sources, water infrastructure and legal pluralism of water rights in Mae Sa Mai (Source: Adapted from Neef et al., 2005; data from Hammer, 2002 and Wanishpradist, 2003).

In Buak Chan, the main sources of irrigation water are communal and private ponds in a narrow valley beneath the village settlement. The communal ponds are converted paddy fields bought from a Thai farmer of the neighbouring village of Gong Hae. All ponds are fed by springs or by stream water and have been dug into the ground. Ponds established by individual farmers on public land are recognized as private property. As all fields are located at a higher altitude and most of them are even on the other side of the mountain ridges, farmers need pumps to transport the water via pipes to their flower and vegetable plots. Hence, in Buak Chan, water and land use rights, which traditionally have been closely connected to each other, are today completely segregated. Private ponds are used either by individual farmers or by close relatives in a shared arrangement. The four communal ponds can be used by any villager who has enough capital to install a pump and connect it through a plastic pipe to a private storage facility in his or her field. Thus, a common-pool resource is being gradually transformed into an individual commodity (Figure 2.3).

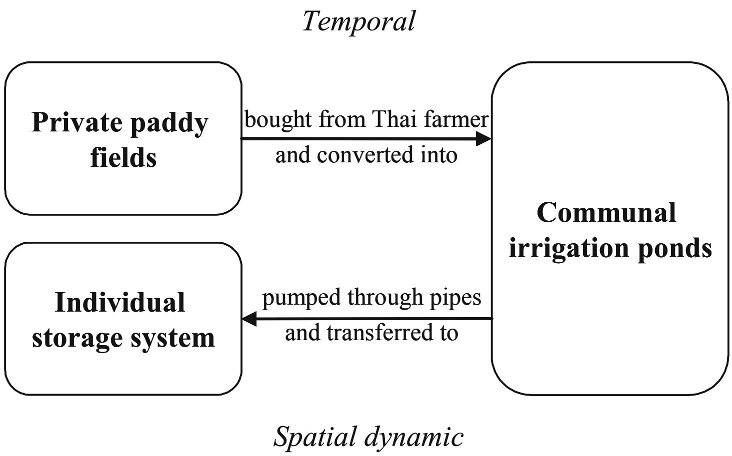

Figure 2.11: Temporal and spatial dynamics of water resource tenure in Buak Chan.

Water-saving irrigation technologies are rapidly expanding in the village with the introduction of hydroponic sweet pepper and tomato production. The individualization of access to water has not caused a high degree of inequality among the villagers, though. The major reason is that most farmers have successfully engaged in profitable and diversified cash crop production, while protecting their land and water resources against outside investors and speculators (NEEF et al., 2004b).

2.3.3.2 Management of Irrigation Water in Thai Communities

Traditionally, water management in Muang Kham was done on a communal basis as long as paddy rice was the most important crop. Water for cultivation of the paddy fields, was gained through the *muang-fai* system which diverts water from the Mae Sa and Mae La Ngun rivers through an elaborate system of weirs and canals. The *muang-fai* system (*muang* = small canal; *fai* = weir) is a traditional, communal form of irrigation system common in many areas of northern Thailand (TAN-KIM-YONG, 1995). In the past there were four main irrigation canals operating in Muang Kham of which three are still in use, but only one remains under the supervision of a *gae muang*[1] whose task has been reduced to calling the members to the annual cleaning of the canals. The Mae Sa river, which feeds one of the canals, is also used directly by farmers who withdraw irrigation water through individual pipes. In the slope areas, farmers would use water directly from the creeks either by installing pipes that lead towards their fields or by constructing small earthen or concrete basins/ponds, funded privately or by the government. These ponds can be located at the stream or directly at the farmers' fields, with pipes leading towards the plantations. Usually water allocation facilities are shared among family members. Only in a few cases are they used jointly by independent parties across family boundaries. Different farmers using the same creek form water user groups which in some cases have compiled a detailed list with rules and regulations concerning water use (NEEF et al., 2004b).

Commercialisation of agriculture and land, which started with the introduction of flowers and cabbage, has induced a shift to more individualized systems of water conveyance and irrigation. The trend towards individualised water management strategies was accelerated by the introduction of strawberries in 1994/95, as

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[1] Traditionally, the *gae muang* has been responsible for allocating water in an equitable way, enforcing the regulations of water use, organizing the communal maintenance work and performing the ceremony for the weir spirit. He is elected by the members of the *muang-fai* system (TAN-KIM-YONG, 1995; ELSTNER and NEEF, 2005).

farmers started to construct their private wells in order to ensure a sufficient supply of clean water. From 1998 onwards, more private wells have been built by contract farmers growing sweet peppers under hydroponic conditions for a foreign company. Clean water is a prerequisite for sweet pepper cultivation to prevent diseases like mould and to ensure a high quality product (NEEF et al., 2004a). The introduction of hydroponics went along with the rapid spread of water-saving irrigation technologies.

As communal forms of water allocation continue to exist – even though they may now have assumed a much lower importance – legal pluralism of water rights has emerged and water management has become far more complex. Legal pluralism exists both at the village and the farm household level. Today, three main types of access to water can be observed in the village, (1) direct access to natural water sources, (2) access through the *muang-fai* system, and (3) private groundwater wells, the latter continuously increasing its importance. The complexity of water storage and conveyance systems is exemplified in Figure 4.

Water distribution among the users is often characterized by strong inequalities because it depends on factors like distance between the resource and the fields, the time of settlement (who came first will have long-established and therefore more secure access rights), the location of the field (due to the first-come/first-served principle upstream users are in a better position) and the financial situation of the farmer (investment is needed to build a conveyance system).

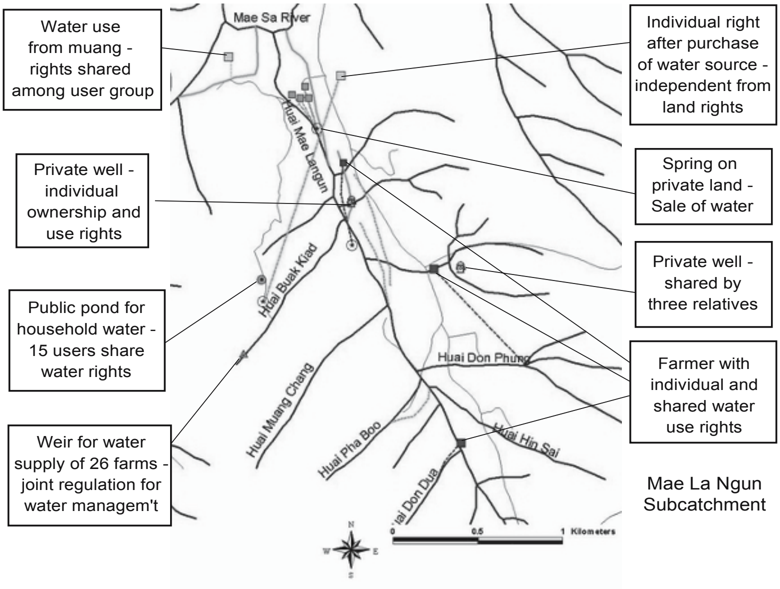

Figure 2.12: Complexity of water rights at village and household level in Muang Kham (Source: Adapted from Elstner and Neef, 2005).

The individualisation of water management, which is still on-going in Muang Kham, seems to be fully completed in the upstream Thai village Pong Krai. Farmers use water either from private ponds or from two streams with individual pipes through gravity irrigation. The village headman even issued a regulation not to share pipes with other farmers in order to prevent any arguments and conflicts. There is a general rule that farmers can only connect one pipe to the stream, but in practice many farmers use more than one pipe.

As about 70 percent of the village territory is owned by outside investors and speculators, farmers have resorted to the capital- and water-intensive production of cut flowers, mainly chrysanthemum, which can yield high returns per land area. Water shortages are common at the end of the dry season. Therefore, each farmer keeps private tanks or reservoirs next to their fields in order to store water for periods of water scarcity. Although there is no major competition for water with the downstream Thai village Pong

Yang Nai (which has a variety of water sources), serious conflicts exist between villagers and private investors who take a large share of the water for their farms, residences or resorts.

2.3.4 Irrigation Technology

The energy supply for the irrigation systems is solely gravity. If water from lower elevations is pumped to the fields, it is led into a storage basin and subsequently fed into the irrigation system. An important part of the irrigation water supply is taken from mountain springs or creeks. The water is dammed by a small earth dike and supplied to the fields by means of PVC pipes. Mostly there are no filters used, except rough structures made from bamboo or textiles at the inlet of the pipeline.

Main irrigated crops in the area are fruit trees, cut flowers and vegetables, the latter being increasingly produced hydroponically under greenhouses. In these production systems trickle-irrigation is the dominant technology. Some vegetable marketing companies sell the irrigation material together with seedlings and substrate to the farmers and later buy the vegetables. In those cases, micro-tube type drippers and inline drip-tapes are used which are either produced in Thailand or imported from Israel. There are also a variety of self-built drip-irrigation systems, which consist of manually perforated PVC-pipes. Some of them are covered by a PVC-clamp. The outflow velocity is thereby slowed down and the pressure drop inside the line can be limited in a manner similar to that in a labyrinth-type dripper.

For field-cropped vegetables and fruit trees, micro-sprinklers are most common. Simple local products are predominant consisting of a large diameter nozzle and a plastic or metal deflector. They do not feature any kind of pressure-compensation, nor do they have a well-defined throwing width. If used in sloping lands, which is common in the research area, this leads to an uneven distribution of irrigation water, as the pressure differences cannot be controlled. Furthermore, the overhead application leads to excessive evaporation losses. The comparatively high pressure requirements and flow-rates of these systems limit the number of sprinklers that can be operated at the same time. Therefore systems with one or two sprinklers supplied by a flexible hose are widespread as they have low investment costs.

The potential for water saving is high in fruit production. Results from on-farm experiments by JANTSCHKE (2002) suggest that the use of pressure-compensated micro-sprinklers can reduce water consumption by 10%, while moisture-controlled irrigation schemes can even save up to 30% of water. However, as long as irrigation water is not priced, investments in water-saving technology are unlikely to be undertaken. On the other hand, many farmers expressed interest in labor-saving technologies.

2.3.5 Management of Water for Household Consumption

2.3.5.1 Water for Household Consumption in Hmong Communities

Household water supply is a high priority in all Hmong villages. In the largest community of Mae Sa Mai, household water supply is managed by the heads of the six zones into which the village is subdivided. These zones are generally inhabited by members of the same clan which leads to water management for household consumption along kinship relations, in contrast to the management of irrigation water which follows geographical locations of fields and technical possibilities. Villagers are not charged any water fees, but have to respect irrigation restrictions in the upper part of the watershed in order not to jeopardize the water supply of the residential area. The household water system in Buak Chan is also managed in a communal way, but users have to pay a water fee – collected by a respected villager – according to the amount of water used, measured by water meters. This system has been installed as a response to the increasing scarcity of water for household consumption. Due to the fact that all water sources are located below the settlement and water needs to be lifted to the residential area, household water allocation in Buak Chan involves relatively high variable costs.

2.3.5.2 Water for Household Consumption in Thai Communities

Like water for agricultural purposes, access to water for household consumption in Muang Kham has undergone a process of individualization. Today, supply of household water is organized on a private basis. In some cases people use the same water sources for both household consumption and irrigation, sometimes they distinguish between uses. Compared to Pong Krai, where one stream is used exclusively for consumption, sources of water for household consumption are not clearly defined in Muang Kham and can be either streams or wells. For drinking purposes, bottled water is getting more important as many villagers are afraid of pesticide residues in their drinking water. A drinking water company located at the village center resumed production in August 2002. It was built on the private initiative of a villager of Muang Kham but declared as a communal village project, and therefore receives governmental support (NEEF et al., 2004a).

Water provision for household consumption in Pong Krai is organized on a communal basis through a system of tanks, in contrast to the completely individualized management of irrigation water. Household water is taken from the upper zone of one of the two streams, above which no water can be withdrawn for other purposes, which guarantees a continuous water supply of high quality. One villager has been assigned to take care of the system maintenance and collection of water fees. These fees do not take into account the amount of water consumed by the individual households, but are the same for each household. If water for household consumption is getting scarce, the four zones into which the village is divided take turns in getting water. Each household has a private water tank near the house to store water in periods of shortage.

2.3.6 Conclusions: A Comparison of the Sustainability of Various Levels of Water Use in Different Communities

Results of the case studies show that the assumption that water in highland watersheds of northern Thailand is an open access resource is largely inaccurate. Instead, control over and use of water resources are subject to different tenure regimes, rights and obligations. With an increase in the relative importance of water used for irrigation, water rights tend to become more complex and contentious. The findings suggest that community rules and regulations are not equally respected by all villagers; local elites or outside investors often use their social or economic status to increase their share in the control over water resources. This is in contrast to the romanticised picture that some NGOs and human rights advocates tend to draw about local communities as harmonious and peaceful entities, working towards a common goal of sustainable resource management and acting according to local rules.

The question whether local communities in northern Thailand are able to manage water resources sustainably cannot be answered by sweeping statements. As the village case studies have shown, water management in highland areas depends on a complex interplay between geographical, biophysical, technical, economic, institutional and social factors. In Table 2.4 we present a synthesis of the findings along the five guiding principles for sustainable land management that are used throughout this volume. It becomes evident that each village shows both strengths and weaknesses depending on the different dimensions and parameters applied to the analysis. A village like Buak Chan, for instance, shows a high degree of social cohesion and a relatively equitable distribution of water resources, which would classify its water management as sustainable from a social point of view. However, the same village has a limited diversity of water sources, a low forest cover and farmers use large amounts of agrochemicals which raises questions as to the sustainability from the point of view of environmental stability. Other villages (e.g. Pong Krai) have high levels of competition and conflict, but this is partly outweighted by a higher diversity of water sources. Hence, all four study villages can at least claim partial sustainability with respect to water management.

Table 2.4: Sustainability of water management in the study villages.

Name of village	Mae Sa Mai	Buak Chan	Muang Kham	Pong Krai
Ethnic group	Hmong	Hmong	Thai	Thai
Social acceptability (social cohesion, equity of water access, competition, conflicts)	++	+++	+	+
Economic viability (crop diversification, income from irrigated land)	++	++	+++	+
Productivity (yield/water unit, use of water-saving technologies)	+	++	+++	+
Stability (diversity of water sources, water storage systems)	++	+	+++	++
Environmental protection (use of agrochemicals, forest cover,ground water extraction)	++	+	+	+

Legend: + low, ++ moderate, +++ high; in brackets are the parameters that were considered in the analysis.

In sum, we conclude that community-based water institutions have the potential for contributing to sustainable water management in northern Thai watersheds. They have to be integrated, however, into a wider system of checks and balances to avoid the dominance of powerful local elites or outside investors and speculators in competing for scarce water resources. The establishment of river basin committees and sub-basin committees as foreseen in the draft water bill could provide such a system, if these new institutions can be equipped with the legitimacy, power and financial resources that are necessary to coordinate effectively the multiplicity of stakeholders involved in water resource management.

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2.4 The Environmental Fate of Agro-Chemicals: A Case Study in the Mae Sa Noi Watershed

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2.4.1 Introduction

"Pesticides spread their toxic reach," and "the source of life is poisoned". These were headlines of the daily *Bangkok Post* in 1997 and 2001. When the agriculture of Thailand shifted from subsistence farming to the production of cash crops about three decades ago, the farmers in the mountainous area of northern Thailand also rapidly increased their use of pesticides. Farmers, whose livelihoods depend on the downstream flow of water claim that there is too much poison in the rivers. Considerable concentrations of pesticide residues have also been detected in soils, food and breast milk (BAUN et al., 1998; THAPINTA and HUDAK, 2000; STUETZ et al., 2001). Moreover, it was reported that local lychee farmers are poisoned by organochlorine pesticides, indicating careless handling of these substances (STUETZ et al., 2001). Careless use of pesticides may also cause a direct input of pesticides into surface waters. Atmospheric deposition of volatilized pesticides, soil surface runoff and leaching through the soil are further potential pathways through which surface water may be contaminated. However, we are not aware of any studies of the flow pathways of water and contaminants in Thai soils. Thus, the overall aim of our study was to quantify the leaching of pesticides through a soil in a lychee orchard in order to evaluate the contribution of this pathway to the total river water contamination. To achieve this aim we conducted an *in situ* field aging experiment with various pesticides, and we analyzed the flow pattern of water and its dissolved agrochemicals. We also compiled an inventory of of various pesticide concentrations in river water.

2.4.2 Pesticide Concentrations in River Water

To assess the concentrations of a selection of pesticides commonly used in the Mae Sa watershed, three subcatchments with different land-uses (lychee, Mae Sa Mai (MSM); vegetables, Ban Nong Hoi (BNH); and flowers, Ban Pong Krae (BPK)) were monitored in September and October 2002. Pesticide concentrations were measured in daily samples when the water flow in the rivers was normal (baseflow concentrations). Additional samples were taken after rainstorms (peakflow events) in both the flower and the vegetable catchment to obtain a high resolution picture of pesticide concentrations. Pesticide analyses were conducted according to NIKOLAKIS et al. (1999); further details are given in the master thesis of BALLARIN (2004).

Out of the 25 compounds we investigated, a total of 15 substances were found in the baseflow of the three rivers (Table 2.5). In nearly all these samples, chlorpyrifos (occurring in 92 – 100 % of them, depending on the river), dicofol (84 - 92 %), Endosulfan isomers α and β (88 – 96 %) and DDT (92 – 100 %) were detected, the latter despite the fact that DDT has been prohibited since 1999. Endosulfan exceeded the threshold for pesticides in drinking water prescribed by the European Union (0.1 μgL^{-1}) in the baseflow of all three subcatchments. Chlorthalonil was particularily prevelant in the catchment used mainly for flower production (BPK), and metalaxyl in that used for vegetable production (BNH). During peakflow events, pesticide concentrations in river water were elevated compared to those in the baseflow partly due to particle-bound transport which was observed to be almost totally absent in baseflow. Mean sum concentrations of samples collected during the peakflow amounted to 1.72 and 2.23 μgL^{-1} in BPK and BNH, respectively (Figure 2.13). Because of almost bare soils and the high application rates of pesticides, BNH is the subcatchment which is most vulnerable to direct river water contamination. Hence vegetable production – more so than flower or lychee plantations – seems to be associated with high levels of pesticide in the surface waters examined.

Table 2.5: Pesticide concentrations [μgL^{-1}] detected in the baseflow of three subcatchments (Ban Pong Krai (BPK), Ban Nong Hoi (BNH), and Mae Sa Mai (MSM); maximum concentration of 25 daily baseflow samples) of the Mae Sa Noi watershed. One of the herbicides (atrazine), eight of the insecticides (carbofuran, cyhalothrin, cypermethrin, deltamethrin, dimethoate, EPN, monocrotophos, and permethrin), and one of the fungicides (captan) we investigated could not be detected in the baseflow although they were used by at least some of the farmers in the study area.

Substance	Use	MSM	BNH	BPK
Chlorpyrifos	Insecticide	0.06	0.08	0.16
DDT	Insecticide	0.03	0.08	0.04
Dicofol	Insecticide	0.09	0.30	0.13
Dicrotophos	Insecticide	0.01	n.d.	n.d.
Endosulfan-α	Insecticide	0.33	0.43	0.31
Endosulfan-β	Insecticide	0.21	0.22	0.20
Malathion	Insecticide	0.03	n.d.	0.05
Mevinphos	Insecticide	0.03	n.d.	n.d.
Parathion-Methyl	Insecticide	0.01	0.06	0.07
Profenofos	Insecticide	0.29	0.24	0.19
Chlorthalonil	Fungicide	n.d.	0.29	0.41
Difenoconazol	Fungicide	0.07	0.11	n.d.
Metalaxyl	Fungicide	0.59	0.46	0.10
Metribuzin	Fungicide	0.05	0.11	n.d.

n.d.: not detected

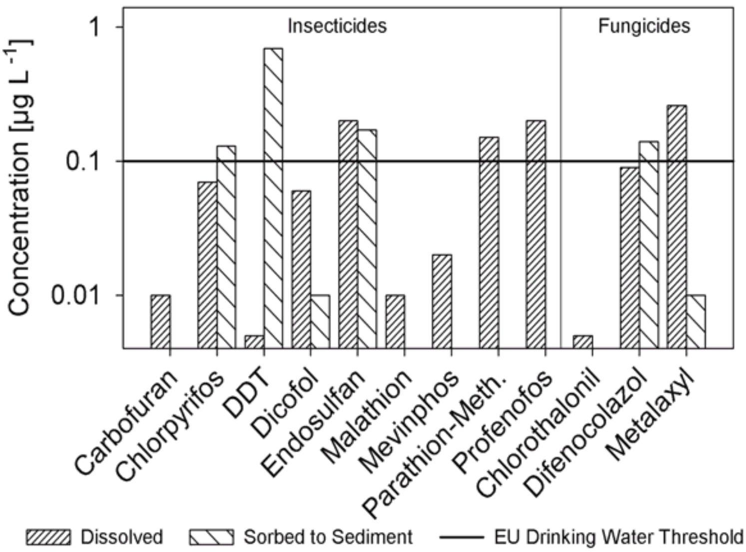

Figure 2.13: Mean sum concentrations of insecticides and fungicides in a peakflow event in the river dewatering the Ban Nong Hoi subcatchment (vegetable production). Total discharge during the peak was ca. 840 m^3.

2.4.3 Field Aging of Pesticides

In a lychee orchard close to MSM, ca. 30 km NW of Chiang Mai, we studied the edaphic fate of insecticides popularly used during lychee production. We applied six substances (chlorpyrifos, dimethoate, endosulfan-α and -β, malathion, and mevinphos), directly onto the soil surface. Following normal local practice, several applications were made (five applications at ten-day intervals). Soil samples were taken regularly and sequentially extracted according to LAABS (2002, modified) to assess dissipation and changes in sorption characteristics. The soil of the study site was classified as a fine kaolinitic thermic Typic Hapludult (acc. to US SOIL TAXONOMY, 1998) or Umbric Acrisol (acc. to WRB 1998). A full description of the experiment is given by BUSCHE (2004).

All six pesticides applied for the aging study dissipated rapidly from the soil (half-life 1.4 – 7.2 d; BUSCHE, 2004). However, the ten-day application intervals were too short to allow complete dissipation of the compounds. That is why we could observe an accumulation in the soil for all pesticides except mevinphos. In Figure 2.14, this tendency is shown using α-endosulfan as an example.

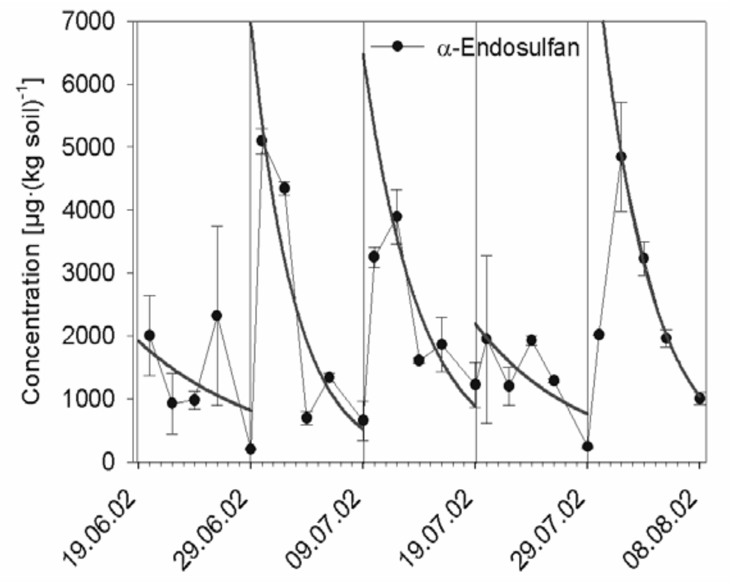

Figure 2.14: Concentrations of α-endosulfan in topsoil (0–0.10 m) in the course of our aging experiment in a lychee orchard. Vertical lines indicate the five pesticide applications; fitted curves show calculated first-order dissipation kinetics. Error bars indicate standard deviation (n=3).

In the course of the experiment, we detected increasing amounts of metabolites in the soil. Endosulfan-lactone, which is a product of both chemical and microbiological degradation of endosulfan (ARCHER et al., 1972; GOEBEL et al., 1982) proved to be more persistent than the parent compound itself (Figure 2.15). This finding indicates that not only the active ingredients, but also the main metabolites have to be taken into consideration if the potential risks of pesticide use are to be evaluated.

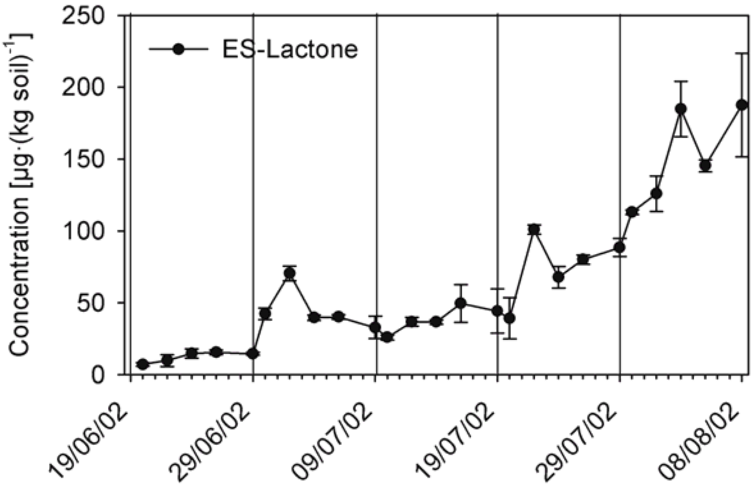

Figure 2.15: Increase in the concentration of endosulfan-lactone, a metabolite of endosulfan, in topsoil (0–0.10 m) during the aging experiment in a lychee orchard. Error bars indicate the standard deviation (n=3).

For some substances such as endosulfan the accumulation in soil during the experiment was accompanied by an increase in "sorption strength". The more time that had gone by, the less extractable the pesticides became, as revealed by the sequential extraction and sorption coefficients (K_{OC}) calculated therefrom (Figure 2.16). This process is referred to as aging (HATZINGER and ALEXANDER, 1995). Due to their reduced extractability, "aged" chemicals are less bio-available and thus less toxic than fresh ones (ALEXANDER, 1995). However, the reduced bio-availability also reduces degradation so that aging promotes the formation of a persistent pool of pesticides in the soil. If environmental conditions change, i.e. with land use change from orchard to arable crops, this pool might be released and pose an ecological hazard.

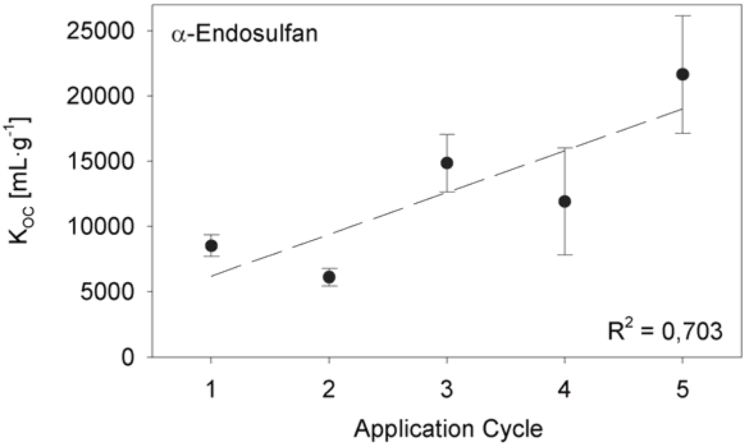

Figure 2.16: Increase of the sorption coefficient K_{OC} of α-endosulfan in the course of the five application cycles (1 application cycle = 10 days). Error bars indicate the standard deviation (n=3).

2.4.4 Water Flow Pattern and Pesticide Fluxes in Soil

At 0.55 m soil depth (B1–B2 horizon transition) two soil profiles on the MSM study plot were equipped with 17 borosilicate suction plates each connected to a computer-controlled soil solution sampling device (CIGLASCH et al., 2005). Soil matric potential was measured automatically, and suction according to this soil tension was continuously applied to the suction plates. In order to avoid chemical decomposition of pesticides in the collected samples (DI CORCIA and MARCHETTI, 1991) and to facilitate their further processing we conducted an *in situ* solid phase extraction with Carbopack B as solid phase (based on NIKOLAKIS et al., 1999).

Differences in the amounts of water delivered by individual suction plates varied substantially both in space and time, indicating a high flow field diversity. This flow field diversity could be described for individual sampling days with a modification of the Simpson Index (SIMPSON, 1949; CIGLASCH et al., 2003):

$$SI = \sum q_i^2$$
$$where\ q_i = \frac{\text{volume delivered by suction plate } i}{\text{total volume of all suction plates}} \quad (2.1)$$

The SI may range from 1 (only one plate delivers water) to $17^{-2} = 0.0035$ (equal amounts of water in all suction plates). Generally, the SI decreased with increasing percolation rates, indicating increasing flow field homogeneity with increasing amounts of leachate. However, we observed a turning point in this correlation at about median percolation rates (4 mm within the two-day sampling interval). We concluded that flow patterns switch from heterogeneous preferential flow to homogeneous matric flow at about median flow rate (Figure 2.17). As the preferential flow occurs at low flux rates and not when the soil is nearly water saturated, it cannot be macropore flow, but must be fingering (HILLEL and BAKER, 1988).

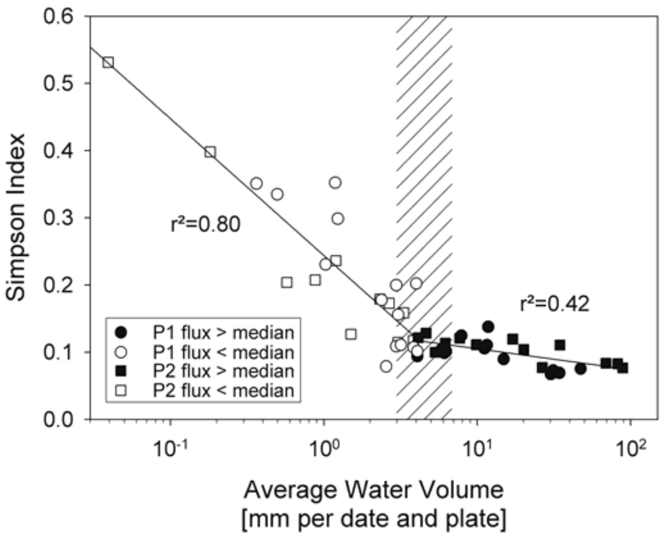

Figure 2.17: Simpson Index (SI) of flow field diversity in relation to leaching rates. P1=Plot 1, P2=Plot 2. The shaded area marks the transition from (heterogeneous) fingering to (homogeneous) matric flow.

However, pesticide leaching could not be linked to the concept of water flow patterns described above. Pesticide translocation occurred almost exclusively during the first rainstorm after application (first flush, Figure 2.18). This translocation was probably caused by preferential flow phenomena, because even the most unpolar pesticides studied were leached into 0.55 m soil depth within 20 h after application. However, we observed a chromatographic separation of the pesticides as described in the literature (ELLIOTT et al., 2000; JAYNES et al., 2001): The more polar the substance, the higher the recovery in soil solution (r^2=0.74; Figure 2.18). Maximum recovery occurred with dimethoate (approx. 2%). Probably, with decreasing polarity, increasing fractions of the freshly applied pesticides had sorbed to the soil surface before the rain set in and translocated the remaining available portions of the compounds.

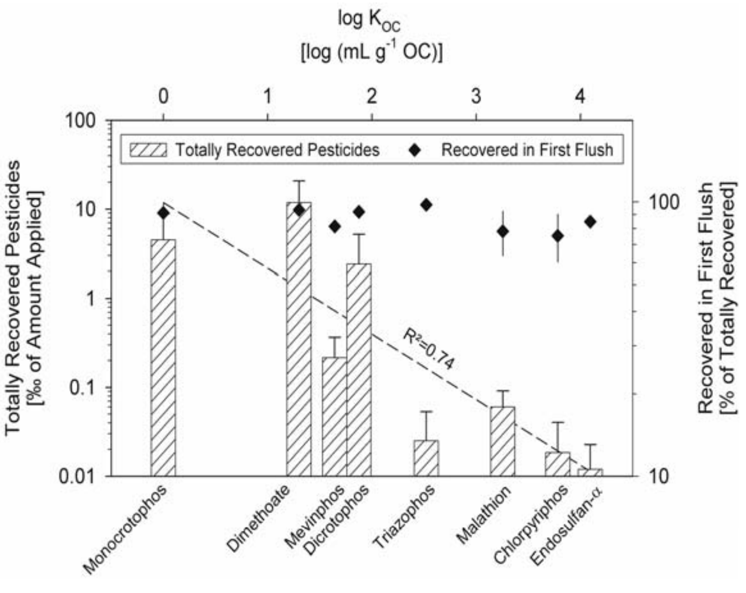

Figure 2.18: Recoveries of the applied pesticides in soil solution (0.55 m soil depth). Vertical bars: total recoveries, diamonds: relative contribution of the first flush to pesticide leaching.

2.4.5 Conclusions

Our experiments revealed that under the given environmental conditions, which are quite representative for the highlands of northern Thailand, pesticides show a rapid initial dissipation after application. Leaching is one pathway that occurs mainly with the first rain storm after application (first flush). This offers the possibility of devising management strategies (timing, single doses) to reduce this effect. As leaching contributes less than 2% to dissipation, other processes such as degradation or volatilisation must exist. As the pesticides studied accumulate in soil after multiple treatments and some compounds tend to be less extractable with increasing time after application we conclude that the formation of bound residues also contributes to the dissipation process. It is possible that bound residues build up a persistent pool of pesticides in the soil that might become active again under changed environmental (i.e. organic matter decomposition due to global warming) or management (land use change from orchard to arable field) conditions. The majority of the substances used in the catchment we investigated could be detected in river water. Thus we conclude that links between the treated area and the surface water exist that are beyond the scope of this study at profile scale. That is why we suggest further investigations of pesticide movement on plot to catchment scale. Since higher concentrations of pesticides and their residues in the river water are partly due to sorbed freights, anti-erosive measures can contribute to a reduction in pesticide loads.

In general, this environmental problem can only be solved by an eclectic approach which includes better education of farmers, alternative pest management strategies and integrated farming systems including adapted equipment. Otherwise sustainable land use as defined in subchapter 2.3 cannot be attained and conflicts between different water user groups will be inevitable.

2.4.6 Outlook

Because we assume that the pesticide loads of the streams are mainly the result of subsurface flow we will pay special attention to lateral transport processes. Consequently, we will extend our investigations to the hill side scale. The experiments will be carried out at the lychee orchard in Mae Sa Mai (i.e. Figure 2.6 and 2.8, chapter 2.2), which covers an area of approximately two hectares and whose variability and hydrological behavior have been partly investigated already (SPOHRER et al., 2005). The aims of our studies are (a) to measure pesticide input to the stream and (b) to model the environmental fate of pesticides at the hill side scale under real conditions. In order to exclude the influences of pre-treatments, tracer pesticides, methomyl and phenmedipham, will be used that are currently not applied in this area. They will be applied at rates and at times common in the region.
Two large flumes were installed at the valley bottom, one upstream and the other downstream to the orchard (Figure 2.8, chapter 2.2). Water samples for pesticide analysis are taken upstream and downstream in proportion to measured discharges, so that it will be possible to directly quantify discharge and pesticide output from the orchard. Direct input of pesticides to the stream from spraydrift will also be assessed (acc. to MELP et al., 2003).

On the hill side, several plot scale experiments will be conducted to directly measure the vertical and lateral movement of pesticides as well as the anisotropy in the hydraulic conductivity of the soil. Tensiometers and TDR (time domain reflectometry) probes will be installed in different lateral positions and at different soil depths to determine the course of hydraulic potentials and water content in the field. The downslope cross-sectional areas of the plots are equipped with fiberglass wick solution samplers. Extracted solutions will be analyzed for the pesticides applied. Each pesticide transport experiment will be accompanied by a bromide and chloride tracer transport experiment.

In addition, a series of topsoil samples was taken from the orchard for analysis of the spatial distribution of pH, organic carbon and clay content. Some of the samples will be used for detailed laboratory experiments on sorption-desorption and degradation. Sorption-desorption experiments will be carried out as described by ALTFELDER et al. (1999). Degradation will be determined as a function of temperature and water content and parameterized by response surfaces (RICHTER et al., 1996).

The experimental results will be used to set up a two-dimensional model, which will be able to simulate transport, sorption/desorption and degradation processes on a hill side scale. The model will be validated by comparison of the measured and simulated pesticide loads in the stream. Based on this model scenarios can be developed to reduce and optimize pesticide application in mountainous non-karst watersheds.

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2.5 Biodiversity and Landscape Structure: Challenges for Insect Management Strategies in Lychee Orchards in the Mountains of Northern Thailand

Dirk Euler, Konrad Martin, Joachim Sauerborn and Vichian Hengsavad

2.5.1 Introduction

Agriculture is the most important of human economic activities. It differs from most other industries in that it is a biological process: the primary products are organic and the resource base is the physical environment including soil, water and solar energy. However, it must always be remembered that other biological components are present in the environment besides the crop plant. A variety of organisms including other plants, animals and microorganisms, representing what is referred to as "biodiversity", are part of the complex agro-ecosystem. What is the relevance of this biodiversity and what are the ways of dealing with it? In the context of agricultural production, global environmental change and the protection of natural resources, several aspects need to be considered.

(1) The establishment of agricultural production systems requires the clearing and preparation of land, thus reducing natural biodiversity in a specific area. In the humid tropics, increasing pressure on land resources due to increasing population results in the reduction of forest areas. The loss of biodiversity due to the decline of such habitats is a well-known fact, and numerous studies deal with the consequences of tropical forest disturbance and fragmentation for fauna and flora (LAURANCE, 2000; WILLOTT et al. 2000, VASCONCELOS et al.,. 2000; DAVIS, 2000; HAMER AND HILL, 2000).

(2) Once established, the agro-ecosystem represents an artificial ecosystem that requires constant human intervention. This

regularly includes a further reduction in biodiversity and changes in natural ecosystem processes. Chemical pesticides replace natural controls on the populations of weeds, herbivores and pathogens. Nutrient and energy flows are altered since plant biomass is harvested and soil fertility is maintained with fertilizers and not by natural decomposition. Thus, the inherent regulation mechanisms of natural communities are lost. Although intensification of management has boosted crop yields, undesirable environmental effects undermine the benefits of modern agriculture. They include environmental and social effects and the costs of pesticide use, soil erosion and salinisation. In addition, the effects on the surrounding environment lead to further reduction in natural biodiversity, largely through eutrophication of terrestrial and aquatic ecosystems by the overuse of fertilizers.

(3) In recognition of the consequences of agricultural intensification, attempts are increasingly being made to develop sustainable agricultural systems. Although the term "sustainable agriculture" lacks a commonly agreed definition, in the context of biodiversity it includes two major aspects. Firstly, a sustainable agricultural system protects the integrity of natural systems, so that negative impacts on natural biodiversity are minimised. Secondly, it incorporates the ecological advantages of natural biodiversity into the production system in order to restore the scattered elements necessary to provide homeostasis of the agro-ecological community.

2.5.2 Effects of Pesticide Use in Lychee Orchards and Dominant Harmful Insects

The present ecological situation in the mountainous regions of Southeast Asia reflects two main problems concerning natural resource management. First, there is the need to develop and establish sustainable land use systems, which fulfil the demands of the farmers and reduce the ever increasing pressure on the remaining natural areas. Second, the loss of natural diversity is not a problem of disappearing species alone, but may also influence functioning and management strategies of agroecosystems.

In the hillsides of northern Thailand, the cultivation of fruit trees (mainly lychee) is one of the major sources of income for local farmers. For example in the research area Mae Sa Valley (ca. 35 km northwest of Chiang Mai), ca. 2500 ha or 65% of the catchment area are used for lychee production. The management is characterized by high inputs of pesticides. Herbicide use results in a grass dominated undergrowth of low diversity.

Although lychee farmers practice intensive use of insecticides, most of the lychee trees are heavily attacked by a number of arthropod pests. Nearly all lychee trees are infected by the Lychee erineum mite (*Eriophyes lycheei*), leaf beetles (*Monolepta rugipenis*), and around 50% are damaged by a bark feeding borer (*Indarbela* sp.). During the harvest season 2001, up to 30% of the lychee fruits were damaged by the lychee fruit borer (*Coponomorpha sinensis*) and other lepidopterous larvae. Another important pest is *Tessaratoma papillosa* (Heteroptera: Pentatomidae, Lychee stink bug): This species sucks sap from young twigs and as a result, fruits drop off before ripening. Scolytidae (Ambrosia beetles) damage the stems by boring galleries which they use as dwelling tubes.

2.5.3 Biodiversity Relationships between Orchards and the Surrounding Landscape

Species diversity and functions, such as the interactions between pests and beneficials, may be influenced by species originating from the habitats surrounding the agricultural site. In general, the arthropod inventory and diversity of (tropical) cultivated landscapes can be strongly influenced by the following factors (BOMMARCO and EKBOM 2000; BUREL et al., 2000, IRWIN et al., 2000; DENNIS et al., 2000):

a) the structure of the landscape in terms of fragmentation, heterogeneity, and proportion of unmanaged areas,

b) the types of land use (e.g. agroforestry systems, orchards, annual crops, abandoned land), and
c) the intensity of production (high vs. low input systems).

Concerning arthropods, the colonization and diversity of species in the different landscape elements depends on their habitat requirements, their mobility and the distances between sites. Thus, studies on the fauna present in different habitat types cannot be restricted to making inventories, but also need to identify the sources and sinks of colonisation.

Several studies have shown the relationship between the structural complexity of the landscape and the diversity of natural enemies in fruit orchards. In general, species diversity of natural enemies was higher in systems surrounded by diverse vegetation, especially woodlands (e.g. GUT et al., 1982; SZENTKIRALYI and KOZAR, 1991).

However, interactions between natural and agricultural systems are more complex. Many studies also show that woody borders enhance both herbivore and pest populations. Woodlands can represent a complementary or refuge habitat for pests, especially if insecticides are used. On the other hand, woody borders can also act as barriers that prevent insects moving out of the fields (BHAR and FAHRIG, 1998 and references therein).

Spatial and temporal movement patterns of two lychee pest taxa (*Tessaratoma papillosa* and Scolytidae) were studied at an experimental site in the Mae Sa valley during the growing season in 2004 in order to evaluate the abundances of specimens migrating between orchards and adjacent forests. Established groups represent immigrants (forest migrants), emigrants (orchard migrants) and specimens that are active only in the orchard (orchard roamers; Fig. 2.19). One-way ANOVA indicates significant differences ($p<0.05$) exist only between the affiliation groups of Scolytidae. The Bonferroni post hoc test reveals significant differences ($p<0.05$) only between orchard migrants and orchard roamers of Scolytidae.

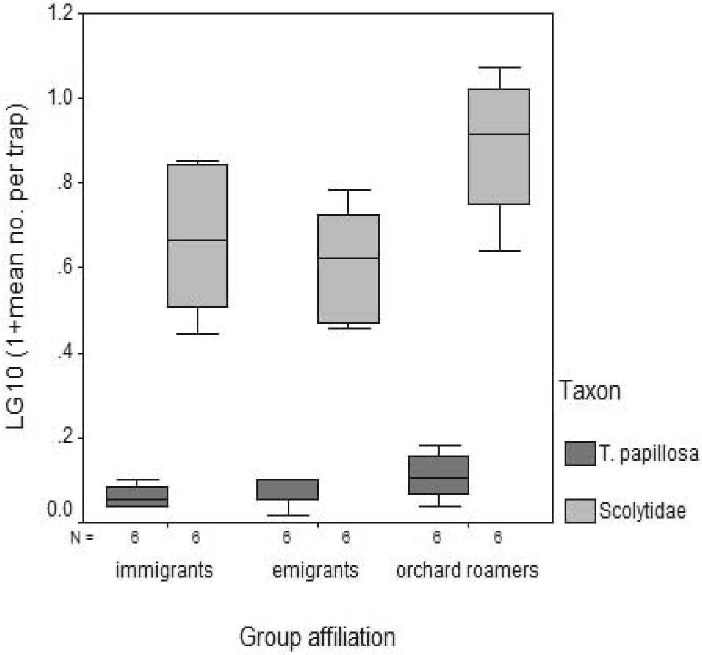

Figure 2.19: Spatial movement patterns of *Tessaratoma papillosa* and Scolytidae at the Mae Sa research plot. (Box and whisker plots illustrate the 5th, 25th, 50th (median), 75^{th} and 95^{th} percentiles).

The results indicate a constant exchange of specimens between the two landscape elements. There is a complementarity between immigrants and emigrants the abundances of which are approximately equal. The activity of the migrants is similar to that of the insects within the orchard so from these data, an equally distributed population structure can be assumed. Consequently, pest control methods will be ineffective if the population in the orchard can be easily replaced by immigrants from adjacent habitats.

The spatial movement patterns and the seasonal activities of *Tessaratoma papillosa* (Fig. 2.20) and Scolytidae (Fig. 2.21) are obviously different. The abundance of *T. papillosa* fluctuated greatly during the season. In contrast the abundance of Scolytidae was high at the beginning of the season and decreased gradually with time. The seasonal activity of *T. papillosa* shows two distinct peaks in March and April. *T. papillosa* depends on fresh shoots for food so these peaks probably represent two successive generations. The number of insects decreases rapidly at the end of the lychee season in May/June. In the off-season it can be presumed that the population density of *T. papillosa* in the orchard remains low.

Since Scolytidae spend most of their life in galleries under the bark of trees they are hard to detect except during the mating season. This part of the life cycle of Scolytidae is related to the phenology of lychee because in the flowering period the plant tissue is richer in nutrients and provides a suitable food for the offspring.

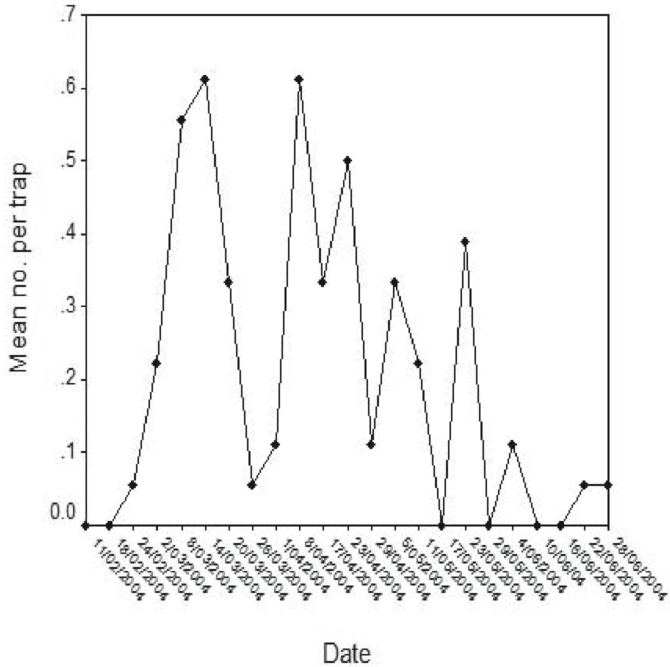

Figure 2.20: Seasonal activity of Tessaratoma papillosa at the Mai Sa research plot.

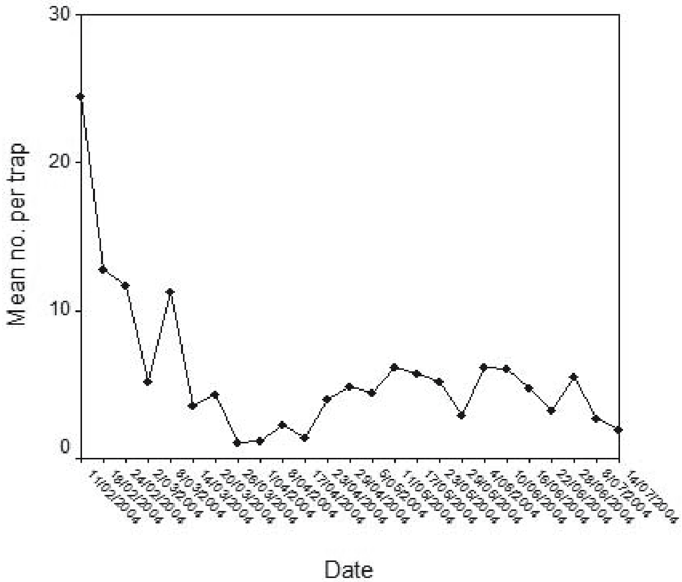

Figure 2.21: Seasonal activity of Scolytidae at the Mae Sa research plot.

2.5.4 Conclusions

Biodiversity in tropical landscapes includes species existing in natural habitats as well as species existing in agricultural systems. The latter may include beneficials, but also pests which migrate in from surrounding structures. With respect to biodiversity, conservation and pest control, strategies in the management of agroecosystems (orchards in this case) need to take these interactions into account. The challenge for new approaches is not only to establish sustainable production systems at the plot or farm scale, but to establish sustainable cultivated landscapes. There is a demand to develop strategies for maximized pest control while maintaining woodlands as natural elements in the conservation of biodiversity. However, for insect pest management, the desirability of woody borders depends on a trade-off between several factors. On the one hand they can cause an increased predation of the pest population by natural enemies and a decreased colonisation of orchards but on the other they can provide an alternative, additional habitat or provide a barrier that prevents certain pests migrating out of the agricultural system. A long-term goal in the study of cultivated landscape biodiversity is to predict the effects of landscape transformation on the diversity of arthropod species originating from natural habitats as well as on species within agricultural systems. This may include the use of simulation models to determine the conditions under which the regional effect of woody borders on colonisation can outweigh local enhancement effects of borders on pest populations, as presented by BHAR and FAHRIG (1998).

To sum up, the results call for a rethinking of i. pest management strategies, ii. traditional land use planning - which is so far solely determined by the physical and socio-economic environment - and iii. the concept of sustainability.

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2.6 Synthesis: Constraints to Sustainable Use of Soil and Water in the Northern Thailand Highlands and Consequences for Future Research

Ludger Herrmann and Mattiga Panomtaranichagul

Research discussed in Chapter 2 leads to the following conclusions for sustainable resource use, land use planning and scenario development:

i. **There is a lack of information on the available resources at an acceptable resolution** (i.e. 1:200.000 and finer). Neither for soil nor for water are sufficient data available (subchapter 2.2). This calls for action by the authorities at both the national and regional level. In future it needs to be recognized that the highlands cannot remain a forest reserve but are – respecting certain constraints and rules - a valuable resource for the growing population.

ii. **Thai soil taxonomy classifies highland soils as "Slope Complex Soil Series" which is meaningless and not helpful for any kind of land use planning**. Modern approaches already call for three dimensional soil and terrain information, eg. including relief, geo-morphology etc. Therefore, the so called "slope complex" needs a detailed inventory with respect to soil and water resources and use.

iii. **Resource management has so far not been sustainable**. Many cropping patterns, including cash crops, off season production, irrigation, hydroponics, have been proposed and tested by national and international institutions (subchapters 2.1 and 3.3). In particular, practicable anti-erosive cultural practices have been identified. However, such systems have not been successfully adopted or widely used by the highland stakeholders. Insecure land tenure, lack of access to markets and credit, and availability of extension services are some of the reasons. Consequently, the highland population needs help with a variety of infrastructure measures including transport and communication, education and institutional support.

iv. **For several decades, overuse of highland resources has caused severe on- and off-site effects** (i.e. depletion of soil nutrients, overconsumption and pollution of water, and loss of water storage capacity). Poor education and a lack of consistent environmental laws prevent reasonable co-ordination and efficient resource allocation.
v. **Finally, the local communities have developed rules for the use of their limited resources** (i.e. water allocation in their territory). Future progress should be built upon existing local knowledge and structures. Increasing shortages call for an overall coordination by state authorities to balance the interests of different stakeholders (i.e. up- vs. downstream users of water).

Research in this area has confirmed that the sustainability concept for land and water management needs to integrate social acceptability, economic viability, productivity, stability and environmental protection (subchapter 2.3). Due to the complexity of this task, the use of modeling tools is needed. However, there are still gaps in our knowledge even of single processes from the micro profile to the watershed scale (i.e. pesticide transformation and translocation in the landscape, subchapter 2.4). Elucidating these single processes involves the emergence of a new paradigm which calls for landscape-scale research even when one is trying to solve a field-scale problem. Entomological research (subchapter 2.5) revealed that field scale population dynamics of arthropods can only be understood by taking the different use patterns of the surrounding land into account. This spatial interdependence is also known to exist for abiotic solute transport in soils. In order to interpret and model these spatial processes, we need to analyse stochastic, oriented and structural (often man-made) variabilities of properties rather than assume homogeneity.

In summary, **developing a sustainable resource management in the highland of northern Thailand is a multi-dimensional problem. It needs an interdisciplinary and cross-cultural approach, working on different scales** and integrating administrative as well as socio-economic and natural processes. This can only be achieved within a co-operative framework. Topics of further research work should be **(i).** developing a consistent regional database (approx. scale 1:200.000 or finer) with respect to natural resources as a pre-requisite of land use planning, **(ii).** addressing environmental problems and possible solutions including legislation on the regional level, **(iii).** providing modeling tools for scenario assessment on different scales, and (iv) developing land use strategy packages rather than single measures for different environments.

3.0 Sustainable Fruit Production and Processing Systems

3.1 Introduction

Pittaya Sruamsiri and Sybille Neidhart

This chapter focuses on adjusted strategies for both production and utilisation of mangoes (*Mangifera indica* L.), lychees (*Litchi chinensis* Sonn.), and longans (*Dimocarpus longan* Lour.) in Southeast Asian highlands. It includes information on the whole production cycle from fruit production through fruit processing to marketing. We will discuss briefly the economic significance of fruit production in the area under study and define the characteristics of sustainable fruit production and processing in an area of the Southeast Asian highlands, typical of northern Thailand.

3.1.1 Economic Significance of Fruit Crops

Agricultural land use in northern Thailand presently covers $4.048 \cdot 10^6$ ha, which is approximately 25 % of the agricultural land of the whole country. Major crops are paddy rice, fruit trees and annual crops such as vegetables, flowers and corn. Such diversification of the cropping systems, in addition to productivity gains, has considerably contributed to recent growth in crop production in Asia, where largest gain came from fruits and vegetables (RERKASEM, 2005). The northern part of Thailand comprises main producing areas for longans, mangoes, and lychees, with total planting areas of 90,864 ha, 55,360 ha, and 17,399 ha, and annual yields of ca. 378,000 t, 250,250 t, and 76,348 t, respectively (OFFICE OF AGRICULTURAL ECONOMICS, 2004; DEPARTMENT OF AGRICULTURAL EXTENSION, 2004). Strawberries also belong to the major crops of the region. Northern Thailand produces 90 %, 75 %, and 21 % of the total yields of longans, lychees, and mangoes, respectively, in the whole country. The development of fruit production is shown in Table 3.1 for these fruit species. Longan is one of the top three of economic fruit crops in Thailand, whereas lychee ranks eleventh (MENZEL, 2002). Together with Southern China and Taiwan, northern Thailand is one of the main cultivation areas for longan worldwide (TINDALL, 1994; CHOO, 2000).

Table 3.1: Development and economic significance of major fruit crops in northern Thailand.

Fruit species	Planting area [ha]				Yield [t]				Export [t]
	2000	2001	2002	2002 (Thailand)	2000	2001	2002	2002 (Thailand)	2002 (Thailand)
Longan	74,016	85,104	90,864	100,960	358,000	187,000	378,000	420,000	113,191
Lychee	18,306	18,915	17,399	20,800	66,783	60,946	76,348	101,798	16,112
Mango	88,640	73,920	55,360	333,172	410,386	361,766	250,250	1,183,677	8,737

Source: Office of Agricultural Economics (2004); Department of Agricultural Extension (2004)

Approximately 27 % and 16 % of the total Thai yields of longans and lychees, respectively, were exported in 2002. With approx. 80,000 t/a and 50,000 t/a, Thailand and Vietnam rank directly after China and India as the major producers of lychees (MENZEL, 2002; STERN and GAZIT, 2003). Thailand contributes significantly to the lychee export market and dominates that of the longan. It has an advantage in the international market-place because fruits are produced earlier in the year there than in the other major regions. In addition to the major longan exporting countries, Vietnam has recently started exporting this fruit (CHOO, 2000). Although longans are one of the top export goods in Thailand, this fruit crop is mainly targeted at ethnic markets, particularly those of Asian communities (CHOO, 2000), unlike lychees and mangoes.

According to the FAO statistics, which do not explicitly show lychees and longans, mango production in Thailand and Vietnam comprised 6.7 % and 1.3 % of world production ($26.3 \cdot 10^6$ t) in year 2004 (FAO, 2005a). After India (41.1 %) and China (13.8 %), Thailand is thus the third largest mango producing country, closely followed by Mexico (5.7 %). However, 23.5 %, 19.5 %, and 15.0 % of the 918,999 t of mangoes offered in international markets in 2003 were exported by Mexico, India, and Brazil, respectively, while Thailand and Vietnam only contributed 0.88 % and 0.0075 %. The proportion of the national crop exported by Thailand and Mexico differs greatly. This is partly due to differences in the local diets, and may also be because each country has its own suite of cultivars. There are two major evolutionary classes of mango cultivars, the tropical East Asian (Indochinese) and the subtropical Indian (syn. West Indian) group (WHILEY et al., 1989). The export market is dominated by three cultivar classes of the latter — the Indian, the West Indian, and the Florida group (LIEBSTER and LEVIN, 1999). The East Asian group is characterised by flattened, kidney-shaped, somewhat elongated fruits with light green or yellow peel, and little or no red colouration. East Asian mangoes generally have a polyembryonic seed, and many are resistant to anthracnose, the major fungal disease of mango. In contrast, the Indian group contains cultivars that are more rounded and plump, and generally have a bright red blush to the skin. Indian mangoes are usually susceptible to anthracnose, and have a monoembryonic seed that facilitates breeding efforts. Hybrids between the two groups have been produced using the Indian type (monoembryonic) as the female parent.

The commercially most important mango cultivars in Thai markets are `Kiew Sawoei´ (= `Khiew Sawoey´), `Nang Klanwan´, `Nam Dokmai´ (= `Nam Doc Mai´), and `Thong Dam´ (LIEBSTER and LEVIN, 1999). Of the numerous local varieties in Thailand, Ok-Rong, Rad, Pimenmun, Fahlan, Petchbanlad, Chackuntip, and Salaya are also important (SUBHADRABANDHU, 1986). Among lychees, the prevailing cultivars in Thailand are the subtropical varieties `Hong Huey´ (= `Tai So´), `Kim Cheng´ (= `Wai Chee´), and `Oh Hia´ (= `Haak Yip´, `Baidum´) (NAKASONE and PAULL, 1998; LIEBSTER and LEVIN, 1999) as well as Chacapat, apart from some tropical cultivars of inferior quality such as `Kom´ grown in the lowlands of Central Thailand (MENZEL, 2002). Vietnamese lychee production is dominated (80-90 %) by `Vaithieu´ (`Thiew Thanh Ha´) as single cultivar (MENZEL, 2002; MITRA, 2002; HAI and DUNG, 2002). Approximately 73 % of the total area under longan in Thailand has been planted with the early-maturing cultivar `Daw´, followed by mid-maturing `Chompoo´ (= `Seechompoo´) and the late-maturing cultivars `Haew´ and `Biew Khiew´ (CHOO, 2000).

Whereas mango production increased from 2000 to 2004 by 6.21 % worldwide and by 7.13 % in Thailand, it rose by 90.1 % over the same time in Vietnam (FAO, 2005a). The area used for cultivation of mangoes increased similarly in this period: by 5.62 % to 3,699,434 ha worldwide, by 7.44 % to 290,000 ha in Thailand, and by 60.6 % to 75,000 ha in Vietnam. Hence, Thailand provided the third largest area for mango cultivation (7.84 %) after India (43.2 %) and China (11.3 %), followed by Mexico (4.70 %), Indonesia (4.59 %), and the Philippines (3.73 %).

Although mango fruits from Thailand are still relatively unknown in international, particularly Western markets, Thailand is a major exporting country of mango pulp. The exported quantity has increased by 35.5 % since year 2000 to 9,060 t in 2003. With 13,125 t of mango juice and 78,750 t of mango pulp, Thailand contributed 8.67 % and 8.84 % to world production in 2004. The importance of fruit drying in Thailand is shown by a production of 90,000 t of dried fruits and 45,000 t of dried tropical fruit of species not specified in the FAO database. This constituted respectively 20.2 % (Vietnam: 3.64 %) and 30.6 % of the world production in 2004 (FAO, 2005a). Thailand has consistently been the leading exporting country for dried fruits. In 2003, it exported 125,857 t or 35.6 % of worldwide export quantity.

3.1.2 Ecological Aspects of the Fruit Crops under Discussion

The mango is naturally adapted to tropical lowlands between 25 °N and 25 °S of the Equator and up to elevations of 3,000 ft (915 m) (MORTON, 1987), but can be grown up to 1200 m in tropical latitudes (BALLY, 2004). However, most commercial varieties do not produce consistently above 600 m (BALLY, 2004), as this fruit grows best in seasonally wet/dry climate zones of the lowland tropics, or frost-free subtropical areas. Mango trees made up respectively 42 %, 34 %, and 23 % of the fruit trees on foothills, hills (500-1800 m), and terraces (400-500 m) in 64 orchards investigated in the northern Thai region of Phrao in 1993 (DE BIE, 2004). A dry and/or cool season causes uniform floral initiation and tends to synchronise bloom and harvest. Trees have a high water requirement during fruit maturation, but tolerate "winter" drought well (MORTON, 1987). However, rain or free moisture caused by high humidity, heavy dew, and fog, during flowering and fruiting encourage the development of fungal diseases that cause flower and fruit drop (BALLY, 2004). According to the comparative performance analysis of northern Thai orchards by DE BIE (2004) for the region of Phrao, one of the factors that contributed to increase in yield was that the orchard was situated on a hill or on soils with relatively high pH or poor water- holding capacity, concordant with good drainage required for mango, although application of supplementary irrigation water had to be possible. Lychees produce best in subtropical regions not subject to heavy frost but cool and dry enough in the winter months to provide a period of rest (MORTON, 1987). The fruit crop thrives best on the lower plains where the summer months are hot and wet and the winter months are dry and cool. Hence they are usually commercially grown at low elevation in the subtropics and from 300-600 m in tropical locations (MENZEL and SIMPSON, 1994), although particular cultivars can be grown up to an altitude of approx. 1000-1100 m (KADAM and DESHPANDE, 1995). The more hardy mountainous types of lychee, like those grown near salt water, are very sour (MORTON, 1987). Mature lychee trees can withstand light frosts, as the cold tolerance of the lychee is higher than that of the mango tree. Longans are indigenous to lowland and middle elevations in Southeast Asia and grow at elevations from 6 to 1500 ft (1.8-460 m) (CRANE et al., 2000), as climatic requirements regarding flowering are less exacting than for lychees (NAKASONE and PAULL, 1998; CHOO, 2000). However, the longan is a subtropical tree that grows well in tropical areas as long as there is a distinct change of seasons to stimulate satisfactory flowering (CHOO, 2000). It can be found growing at higher latitudes and altitudes than the lychee (MORTON, 1987). On the higher elevations of the mountainous regions which are subject to frost, the subtropical longan may even appear more often than the lychee but it, too, cannot stand heavy frosts.

According to MORTON (1987), the mango tree is not too particular as to soil type, providing it has good drainage. Rich, deep loam contributes to maximum growth, but if the soil is too rich and moist and too well-fertilised, the tree will respond vegetatively but will be deficient in flowering and fruiting. The mango performs very well in sand, gravel, and even oolitic limestone. The lychee, too, grows well on a wide range of soils.

Though it has a high water requirement, it cannot stand water-logging so the soil should be always moist and the drainage good (MORTON, 1987).

3.1.3 Characteristics of Sustainable Fruit Production and Processing

Plantation of perennial fruit trees with cover crops could be an ecologically important and economically valuable alternative to the use of erosion-prone annual crop and vegetable production systems on sloping sites in the mountainous regions of Southeast Asia. Sustainability of fruit production as a necessary prerequisite for acceptance or further extension by the local farmers has been already emphasised in Chapter 1. The most striking characteristics of sustainable fruit production and processing systems might be their ecological compatibility as well as the profitable production and distribution of safe products with high nutritive value at all levels of the food chain. In this context, safety means both hygienic handling of the good and the absence of intolerable levels of agrochemical or environmental residues (see Chapters 2.4 and 5.3). Moreover, ecologically compatible systems are dedicated to the responsible use of necessary resources (Chapters 2.3 and 3.5) and, especially in processing, to minimisation of waste production by recycling of waste material. However, implementation of these objectives in real interwoven systems is far from being simple and involves many compromises. On the way towards sustainable production systems at each level of the food chain, the challenge is to find a balance between partly contrary objectives.

It has been claimed for a long time that alternate or irregular bearing is the natural behaviour of many economically important tropical and subtropical fruit trees (WESTWOOD, 1995), in particular for the fruit crops under study (CHOO, 2000; STERN and GAZIT, 2003; DE SOUZA et al., 2004; DE BIE, 2004). The plant develops strong flowering and high fruit-set one year and very poor yields the following year. This phenomenon complicates yield estimation and marketing management. In spite of numerous research approaches throughout the world, few successful measures have been reported (see Chapter 3.3). Efficiency of treatments was ambiguous, as flowering and fruit-set could often be promoted in some years only. Further studies were therefore required to stabilise and improve fruit production in Thailand (Chapters 3.2-3.4). In recent years, for several reasons, prevention of alternate bearing of fruit trees by the application of relatively low-cost technologies that enable stable long-term productivity has become increasingly important in northern Thailand:

- Since the growth of tourist and service industries in large cities accelerates labor migration out of the agricultural sector, the remaining farmers have to change their crop pattern from labor-intensive annual cash crops to fruit orchards with much lower labor demand.
- In view of the attempts to encourage export-based economic development, including the export of fresh and processed fruit products, food safety and quality as well as low investment costs are vital to retaining international competitiveness (see e.g. Chapter 3.6).
- As a consequence of reallocation and legalisation of land ownership policies, farmers have changed land use strategies. Planting of fruit and forest trees has dramatically expanded in some watersheds to demonstrate long-term land ownership. In this case, fruit harvesting is of secondary importance.

As there are many factors involved in attempts to stabilise and improve fruit production, an interdisciplinary approach is needed. Plant nutrition and water-saving irrigation techniques, horticultural aspects regarding flowering and fruit-set as well as postharvest utilisation of the crop are discussed in this chapter (Chapters 3.2-3.7) while other related topics such as optimised pest- and water-management have already been addressed in Chapter 2. To optimise the water and nutrient balance of a fruit orchard, information about local climatic conditions (weather station), water retention capability and nutrient composition of the soil as well as water demands of the trees has to be gathered. In this way, irrigation systems that match the needs of the plants can be installed and proper watering schedules can be developed and used in combination with fertilisation to improve the yield and quality of the fruits (Chapters 2.2, 2.3 and 3.2). Identification and evaluation of the major pests is considered an essential first step towards improved pest management. In this context, further attempts to

optimise chemical pest control and to promote predators by improving agro-biodiversity through introduction of various cover crops or manipulation of the existing vegetation, for example by regular mowing, will be of increasing interest (Chapter 2.5).
Productivity of both fruit production and fruit processing ideally requires steady operation with respect to time and quantity. For many years, however, the utilisation of the three fruit species under discussion has been limited owing to the short harvesting seasons of a few weeks (harvesting periods: see Chapter 3.3) and the alternate bearing of the trees. Fruit yield, farmers′ income, and availability of raw material to food manufacturers have been irregular and thus hardly commercially attractive. Consequently, fruit production has almost exclusively focused on fresh fruit marketing. Processing has been restricted to small seasonal amounts and hence based on rather simple processes, mainly canning and drying (KADAM and DESHPANDE, 1995; CHOO, 2002). The economic significance of dried fruit products has been shown above (FAO, 2005a). Labor-intensive multi-purpose processing lines have been established, mostly consisting of a minimum of basic equipment for food preservation, and applicable to many types of raw material, to ensure efficient use of the equipment throughout the year (Chapter 3.7). Employment has mostly been characterised by seasonal peaks. Such processing lines have been advantageous to the dynamics of the market. Product quantities can be provided according to market demand, at least as long as demand and raw material quantities are low enough to be managed by the available manpower.

Exclusive processing of fruits into solid goods often results in an unequal competition between processing and fresh fruit marketing for upper-grade fruits, which provide the best profits for farmers and manufacturers. On the other hand, sustainable utilisation of the fruits should mean that seasonal overproduction and losses by spoilage are minimised. In fresh fruit marketing, sufficient access to fresh product markets is thus a prerequisite; in processing, profitable use of fruits of varying sizes and specifications should be enabled by diversified processing to meet natural variations in fruit size and quality.

To withstand varying climatic effects in fruit production and changing market demands in processing, options for

diversification, based on a central pool of skills, are needed in fruit production and processing at each level of the food chain. In Chapters 3.6-3.7, this has been exemplified for fruit processing by presenting adapted multi-utilisation concepts.
Such multi-utilisation concepts require the supply of specific qualities of raw material for individual processing alternatives. Quality control of the raw material as well as fast and reliable sorting mechanisms are consequently of utmost importance for manufacturers (Chapter 3.6). However, profitable utilisation alternatives involve even more: They should be independent of fresh fruit markets for both farmers and manufacturers since the quality demands in fresh fruit marketing and processing may differ considerably. The required quality of raw material should be provided to the factories by the most direct delivery routes possible. Diversification would thus also mean that the further utilisation of the fruits has to be considered at the outset and during their cultivation and harvest (goal-oriented fruit production with fresh-fruit marketing and different processing variants as various parallel ends).

Recent research, therefore, has focused primarily on productivity of fruit trees and extension of fruit availability, since these are the main prerequisites for attractive fruit tree cultivation. Research into northern Thailand's scarce resources, ranked in Chapter 1, was accompanied by investigations into water-saving irrigation techniques (Chapter 3.5). Progress and observed effects are discussed in the next four contributions (Chapters 3.2-3.5), mainly with longan as an example. In parallel, the potential of the fruit species was investigated, characterising the properties of local cultivars, especially for mangoes and lychees. Emphasis was laid on the evaluation of the quality of raw materials and on possibilities for innovative sorting mechanisms (Chapter 3.6). Considering processing options for specific qualities of raw material, process technologies were developed or optimised for the maintenance of high nutritive value and attractive sensory profiles (Chapters 3.6-3.7). Finally, key results and consequences for future research strategies are discussed in Chapter 3.8.

3.2 Stabilisation of Fruit Production by Optimised Plant Nutrition

Sithidech Roygrong, Pittaya Sruamsiri, Fritz Bangerth, Ludger Herrmann, Volker Römheld

3.2.1 Introduction and Objectives

In the orchards of small-scale farmers in northern Thailand, low input of fertiliser often results in insufficient, low quality fruit yields particularly from older trees. This generally low input of fertilisers and other agrochemicals has been well documented. Deficiencies of micronutrients such as boron (B) and zinc (Zn) have also been frequently reported for Southeast Asia (DONG et al., 1997; BAHADUR et al., 1998) and might affect flower induction, fruit set and fruit growth.

As a prerequisite for the development of optimised fertilisation management of subtropical fruit orchards in northern Thailand, an inventory and evaluation of the nutritional status of soils and trees seemed to be necessary. For this purpose, lychee orchards at representative sites near Chiang Mai in northern Thailand with soils derived from different parent material (granite, sandstone and limestone) were selected for leaf and soil sampling.

Fully expanded leaves of the 2nd youngest flush were collected at different dates during the growing season in 2001 and analysed for macronutrients (N, P, K, Ca, Mg, S) and micronutrients (Mn, Fe, Zn, Cu, B). At one site (Mae Sa Mai), leaves and fruits growing on the North, South, East and West sides of trees were collected separately and analysed in an attempt to explain the observed differences in fruit set at the four different quarters of the same lychee tree. Representative soil samples were collected at the three sites and analysed for pH and extractable mineral nutrients following standard soil analysis methods (ROYGRONG, 2002) and evaluated in the light of data from the literature (BERGMANN, 2002).

3.2.2 Nutritional Status of Lychee Orchards in Northern Thailand

The data from leaf analysis revealed adequate levels of most macronutrients (N, K, Ca, Mg, and S) as well as the micronutrients Mn and Fe (data not shown). Lychee trees at the site where the soil was of granitic origin had a low (L) nutritional status for P (deficiency range) in comparison with those at the other two sites whose nutritional status was adequate. However, it was obvious that leaves contained very low levels of Zn (deficiency range, L) and particularly B (extreme deficiency range, VL) (Table 1). The results for the concentrations of mineral elements in fruits were similar to those for leaves. There were no significant differences between the mineral concentrations of leaves and fruits taken from the four different quarters of the same lychee tree nor between those measured at different times during the growing season (data not shown).

The low levels of P and particularly Zn and B in the fruit and leaves of the trees corresponded closely with the levels of extractable mineral nutrients found in the soil at depths of 0 – 15, 15 – 30, 30 – 45, and 45 – 60 cm (Table 3.2).

Table 3.2: Nutritional status of top soil and of fully expanded leaves of the 2nd youngest flush of lychee trees at three different sites with soils from various parent materials.

Mineral nutrient	Parent materials of representative lychee orchards		
	Granite (pH 5.8)[a]	Sand stone (pH 4.8)	Lime stone (pH 7.5)
	Extractable nutrients in soil		
P[b] (mg/kg)	8.8 (VL)[c]	13.2 (VL)	18.5 (VL)
Zn[d] (mg/kg)	1.1 (L)	2.6 (L)	1.7 (L)
B[d] (mg/kg)	0.1 (L)	0.2 (L)	0.1 (VL)
	Mineral nutrient concentration in leaves		
P (%)	< 0.1 (L)	0.3 (A)	0.3 (A)
Zn (mg/kg)	11.0 (VL)	15.0 (L)	15.0 (L)
B (mg/kg)	4.8 (VL)	6.3 (VL)	7.1 (VL)

[a] pH ($CaCl_2$) in the top soil under lychee trees
[b] Calcium acetate lactate (CAL) extraction method
[c] Nutritional status: H = high, A = adequate; L = low; VL = very low
[d] Diethylenetriaminepentaacetate (DTPA) extraction method
All experimental details as described by ROYGRONG (2002).

3.2.3 Evaluation of the Mineral Status of Lychee Trees for Optimal Flower Induction and Fruit Set

The low B and Zn nutritional status of lychee trees at the three representative sites (Table 3.2) have to be recognised as a possible cause of the inadequate flower induction and fruit set observed in numerous orchards belonging to local farmers in the area under study.

During the winter season 2001/2002 transient symptoms of chlorosis could be observed on leaves of lychee trees (2nd youngest flush) at the Mae Sa Mai site, but only on the south/south-west side of the trees where the intensity of sunlight was highest. On the north side, no such symptoms of chlorosis could be observed (Figure 3.1 (A)). These symptoms resembled the 'bleach out' of chlorophyll caused by photooxidative stress as observed in cases of Zn deficiency (MARSCHNER and CAKMAK, 1989; CAKMAK et al., 1995) and/or B deficiency (CAKMAK and RÖMHELD, 1997) at similar high light intensities.

Figure 3.1: Lychee trees showing leaves of the 2nd youngest flush with chlorosis symptoms (A) and different extents of flower formation (B) depending on their orientation (south/south-west versus north/north-east).

It is interesting to note that the orientation affected not only the appearance of chlorosis symptoms but also flower induction and fruit set which were observed to be much more vigorous on the north/north-east side of the trees (Figure 3.1B). On the south side, the flower induction was much less expressed. From this observation, it could be speculated that these distinctive leaves of the 2nd youngest flush are in some way involved in the phytohormonal signaling for flower induction during this period in winter (Dec./Jan.). At this time of year, the sunlight intensity is high and the appearance of light-induced chlorosis associated with low Zn and/or B status might inhibit the flower induction. The cause of this coincidence of chlorosis and inhibited flower induction on the south/south-west sides of trees merits further experimental investigation including differential foliar application of Zn and/or B as well as phytohormonal analysis. Such an investigation would require an interdisciplinary approach in close cooperation with the horticultural subproject of The Uplands Program (SFB 564).

3.2.4 Conclusions

From the data presented here, it can be concluded that fertilisation with appropriate levels of Zn and B as well as P is required for high productivity in lychees. Optimised fertilisation with Zn, B and P either by soil or foliar application or via fertigation can guarantee sustainable production of high quality lychee, and presumably also longan and mango, in northern Thailand.

3.3 Strategies for Flower Induction to Improve Orchard Productivity: From Compensation of Alternate Bearing to Off-Season Fruit Production

Pittaya Sruamsiri, Amonnat Chattrakul, Pawin Manochai, Martin Hegele, Daruni Naphrom, Winai Wiriya-Alongkorn, Sithidech Roygrong, Fritz Bangerth

3.3.1 Introduction

Due to alternate and irregular bearing of fruit trees, which occurs at various extent amongst different species and cultivars, the yield of many species of fruit tree is erratic. Uncertainties regarding the time of harvest and the quality and quantity of fruit can seriously affect the marketability of the product (MONSELISE and GOLDSCHMIDT, 1982; WESTWOOD, 1995; SUBHADRABANDHU, 1999; SOUZA et al., 2004). Unfavourable climatic conditions during flower induction (FI) or the flowering period are amongst the most important causes of this phenomenon. Often large areas or even whole countries face the same problem simultaneously leading to overproduction and low prices in one year and a low return from fruit production the next. Equalising these fluctuations therefore would help to make fruit production more profitable and sustainable. Another option for raising the return from fruit production would be to extend or totally shift the harvest season by artificially influencing conventional and off-season flowering.

Figure 3.2: Longan tree with high off-season crop load after $KClO_3$ (Potassium chlorate) application.

In the last four years, research has focused on off-season flower induction of longan (*Dimocarpus longan* Lour.), lychee (*Litchi chinensis* Sonn.), and mango (*Mangifera indica* L.) trees. The work on longans was especially successful and comprehensive. The effects of treatment with potassium chlorate ($KClO_3$) were clearly demonstrated both in the field trials (Figure 3.2) and the laboratory analyses of the resultant hormonal changes. In this sub-chapter, the observed effects of related horticultural procedures are presented, and the factors influencing flower induction are discussed. The overall aim of our research was to optimise fruit production and stabilise the yield of high quality fruit.

3.3.2 Stabilising Yield and Quality of Lychee Fruits

To optimise the water balance of fruit trees, information about local climatic conditions (weather station), water retention capability of the soil and water demands of the trees was gathered at Mae Sa Mai lychee orchard. This plot was shared with other participants in The Uplands Program (for details see Chapter 2). A balanced irrigation system was installed and a proper watering schedule developed which was capable, in combination with fertilisation, to improve the yield and quality of lychee fruits. The optimal amount of water per tree in relation to the climatic water balance (100 %) was calculated by means of CROPWAT, a shareware program supplied by the FAO. The first results, summarised in Table 1, show that 66 % irrigation and 2 kg of NPK-fertiliser / tree were sufficient to achieve the highest yields. Stronger vegetative growth might have caused reduced yields. For best fruit size, however, 6 kg of fertiliser / tree and full irrigation were necessary. The fact that the increase in the size and weight of fruit was not simply due to a higher uptake of water is clearly shown by the constant value of total soluble solids (TSS) observed in all variants. Moreover, constant results for the sugar-acid ratio and the peel colour reflected uniform internal quality and ripeness at harvest, irrespective of the treatment.

The appearance of fruit cracking, i.e. the cracking of the shell during the last stage of ripening, is another serious problem which often affects the quality of lychees. Although several attempts have been made to solve this problem, the causes are still unknown. Techniques include protecting the peel from external influences by wrapping the fruit clusters in bags made of newspaper or other materials and stabilising the membranes of the shell by spraying the leaves of the trees with solutions containing calcium salts. However none of the treatments was successful in preventing cracking.

In the region under study, lychee trees require relatively low temperatures of approximately 17 °C for 10-12 days in order to flower in early January (SETPAKDEE, 1999). Elevated temperatures exceeding 17 °C or lower temperatures with large daily fluctuations during the period of flower induction are among the main factors associated with alternate bearing (i.e. trees only producing fruit every second year).

Table 3.3: Effect of irrigation and fertilisation on yield, fruit size and internal quality parameters of lychee fruits harvested at Mae Sa Mai orchard [a].

Treatment	Yield per tree [kg]	Size [b] A-C [%]	Size [b] D-E [%]	TSS (aril) [%]	TSS/TA [c]	Pericarp colour [d] C*	Pericarp colour [d] H°
Control	27± 8.5	4± 2.3	96± 9.0	19.7±0.7	53± 2.4	38.1±1.0	43±3.7
100% irrigation +2 kg NPK / tree	41±17.1	57± 7.1	43± 8.4	19.2±0.1	52±10.9	38.2±0.7	43±3.5
100% irrigation +6 kg NPK / tree	39± 8.5	58± 7.8	42± 7.9	19.2±0.4	51± 1.9	37.9±0.6	42±2.0
66% irrigation +2 kg NPK / tree	41± 6.5	41±12.5	59±15.1	19.4±0.6	45± 4.6	38.2±1.2	44±3.0
66% irrigation +6 kg NPK / tree	29±11.0	15± 7.6	85±17.7	19.3±0.5	48± 3.4	38.3±0.7	43±3.2
33% irrigation +2 kg NPK / tree	33± 4.8	11± 4.9	89±12.6	19.4±0.5	42± 3.1	38.8±0.5	39±1.6
33% irrigation +6 kg NPK / tree	34± 5.1	34± 8.7	66±10.7	19.1±0.4	42± 1.8	38.9±0.9	40±2.1
Total mean ± SE [e]	---	---	---	19.3±0.2	48± 1.8	38.3±0.3	42±1.0

[a] CHATTRAKUL et al., to be published.
[b] Grading system (g/fruit): A >25, B >22.2 - 25, C >20 - 22.2, D >17 - 20, E ≤17; fruit size distribution: absolute weight-related frequencies (g fruits per class / 100 g total fruit weight) summarised for size classes A-C and D-E, respectively
[c] Sugar-acid ratio of the edible aril calculated from total soluble solids (TSS in °Brix, i.e. g sucrose / 100 g) and titratable acids (TA, determined as citric acid by titration to pH 8.1)
[d] Colour according to the CIE L* a* b* colour space: Colour intensity and the hue are characterised by the length of the colour vector (chroma $C^* = (a^{*2} + b^{*2})^{0.5}$) in the a* x b* colour hue space and by the hue angle $H° = 180°/\pi \cdot \arctan(b^*/a^*)$ of this vector, respectively. H° changing from 90° to 0° marks a transition from pure yellowness to pure redness.
[e] SE = standard error. Total variation among trees: SE for n = 28 trees. Variation within variants: SE for n = 4 trees per treatment.

As shown in Figure3.3, the harvest period of lychee is quite short, resulting in a seasonal overflow of the markets and low prices for the farmers.

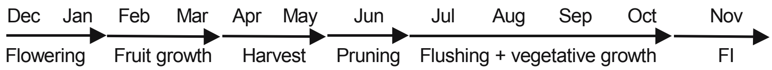

Figure 3.3: Schedule for normal-season lychee production / development in northern Thailand (FI = flower induction).

Therefore several experiments were conducted not only to reduce alternate bearing, but also to produce off-season fruits, using already proven measures to induce off-season flowering and hence facilitate off-season harvest of other fruit species. A combination of hard pruning, i.e. a deep cut-back of branches after harvesting, and appropriate fertiliser application, both known to enhance growth, was shown to induce regular flushing of the whole trees. Subsequent girdling of 50 % of the branches, promoted a more regular flowering (Table 3.4). In this technique, which must be carried out not later than end of September, a small stripe of bark around a stem or branch of a tree is removed to repress carbohydrate and hormone transport to the root.

Table 3.4: Inhibition of vegetative flushing of lychee trees (% out of 20 shoots / replication)[a].

Treatment	Days after treatment					
	32	60	88	95	102	112
Control	41 a	43 a	47 a	47	47	47
Girdling	11 b	18 b	24 b	27	38	39
Girdling+0.1 % MF	12 b	14 b	20 b	28	35	39
Girdling+1.0 % MF	10 b	14 b	26 b	32	36	41
LSD 0.05	0.008	0.005	0.008	0.116	0.453	0.692

[a] CHATTRAKUL et al., to be published; MF: morphactin; LSD: least significant difference. Means in the same column followed by different letters significantly differed at $p \leq 0.05$

Table 3.5: Percentage of flushing (after 33 d) and flowering of lychee shoots (after 128 d) [a].

Treatment	Flushing [%]	Flowering [%]
Control	53	0
Girdled	13	50
Girdled + $KClO_3$ 15 g/m² [b]	20	48
Girdled + NaOCl 10 g/m²	35	52
Girdled + NaOCl 15 g/m²	48	40
Girdled + NPA 1500 ppm	22	45
Girdled + NPA 3000 ppm	35	58
Girdled + PBZ 1000 ppm + Ethrel 500 ppm	15	20
Girdled + PBZ 2000 ppm + Ethrel 500 ppm	18	28
Girdled + Morphactin 6000 ppm	5	18

[a] CHATTRAKUL et al., to be published; NPA: naphthylphthalamic acid; PBZ: paclobutrazol, MF: morphactin
[b] Dosage of agrochemicals in g active ingredient per square metre of ground area under canopy

Other potentially flower inducing horticultural procedures that were tested included bending and the use of various chemicals either sprayed onto the leaves (Ethrel[1]) or applied directly into the girdling wound (auxin transport-inhibitors etc.). In most cases, girdling in combination with flower inducing chemicals had no additional beneficial effect on flowering in lychee trees (Table 3.5). This was probably because the desired inhibiting effect of girdling on vegetative flushing had been partly replaced by that of the other treatments. An exception was the case of morphactin, where enhanced growth inhibition could be observed at least in the beginning, but flower induction was reduced (Tables 3.4 and 3.5).

Although girdling was able to improve flowering by 50 %, it could not completely replace stimulation by cool temperatures. Hence in none of the experiments, induction of off-season flowering was achieved by these procedures, but the undesirable

1 Contains ethephon (IUPAC name: 2-chlorethyl phosphonic acid) as active ingredient and decomposes into ethylene, a volatile plant hormone

vegetative flushing during the period of flower induction was reduced and flowering was considerably improved by some of the treatments.

Young leaves inhibited the process of flower induction. In their presence, manipulations that usually provoked flowering, became either less effective or totally ineffective as is clearly demonstrated in Table 4 for the example of girdling in lychee production.

Table 3.6: Percentage of flowering lychee shoots at different age of the leaves [a].

Treatment	Flowering (%)
Non-girdled + young leaves	3.3
Non-girdled + old leaves	17.3
Girdled + young leaves	3.3
Girdled + old leaves	41.3

[a] CHATTRAKUL et al., to be published

3.3.3 Possible Factors Influencing the Response of Longan Trees to Potassium Chlorate

In contrast to its lack of effectiveness in lychee cultivation, the use of potassium chlorate ($KClO_3$) in longan production, whether applied as a soil drench, foliar spray or stem injection, successfully prevented alternate bearing. It even proved to be the ideal method for inducing flowering. Thus off-season fruits could be produced almost all the year round, whereas the normal harvesting period is limited to July-August in the area under study. Since recovery periods are no longer required after harvest, three harvests could theoretically be achieved from the same tree within 2 years. The harvest time could be chosen for each individual tree according to the schedule of $KClO_3$ application, but there would be some limitations due to leaching during the rainy season (paragraph 3.3). Although $KClO_3$ (Potassium chlorate) is well known amongst Thai farmers as a means of inducing flowering in longan trees, severe problems are frequently encountered when they try to use it for off-season fruit production. In many cases, application of inappropriate doses results in a poor response by the longan trees to $KClO_3$ and poor fruit quality. Farmers will sometimes double or even triple the recommended dose, which eventually damages or kills the trees, since chlorates are also potent herbicides (HANSEN, 1929). Consequently, studies of the factors affecting the response of longan trees to $KClO_3$ were necessary, focusing particularly on the development of proper technologies for its safe use. As summarised in Table 3.7, many relevant factors emerged. They will be discussed in detail in the following paragraphs.

Table 3.7: Factors affecting the response of longan trees to $KClO_3$

Factor	Influence
Cultivar	Variability in sensitivity to $KClO_3$
Leaf age	Influences susceptibility to $KClO_3$
Application frequency	Health and yield of the trees
Environmental conditions	Low soil humidity and full sunshine enhance the quality of the flowering response

3.3.3.1 Impact of the Longan Cultivar

The sensitivity of different longan cultivars to various concentrations of $KClO_3$ was examined in order to find out the minimum dosage necessary to achieve maximum flowering response.

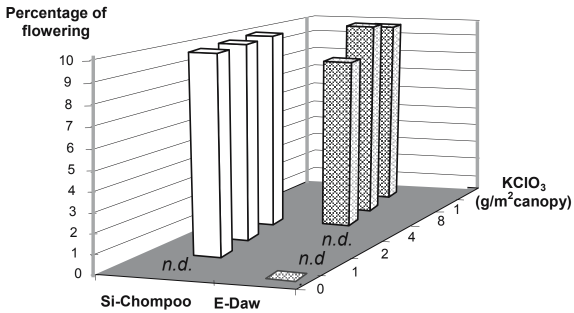

Figure 3.4: Effect of various concentrations of $KClO_3$ applied as soil drench on flowering of longan cv. E-Daw and Si-Chompoo at 3 weeks after treatment (MANOCHAI et al., 2005).

In healthy trees, a soil drench of $KClO_3$ at a dose of only 4 g/m^2 of ground area under the canopy could successfully induce off-season flowering in the 'Si-Chompoo' cultivar. For the cultivars 'E-Daw' and 'Haew', the concentration had to be increased to 8 g/m^2 to achieve the best flowering response (Figure 3.4). These results show that, the cultivar is the first factor that has to be considered when choosing the proper $KClO_3$ dose for successful off-season longan production.

3.3.3.2 Influence of Leaf Age

Under natural conditions in northern Thailand, longan trees start to flower in January to February after being subjected to cool temperatures in November and December. If vegetative shoot flushing occurs during the cold-temperature period, e.g. in November, trees will not produce flowers in the following season unless treated with $KClO_3$. Similarly, flowering was considerably reduced when $KClO_3$ was applied to trees at the young leaf stage (Table 3.8). The best application time was at the "full mature" leaf stage, resulting in flowering within 4 weeks after $KClO_3$ application. When trees were treated at the "leaf expansion" stage, they required up to 7 weeks after the use of $KClO_3$ before they flowered.

Table 3.8: Flowering response of longan shoots depending on leaf stage and treatment with $KClO_3$ (8 g/m² of ground area under the canopy) as a soil drench (HEGELE et al., 2004).

Leaf stage/treatment	Percentage of flowering after application (wks)			
	4	5	6	7
Young leaf	0.0 b	0.0 b	0.0 d	0.0 c
Mature leaf	1.0 b	11.0 b	32.0 b	39.0 b
$KClO_3$ at young leaf	9.0 b	12.0 b	16.0 c	78.0 a
$KClO_3$ at mature leaf	88.0 a	100.0 a	100.0 a	100.0 a

Means in the same column followed by different letters significantly differed at $p \leq 0.05$
Young leaf = 15 days after flushing
Mature leaf = full green mature (45 days after flushing)

Table 3.9: Effect of leaf stage and treatment of longan trees with $KClO_3$ (8 g/m²) as a soil drench on the size of inflorescences (HEGELE et al., 2004).

Leaf stage/treatment	0Length [cm]	Width [cm]
Young leaf	0.0	0.0
Mature leaf	13.8 b	20.1 b
$KClO_3$ at young leaf	17.4 b	26.3 b
$KClO_3$ at mature leaf	23.0 a	33.5 a

Means in the same column followed by different letters significantly differed at $p \leq 0.05$
Young leaf = 15 days after flushing
Mature leaf = full green mature (45 days after flushing)

The experimental findings in Tables 3.8 and 3.9 confirmed the necessity of leaf maturation for a good response by the plant to $KClO_3$. In many cases, farmers want to treat the plant at the time of shoot emergence, in order to obtain a good market price. Optimal crop management techniques should therefore allow the farmer to produce fruits all the year round and without interference from young shoots. Eradication of young leaves was found to be one way of enhancing the ability of longan trees to respond to $KClO_3$. Young shoots could be eradicated by labor-intensive cutting. Alternatively, foliar application of Ethephon at a concentration of 300 mg/L could dry out the youngest shoots and retain a good response to $KClO_3$ (Table 3.10).

Table 3.10: Percentage of flowering of longan trees treated with $KClO_3$ at the young shoot stage, after shoot cutting or young shoot eradication with Ethephon.

Treatment	Percentage of flowering			
	3	4	5	6
$KClO_3$ at young shoot stage	10.0 b	13.8 b	13.8 b	13.8 b
Shoot cutting + $KClO_3$	51.3 a	57.3 a	61.3 a	66.3 a
Shoot eradication with Ethephon + $KClO_3$	66.3 a	67.6 a	70.0 a	80.0 a
Significance	+	+	+	+

Means in the same column followed by different letters significantly differed at $p \leq 0.05$

3.3.3.3 Environmental Conditions at the Time of Potassium Chlorate Application

Farmers observed a poor response of longan trees to $KClO_3$ in the rainy season, especially when the treatment was performed on rainy days. Researchers also found that shoots on the southern/south-western sides of trees flowered better. Concerning the season, plants responded better to $KClO_3$ and produced more flowers in the hot and cool dry seasons than during the rainy season (Figure 3.5 in paragraph 5). Experiments with potted trees showed that this effect might be related to a leaching of $KClO_3$ during heavy rains (MANOCHAI unpubl.). This general information confirmed the influence of environmental conditions on the reaction of trees to $KClO_3$.

Results of this research program demonstrated the enhancing effects of light intensity and dryness of the soil on the efficiency with which $KClO_3$ promoted flowering. Temperature fluctuations in the range of 15 to 40 °C had no significant effect on flowering.

3.3.4 Options for Optimised Mango Production

Paclobutrazol (PBZ) is a substance that inhibits gibberellin biosynthesis. Similarly to $KClO_3$ in longan cultivation, it has proved to be suitable for inducing flowering in mango trees when applied as a soil drench (TONGUMPAI et al., 1989). In this project, the appropriate dose for local varieties in northern Thailand was investigated. For the mango cultivars \`Nam Dokmai´, \`Falan´ and \`Chok Anan´, 1.0 g a.i. / m of canopy diameter proved to be sufficient for successful flower induction, whereas in the case of cv. \`Khiew Sawoei´, \`Rad´, \`Kaew´ and \`Nga´ up to 1.5 g a.i. / m seemed to be necessary.[2] When relating the PBZ dose to the ground area under the canopy as shown in Figure 3.4 for $KClO_3$ applications to longan trees, corresponding PBZ dosages of 0.25 and 0.38 g a.i. / m^2 resulted for trees with 5 m of canopy diameter in the first and the second cultivar group, respectively. Additionally strong pruning and spraying with thiourea and KNO_3 were required to force and synchronise a new leaf flush, since the hardening stage of a flush was found to be the optimal time for PBZ application. The removal of normal season flower clusters by hand pinching, spraying of Ethephon or severe branch cut-back proved to be essential to delay normal or off-season flowering.

In mango trees cv. \`Kaew´, the flower promoting activity of PBZ applied to the soil was also compared with that of prohexadione-calcium applied as a spray. The latter is a less persistent and therefore a less critical inhibitor of gibberellin biosynthesis than PBZ. Both substances showed positive effects after 21 days of treatment[3] and will be further tested on a larger scale, especially prohexadione-calcium whose effectiveness still needs to be improved.

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2 SRUAMSIRI, P., MANOCHAI, P., to be published

3 NAPHROM, D. et al. to be published.

3.3.5 Conclusion: Challenges in Sustainable and Economical Fruit Production in Mountainous Areas of Northern Thailand

During our investigation of flower induction in three fruit species in the region under study, it became evident that the techniques used must be specific for each species. Nevertheless, some common factors promoting flowering emerged. In mango, lychee and longan trees, a strong correlation between the inhibition of young leaves and the promotion of flowering could be observed. When young leaves were present, manipulations or chemical treatments, which normally promote flowering became either less or non-responsive as clearly demonstrated in Tables 3.6, 3.8, 3.9 and 3.10 for the examples of girdling in lychee and $KClO_3$ application in longan production, respectively. In this research program, appropriate techniques for year-round longan production by use of $KClO_3$ have been developed and disseminated (Figure 3.5). Similar developmental steps will also be monitored in lychee and mango cultivation. If these investigations are successful, regular, year-round bearing and high yields can be expected from these three fruit crops. This will facilitate sustainable and economical fruit production in the mountainous areas. To achieve this, more research and development is still required. New strategies for marketing, storage, drying etc. of off-season fruit have to be worked out. In principle, two major fields of knowledge and technology must be developed for successful marketing and export of fruit products.

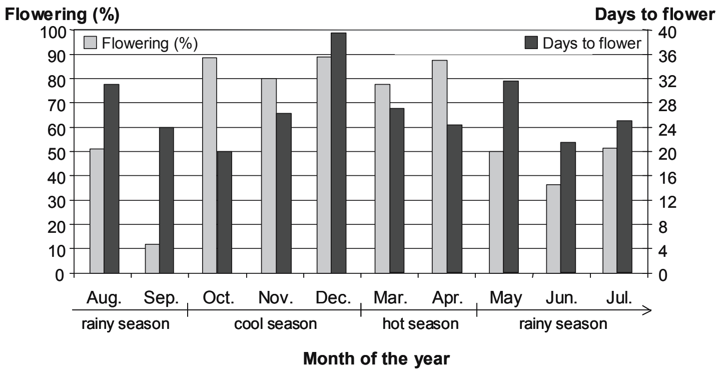


Figure 3.5: Effect of $KClO_3$ on flowering of longan trees and days until flowering after $KClO_3$ application by soil drench at different months all the year round (MANOCHAI et al., 2005).

Firstly, the products must meet international standards of food safety and be produced with low investment costs, using environmentally friendly horticultural practices and processing techniques. Secondly, management systems within the supply chain from handling raw materials, through processing, logistics, and marketing to delivery to the consumer must all be developed in a way that ensures a better understanding of the interactions between the single links in the chain so that the system as a whole will be better integrated. Both aspects require a bigger labor force, more time and more finance, but we are confident that these challenges can be met.

3.4 The Plant-Physiological Basis of Flower Induction in the Control of Fruit Production

Martin Hegele, Fritz Bangerth, Daruni Naphrom, Pawin Manochai, Pittaya Sruamsiri, Winai Wiriya-Alongkorn, Amonnat Chattrakul, Sithidech Roygrong

3.4.1 Introduction

In the last four years, research has focused on off-season flower induction of longan, lychee and mango trees (Chapter 3.3). In order to achieve control over the flower induction process of fruit trees, it is necessary to address the key factors responsible for the transition from vegetative to generative bud development. Various, partly competing theories have been developed in the past about the physiological 'Who's Who' in flower induction (BERNIER et al., 1993). One theory favours the role of carbohydrates, which need to be present in sufficient amounts as a prerequisite for flower induction (SACHS, 1977). Other theories of flower induction focus either on the genetic control of a developmental switch from vegetative to generative development (LEVY and DEAN, 1998), control by particular hormones (BERNIER et al., 2002), the existence of specific promoting or inhibiting factors or a mixture of both. However these theories do not apply to adult perennial fruit trees (GOLDSCHMIDT and SAMACH, 2004). Knowledge and understanding of the hormonal changes associated with the treatments previously described (Chapter 3.3) can be beneficial for future trials to induce flowering in mango, lychee and other fruit trees. Therefore studies on the hormonal levels in buds, leaves, wood, and bark and physiological changes such as photosynthetic rate of leaves were performed with respect to flower induction, comparing 'naturally' flowering trees, which had been exposed to cool temperatures, with those after artificial flower induction and equivalent non-induced control trees.

3.4.2 Physiological Characteristics of Fruit Trees According to Leaf Age

Young leaves have proved to be one of the major factors inhibiting the natural flowering response of subtropical fruit trees as well as the reaction of longan trees to $KClO_3$ treatments (Chapter 3.3). Therefore a closer understanding of the physiological changes in leaves at different ages appeared to be necessary. Comparative analyses of longan trees revealed that young leaves, which are centres for carbohydrate attraction, needed up to 29 days to reach the same level of photosynthesis as mature leaves. Almost the same time elapsed until rates of transpiration and stomata conductance of young leaves reached or surpassed the values of old ones. Therefore the delivery of xylem-mobile substances from the roots, i.e. cytokinins, might be limited during this time of leaf maturation (Figure 3.6).

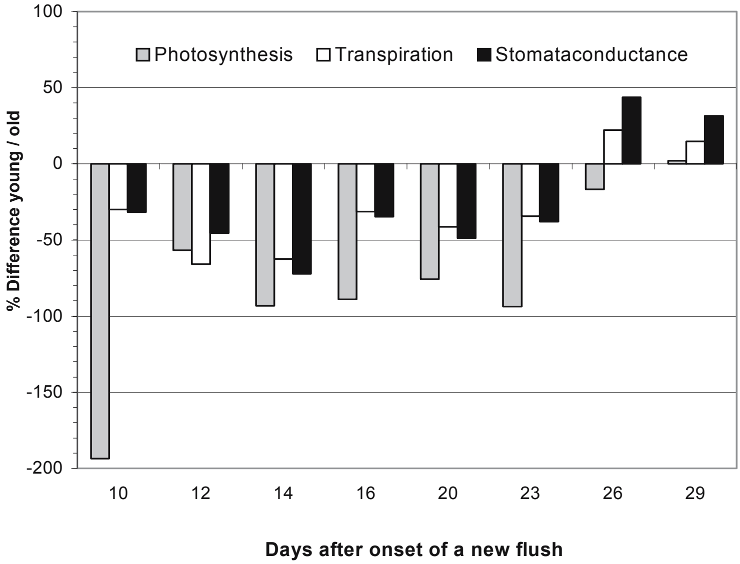


Figure 3.6: Changes in rate of photosynthesis, leaf transpiration and stomata conductivity in young leaves of a new flush from a 5-year-old longan tree compared to mature leaves on the same branch (HEGELE et al., 2004).

In another experiment (Figure 3.7), in which the days were counted from the beginning of the measurements, but not from the onset of the new flush as in Figure 3.6, the average day value of photosynthetic rate for young expanding leaves was only 1 µmol/m²/s at an age of less than 1 month. From day 13 to day 18, when the leaves turned dark green (mature leaf), the assimilation rate drastically increased up to 7-9 µmol/m²/s.

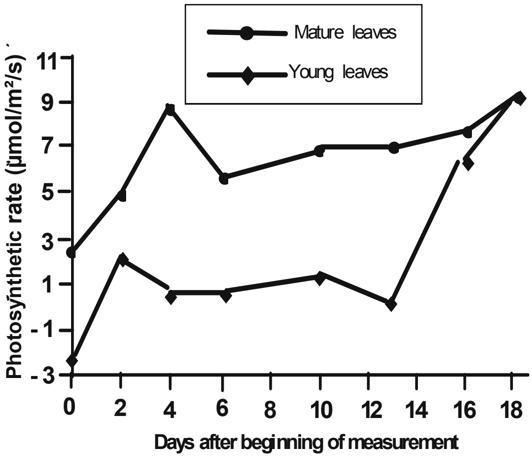


Figure 3.7: Photosynthetic rate of young longan leaves in comparison with mature leaves.

A low photosynthetic rate at the young leaf stage causes the retranslocation of accumulated carbohydrates and substances from old leaves to support normal leaf growth of young ones. At this young leaf stage, imbalance and limitation of carbohydrates and metabolites in leaves and other organs might be the main reason for the low response of trees to $KClO_3$.

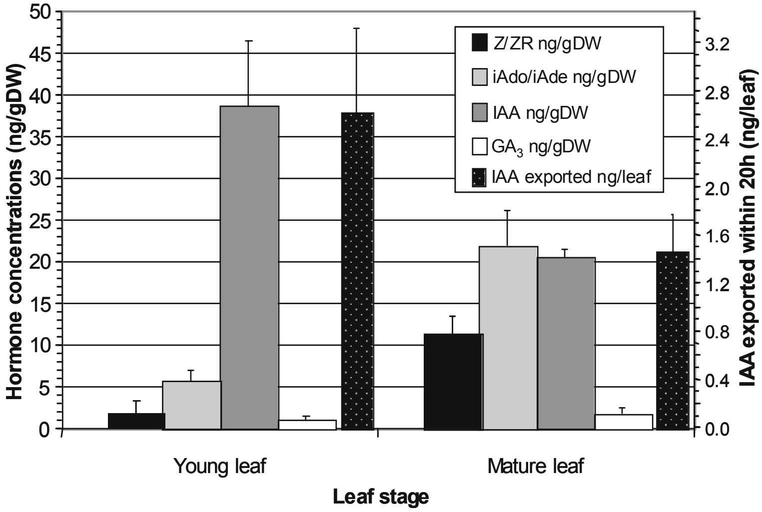


Figure 3.8: Endogenous plant hormone levels (CKs, IAA, GA_3) and IAA export of young and mature longan leaves (HEGELE et al., 2004).

Looking into the endogenous hormone levels of leaves, the young leaves contained significantly lower concentrations of cytokinins (Z (Zeatin)/ZR (Zeatin riboside), iAdo (Isopentenyl adenosin)/iAde (Isopentenyl adenin)) but showed notably higher values for auxin (IAA), which also resulted in a considerably higher auxin export (Figure 3.8). Thus a high IAA (Indolyl acetic acid) content in young leaves seemed to be necessary to strengthen the capability of young leaves to attract carbohydrates in competition with other organs. Large amounts of exported IAA from young leaves might play an important role in the inhibition of longan flowering even when $KClO_3$ (Potassium chlorate) was applied. As reported elsewhere, a strong export of IAA can suppress the cytokinin supply from the roots to the shoots, which presumably could limit floral induction.

3.4.3 Physiological Response of Fruit Trees to Flower Induction

To investigate the potential role of carbohydrates in flower induction (SACHS, 1977), the effect of flower promoting treatments on photosynthesis was studied. However, it should be noted that treatments which normally promote flower induction, such as $KClO_3$ application to longan trees (Figure 3.9), application of paclobutrazol or prohexadione-calcium to mango trees, cool-temperature-treatments of mango and lychee trees, girdling of lychee trees in combination with different growth retardants (CHAIKIATTIYOS et al., 1994) etc., all restrict photosynthesis and hence the delivery of carbohydrates from the leaves to the buds. It therefore seems unlikely that carbohydrates would play any role in actually inducing flowers.

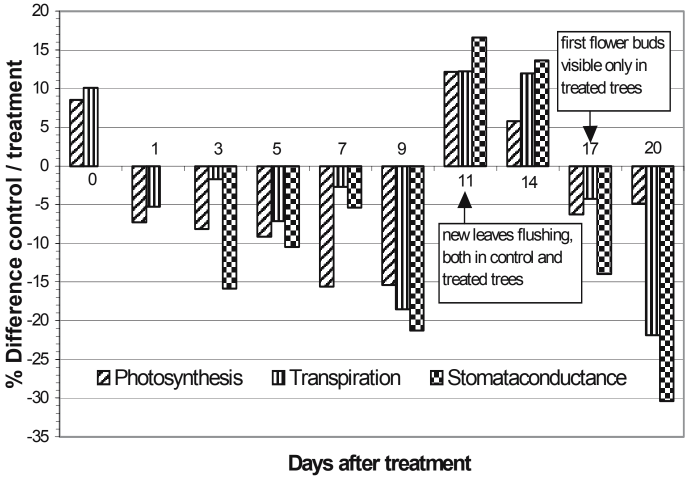


Figure 3.9: Changes in photosynthesis rate, leaf transpiration and stomata conductivity in 5-year-old longan trees after treatment with 16 g $KClO_3$ per tree as a soil drench (HEGELE et al., 2004).

As can be deduced from Figure 3.9, there was a rapid decline not only in photosynthesis but also in transpiration and stomata conductance. The latter parameter is mainly related to the opening of stomata. This decline was interrupted for only a short time period when, after 11 days, a sudden flush of new leaves occurred. This phenomenon could be explained by the higher demand for assimilates to be delivered to fast growing new leaves. In this case, these young leaves obviously appeared too late to inhibit flower induction, since only 6 days later the first flowers became visible.

Data from another experiment, in which the effect of $KClO_3$ on CO_2 assimilation rate was measured, are shown in Figure 3.10. Here the photosynthetic rate also drastically decreased in treated plants up to 6 days after $KClO_3$ application and remained rather low compared to the control up to 11 days. As in the first experiment, decrease of photosynthetic rate occurred in parallel with the reduction in stomata conductance. But it could not be determined whether the latter phenomenon was the cause or the result of the former .

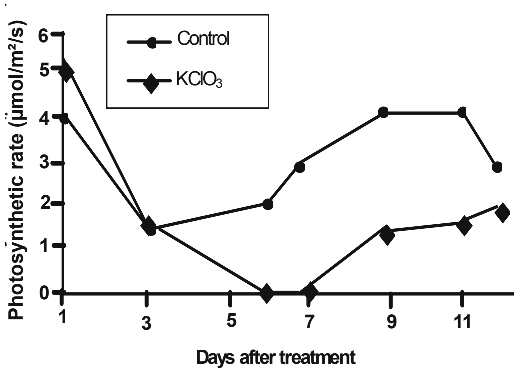


Figure 3.10: Changes in the photosynthetic rate of longan leaves as affected by $KClO_3$

Changes in plant hormone levels following $KClO_3$ application were analysed in parallel. Compared to the control, auxin (IAA) levels in terminal buds clearly decreased during the first two weeks after $KClO_3$ application (Figure 3.11A). This appears to be of interest, because IAA is known to play an important role in many vegetative growth processes, such as cell division, cell enlargement, stem growth, vascular tissue differentiation etc. Cytokinin concentrations, especially iAdo and iAde, which are precursors of zeatin (Z) as the most common cytokinin base in plants, reacted contrarily and increased throughout the 3 weeks of flower induction (Figures 3.11B and 3.11C). For some time now, cytokinins have been assumed to be involved in the transition process from vegetative to generative bud development (RAMIREZ and HOAD, 1981) and in apple, for example, it was possible to stimulate flowering by application of cytokinins directly to the buds (SKOGERBØ, 1992).

Therefore these data on elevated cytokinin concentrations under otherwise non-inductive conditions (no cool temperatures) are particularly interesting and have not been published previously.

The results suggest that $KClO_3$ might play a significant role in flower induction by affecting the balance of cytokinins and IAA. Reduction of IAA activity and increase of free cytokinins like zeatin, iAdo, and iAde seem to be important preconditions. The influence of gibberellic acids (GA_s) on the flowering of longan as a consequence of $KClO_3$ treatment is obviously less evident and should be subjected to further investigations.

By analogy with flower induction by means of $KClO_3$ application to longan trees, plant hormonal changes associated with other flower promoting treatments of fruit species under study were investigated. According to the relevant findings so far, similar patterns of hormonal changes can be observed, for example in mango after treatment with paclobutrazol, an inhibitor of gibberellin biosynthesis. Irrespective of whether flowering had been induced naturally by cool temperature or artificially by certain manipulations or chemicals, there was always a rise in the level of cytokinins, while those of auxin and gibberellins were reduced (Table 3.11, Figure 3.11). A knowledge of the sequence and direction of hormonal changes during flower induction will help to design more precisely adapted, more environmentally compatible and hopefully more effective methods to overcome alternate bearing and to produce off-season fruits even for those species which so far have not responded in the desired way, such as lychee.

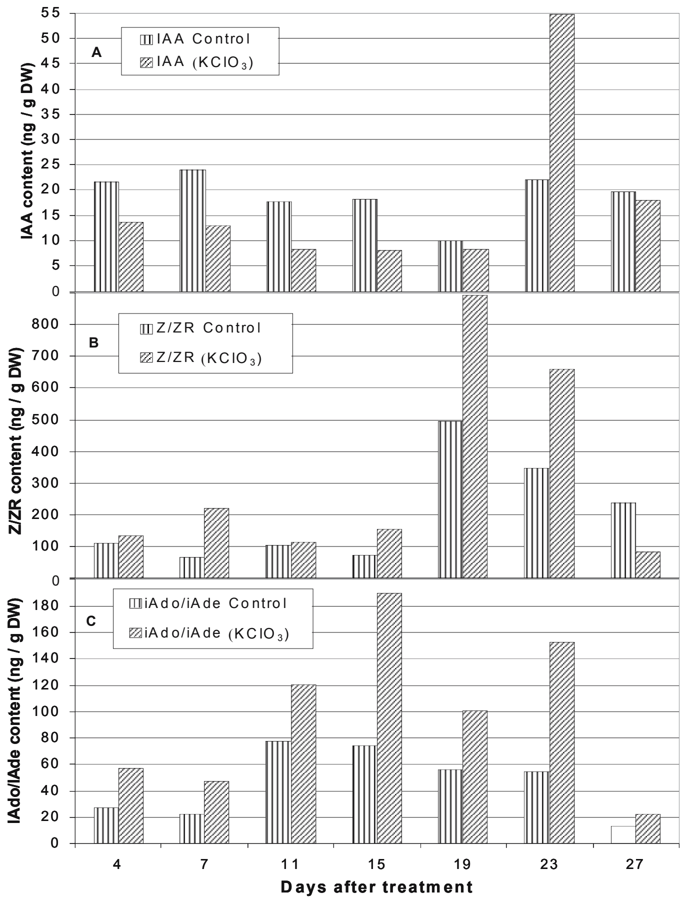


Figure 3.11: Comparison of endogenous IAA (**A**) and cytokinin [Z/ZR (**B**), iAdo/iAde (**C**)] levels in terminal buds of $KClO_3$ (4g/m² of ground area under the canopy) treated and control trees during 27 days after application (HEGELE et al., 2004).

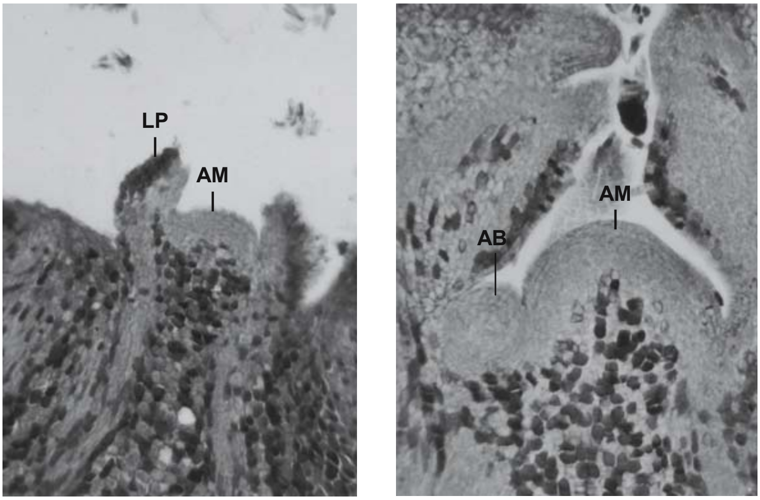
Table 3.11: Hormonal concentrations (ng/g DW) in various tissues of mango after exposure to cool or warm temperature (NAPHROM et al., 2004).

Plant tissue		13 °C				25 °C			
(days after treatment)		Z/ZR	IAA	GA_3	ABA	Z/ZR	IAA	GA_3	ABA
Terminal bud	13 days	55.3	10.4	4.1	14.0	45.4	13.9	6.3	16.3
	16 days	44.4	15.7	4.5	16.3	36.5	12.3	5.2	16.8
Wood	13 days	337.0	23.0	1.2	2.6	184.0	26.0	1.3	2.4
	16 days	568.0	22.0	1.1	2.8	92.2	28.7	1.5	1.9
Bark	13 days	164.0	9.0	1.7	2.2	59.0	26.0	1.5	2.5
	16 days	41.0	16.0	1.7	4.1	21.0	17.0	2.3	4.6

Abbreviations used: ABA: Abscisic acid; DW: Dry weight; GA_s: Gibberellins (GA_3, gibberellic acid equivalents); IAA: Indolyl acetic acid; Z: Zeatin; ZR: Zeatin riboside

3.4.4 Development of Terminal Buds during the Floral Induction Period

According to microscopic studies on terminal buds at different days after soil drench with $KClO_3$ (Figure 3.12), a clear change in development could be observed at about 6-10 days. The apical meristem increased in size both vertically and laterally. Floral primordia visually occurred 18 days after treatment and flowering appeared after 23-27 days. The change in terminal bud development matched the change in cytokinin and IAA levels as illustrated above and confirms a close relation between cytokinin and IAA balance in the flowering of longan.



Control **16 days after $KClO_3$ treatment**

Figure 3.12: Longitudinal section (100 ×) of longan meristems: control and treatment 16 days after soil drench with $KClO_3$ at a rate of 8 g/m^2 of ground area under the canopy (MANOCHAI, unpublished). AM = apical meristem, AB = axillary bud, LP = leaf primordium).

3.4.5 Conclusions

From our results it can be concluded that flower induction in longan by $KClO_3$ proved to be an excellent model for studying the physiological changes involved in the transition process from vegetative to generative bud development and that, although different methods of flower induction were applied, similar changes could be observed in all tree species under investigation.

Looking at the activity of young leaves in inhibiting flower induction, it was interesting to see that the ratio of cytokinins / auxin in young longan leaves was opposite to that found in buds during flower induction (Figure 3.8 in comparison to Figure 3.11). As the leaves are potential sources of these hormones for the buds, this might be one of the reasons for the inhibiting effect of young leaves on flower induction.

3.5 Alternative Techniques for Water-Saving Irrigation and Optimised Fertigation in Fruit Production in Northern Thailand

Somchai Ongprasert, Wolfram Spreer, Winai Wiriya-Alongkorn, Saksan Ussahatanonta and Karlheinz Köller

3.5.1 Introduction

The acreage of irrigated orchards in northern Thailand has dramatically increased since the discovery of flower induction by potassium chlorate in 1998 (see Chapter 3.1). As the availability of water is limited, alternatives for the more efficient use of water and fertilisers in fruit production are urgently needed. As longan and mango represent an important share of fruit production in the area under study, they have been the main focus of research on water-saving irrigation techniques.

In this study, efficiency of sprinkler irrigation was evaluated as a water-saving option in longan cultivation, since simple forms of this technique have already been adopted by some farmers in the examined region. Deficit irrigation is another agricultural practice that offers interesting opportunities for water saving. Among the tested deficit irrigation strategies, partial root-zone drying (PRD) is the most recently developed method. Using PRD, the root-zone of the plant is split into two parts which are irrigated alternately during ten to fifteen days, while the other side dries out. According to theory, the plant-stress hormone abscisic acid (ABA) should be produced in the dry part of the root, inducing stomatal closure to reduce water loss by plant transpiration. It is claimed that the associated decrease in photosynthesis has a minor negative effect on fruit development, because water can be taken up through the moist part of the root. Nevertheless, vegetative growth will clearly be hampered. Thus, although yield decline is expected to be minor, water use efficiency should increase considerably. A useful side effect may also occur: as long as the plant suffers drought stress, the biomass production that needs to be pruned is reduced (STOLL et al., 2000). Numerous experiments to back this theory have been reported (e.g. DRY et al., 2000). However, there is an ongoing debate on the functioning of PRD as the hormonal balance of plants, other than grape vines, has been only poorly described (DAVIES et al., 2002). Furthermore, there are a number of studies which claim the increase in water-use efficiency to be an effect of lower overall water availability, known as controlled deficit irrigation (CDI) (CASPARI et al., 2002).

The research reported in this sub-chapter aimed at (1) determining the response of longan and mango trees to cultivation techniques that save fertilisers and/or water and at (2) analysing the influence of water supply on the distribution of longan root systems in order to develop optimised irrigation techniques.

3.5.2 Materials and Methods

Two experiments concerning fertigation (3.5.2.1) and irrigation (3.5.2.2), respectively, were conducted in four private longan plantations with 5 to 8-year-old trees on red loamy and white sandy soils (Tables 3.13 and 3.14). By analogy, another irrigation experiment was performed with 10-year-old mango trees at an experimental station of Mae Jo University (3.5.2.3).

3.5.2.1 Experimental Design of the Fertigation Studies in Longan Production

Fertigation, which is the application of fertilisers with the irrigation water, is not yet well established in the area under study. The specific aim of this experiment was to investigate the response of longan trees to different fertigation regimes. Four fertigation strategies were compared to conventional solid fertiliser application by soil drench (Table 3.12). In the latter, nutrients were applied in the form of urea, triple super-phosphate and potassium chloride, with a dosage of 2X (control variant LF_{SD2}), where X is the estimated annual nutrient requirement for two periods of leaf flushing and fruiting (KAOSUMAIN et al., 2000).

Table 3.12: Fertigation treatments applied to longan trees (total fertiliser amounts per annum).

	Loamy soil (FerLS)				Sandy soil (FerSS)			
	N	P_2O_5	K_2O	ratio	N	P_2O_5	K_2O	ratio
	[g / tree]				[g / tree]			
F_{SD2}	2250	750	1250	3.0 : 1 : 1.6	1500	500	1250	3.0 : 1 : 2.5
F_{STD1}	1250	420	920	3.0 : 1 : 2.1	833	275	750	3.0 : 1 : 2.7
$F_{STD1.5}$	1875	632	1380		1250	420	1125	
F_{CH1}	1250	750	920	1.7 : 1 : 1.2	833	500	750	1.7 : 1 : 1.5
$F_{CH1.5}$	1875	1100	1376		1250	750	1125	

Mono-ammonium phosphate and potassium nitrate being water-soluble fertilisers were applied via sprinkler irrigation as the sources of N, P and K, in the standard fertigation procedures (LF_{STD1}, $LF_{STD1.5}$). In cost-saving fertigation variants (LF_{CH1}, $LF_{CH1.5}$), urea and potassium chloride were applied by means of sprinkler irrigation as the sources of N and K, while triple super-phosphate was used in the solid form as the source of P. Increased P_2O_5 dosages reflect the expected lower application efficiency of the P source in the latter variants. Nevertheless, fertigation costs were only 40 % of the standard fertigation treatments at equivalent dosage (LF_{STD1} and $LF_{STD1.5}$, respectively).

Solid fertilisers were applied four times a year, i.e. (1) after harvesting and subsequent pruning, (2) one month before application of potassium chlorate used for flower induction (see Chapter 3.3), (3) during flowering and (4) during rapid fruit growth, approximately six weeks before harvest. In the last application, the share of potassium was doubled to obtain good colouring of the fruits. The ratio of N : P_2O_5 : K_2O based on the total annual application is described in Table 3.12. Sprinkler fertigation was applied fortnightly, except a fortnight before and after application of potassium chlorate. Fertiliser ratios applied at each growth stage were optimised to site conditions and the technology used was based on local farmers' practice. Four replications were performed per variant, treating a single longan tree as one experimental unit. A description of the studied sites is given in Table 3.13.

Table 3.13: The studied sites used in the longan fertigation experiments.

Plot	Experimental variants	Age and canopy diameter of trees	Soil types	Previous mode of irrigation and fertigation used by the farmer
FerLS	LF_{SD2} LF_{STD1} $LF_{STD1.5}$ LF_{CH1} $LF_{CH1.5}$	Dimocarpus longan Lour. cv. \`Dor´ 7-8 years, 7 m	Deep red loamy soil	Sprinkler with limited water (approx. 7 mm/day in dry season) Fertilisers were applied in solid form in sufficient quantity [a]
FerSS	LF_{SD2} LF_{STD1} $LF_{STD1.5}$ LF_{CH1} $LF_{CH1.5}$	Dimocarpus longan Lour. cv. \`Dor´ 7-8 years, 6 m	Deep white sandy soil	Flooding with limited water (approx. 6 mm/day in dry season) Fertilisers were applied in solid form in limited quantity [a]

[a] according to farmers' experience

Potassium chlorate was applied as solid or dissolved in water, consistent with local practice, in a circular band around the canopy area of each tree in the middle of November 2003 at rates of 800 - 1000 g per tree according to tree size to assure homogeneous flowering of all experimental trees. Good flowering and fruit set were observed in December 2003 and January 2004, respectively. Fruits were harvested in July 2004, which corresponded to usual in-season harvest of longan fruits.

Twenty fruit bunches on each experimental tree were randomly selected and tagged for monitoring the growth of fruits in every fortnight. There was some variation in the sizes of the trees in each experiment. Therefore, the yield of each tree was corrected by a size factor according to canopy surface in order to eliminate the effect of size variation on the yields before running a statistical analysis.

3.5.2.2 Experimental Design of Irrigation Studies in Longan Production

The specific aim of the irrigation experiment was to examine the response of longan trees to partial root-zone sprinkler irrigation (variant LI_{PRD66}) and two deficit sprinkler irrigation procedures

(LI_{SP75}, LI_{SP50}) in comparison to conventional sprinkler irrigation (LI_{SP}). In the reference variant LI_{SP}, water was applied within 90 % of the canopy area using mini-sprinklers every 3-4 days, the water quantity being equal to evapotranspiration (1,008 mm for 165 days of the experimental period). In variant LI_{PRD66}, water was applied within 45 % of the canopy area alternately on every 3rd to 4th day, using 66 % of the reference water quantity applied in LI_{SP}. 75 % and 50 % of the reference water amount used in LI_{SP} were applied within 90 % the canopy area every 3-4 days during the development of seeds and peels in LI_{SP75} and LI_{SP50}, respectively. Fertilisers were applied with standard fertigation as described above for variant $LF_{STD1.5}$ (see 3.5.2.1). Four replications were performed per variant. One longan tree was treated as an experimental unit. The studied sites are briefly described in Table 3.14. Flower induction and collection of data regarding yield and yield components were performed as described above (3.5.2.1).

Table 3.14: The studied sites used in the irrigation experiments on longans and mangoes.

Plot	Experimental variants	Age and canopy diameter of trees	Soil types	Previous mode of irrigation and fertigation used by the farmer
IrrLS	LI_{SP} LI_{PRD66} LI_{SP75} LI_{SP50}	Dimocarpus longan Lour. cv. \`Dor´: 7-8 years, 7 m	Deep red loamy soil	Sprinkler with limited water (approx. 7 mm/day in dry season) Fertilisers applied in solid form in sufficient quantity [a]
IrrSS	LI_{SP} LI_{PRD66} LI_{SP75} LI_{SP50}	Dimocarpus longan Lour. cv. \`Dor´: 5-6 years, 7 m	Deep white sandy soil	Flooding with excessive water (approx. 10 mm/day in dry season) Fertilisers applied in solid form in excessive quantity [a]
IrrM	MI_{Con} [b] MI_{CDI} MI_{PRD} MI_{OV}	Mangifera indica L. cv. \`Chok Anan´: 10 years, 4 m	Regosol, anthropogenic	No irrigation

[a] according to farmers' experience
[b] Descriptions of irrigation variants in mango production see in 3.5.2.3.

3.5.2.3 Experimental Design of Studies on Partial Root-Zone Drying in Mango Production

To study the mode of functioning of PRD, an additional irrigation experiment was set up in the mango orchard of Mae Jo University, Chiang Mai, Thailand (plot `IrrM´, Table 3.14). The research hypothesis to be investigated was whether there was a difference in efficiency between PRD (MI_{PRD} in Table 3.14) and controlled deficit irrigation (CDI) applied in variant MI_{CDI}. Due to their high tolerance to drought stress (REHM and ESPIG, 1991), mango trees are especially appropriate for this comparison of water-saving irrigation procedures. As a natural reaction to the periodical lack of water during the dry season in northern Thailand (November until May), this tree-crop closes its stomata and thus reduces water consumption. This natural effect should be artificially enhanced by PRD irrigation.

On the experimental plot, stress symptoms and yield were monitored with respect to four different irrigation treatments: (1) control with sufficient irrigation (MI_{Con}), (2) controlled deficit irrigation (MI_{CDI}), (3) partial root-zone drying (MI_{PRD}) and (4) a non-irrigated control (MI_{0V}). Irrigation water supplied to the trees is shown for each variant in Table 3.14. In variants MI_{CDI} and MI_{PRD}, artificial water supply was limited to 48-50 % of that used in complete irrigation (MI_{Con}). In the treatments MI_{Con} and MI_{CDI}, irrigation water was applied using micro-sprinklers Superjet50 (NETAFIM, Tel Aviv, Israel). The PRD treated trees (MI_{PRD}) were equipped with six drippers JR8 of the same manufacturer. Irrigation was performed from February 1^{st} to May 6^{th}, 2004, when fruits were harvested. The latter corresponded to the main harvest season for `Chok Anan´ mangoes in the region under study. Yield per tree and fruit size distribution were recorded to evaluate the efficiency of the irrigation techniques with respect to the amount of marketable fruits.

In order to investigate drought stress symptoms in the PRD treatment (MI_{PRD}), the stomatal resistance was measured throughout the day, using a portable porometer AP4 (Delta T, Cambridge, UK). This device measures the increase in humidity within a measuring cup and correlates this value with the stomatal resistance. Measurements were performed at regular intervals during the month of April, when the highest temperatures were reached, until the end of the dry season before occurrence of the first rains (end of May). At half-hour intervals, five leaves per tree were examined in each orientation (N, S, E, W). The resulting curves were analysed with respect to drought stress.

3.5.2.4 Study on Root Distribution in Longan Trees

Since information about the root distribution pattern is essential for the appropriate design of irrigation and fertigation of trees, longan roots were studied by core sampling at various positions and depths under the canopy areas of four trees in each of the sites used for the longan irrigation experiments (`IrrLS´, `IrrSS´, Table 3.14) on July 3rd, 2004. The trees used were not part of the irrigation experiments (3.5.2.2). Irrigation and fertigation were performed according to the original farmers' practice (Table 3.14). The cores used for sampling were 7.0 cm in inner diameter and 20 cm in length (KUMAR et al., 1993). Active roots (white roots) and inactive roots (brown roots) were separated and stored in a refrigerator prior to being weighed or having their length measured using a leaf-area-and-root-length-meter (Delta T, Cambridge, UK).

3.5.3 Results and Discussion

3.5.3.1 Longan Yield after Different Fertigation Regimes

The data obtained under fertigation on loamy soil (Table 3.15) revealed that yield and bunch weight corresponded to the quantity of fertilisers (active ingredients). Variants $LF_{STD1.5}$ and $LF_{CP1.5}$ resulted in better yield and bunch weight than LF_{STD1} and LF_{CP1}, which is consistent with the higher total dosages of fertiliser applied to the former variants. Yields and bunch weight after low-cost fertigation were comparable to those after standard fertigation at the same fertiliser dosage.

Table 3.15. Response of longan trees to fertigation treatments in the loamy soil of plot `FerLS´.

Treatment	Corrected yields [kg/plant]	Bunch weight [g/bunch]	Fruit weight [g/fruit]
LF_{SD2}: Conventional soil drench (2X)	190.65 ab	265.37 ab	10.70
LF_{STD1}: Standard sprinkler fertigation (1X)	158.82 b	174.59 c	10.66
$LF_{STD1.5}$: Standard sprinkler fertigation (1.5X)	176.95 ab	196.78 bc	10.85
LF_{CP1}: Low-cost sprinkler fertigation (1X)	162.61 b	178.51 c	11.09
$LF_{CP1.5}$: Low-cost sprinkler fertigation (1.5X)	218.44 a	283.37 a	11.54
Coefficient of variation	12.71 %	17.67 %	

Table 3.16: Response of longan trees to fertigation treatments in the sandy soil of plot `FerSS´.

Treatments	Corrected yields [kg/plant]	Bunch weight [g/bunch]	Fruit weight [g/fruit]
LF_{SD2}: Conventional soil drench (2X)	NA[a]	175.20 a	11.25
LF_{STD1}: Standard sprinkler fertigation (1X)	NA	169.21 a	10.70
$LF_{STD1.5}$: Standard sprinkler fertigation (1.5X)	NA	209.32 a	10.47
LF_{CP1}: Low-cost sprinkler fertigation (1X)	NA	173.12 a	10.94
$LF_{CP1.5}$: Low-cost sprinkler fertigation (1.5X)	NA	216.05 a	10.45
Coefficient of variation		19.17 %	

[a] NA: not available

On sandy soil (Table 3.16), only bunch weight and fruit weight were recorded. Even though the differences among the fertigation treatments were not statistically significant, the trend towards increased bunch weights induced by 1.5X fertigation was evident when compared to 1X fertigation. Moreover, bunch weights obtained by low-cost fertigation were comparable to those after standard fertigation, as shown for both sites (Tables 3.15 and 3.16).

3.5.3.2 Longan Yield after Different Irrigation Regimes

Longan irrigation on loamy soil (Table 3.17) showed that the lowest irrigation rates (LI_{PRD66}, LI_{SP50}) significantly reduced fruit size, but not necessarily the overall yield. The effect in any particular instance depended on the technique used. In particular, the partial root-zone sprinkler irrigation (LI_{PRD66}) resulted in similar yields and bunch weights to those obtained for the control variant (LI_{SP}). The observed effects of the analogous treatments on sandy soil (Table 3.18) were statistically insignificant. However, restricted irrigation in variant LI_{PRD66} markedly reduced fruit size.

Table 3.17: Response of longan trees to irrigation treatments on plot \`IrrLS´, loamy soil.

Treatments	Corrected yield [kg/plant]	Bunch weight [g/bunch]	Fruit weight [g/fruit]
LI_{SP}: relative water supply 100 %	140.39 ab	151.78 a	11.28
LI_{PRD66}: relative water supply 66 % (PRD)	136.99 ab	171.26 a	10.40
LI_{SP75}: relative water suply 75 % (CDI)	190.65 a	180.13 a	12.16
LI_{SP50}: relative water supply 50 % (CDI)	120.36 b	157.29 a	11.00
Coefficient of variation	17.35 %	27.38 %	

Table 3.18: Response of longan trees to irrigation treatments on plot \`IrrSS´, sandy soil.

Treatments	Corrected yield [kg/plant]	Bunch weight [g/bunch]	Fruit weight [g/fruit]
LI_{SP}: relative water supply 100 %	197.07 a	292.31 a	10.86
LI_{PRD66}: relative water supply 66 % (PRD)	186.98 a	228.97 a	8.29
LI_{SP75}: relative water supply 75 % (CDI)	168.08 a	261.34 a	11.92
LI_{SP50}: relative water supply 50 % (CDI)	185.59 a	306.72 a	10.13
Coefficient of variation	20.79 %	20.83 %	

3.5.3.3 Mango Yield after Different Irrigation Regimes

At harvest, fruit weight, number of fruits and yield per tree were determined. All fruits were classified according to the size classes recommended by the Ministry of Agriculture of Thailand (Figure 3.13). The yield obtained under PRD (MI_{PRD}) did not significantly differ from that of the completely irrigated control (MI_{Con}), but the CDI treatment (MI_{CDI}) resulted in a lower yield (Table 3.19). Furthermore, CDI and the variant without irrigation (MI_{0V}) produced a high percentage of small-sized fruits (< 300 g), which could not be directly marketed, but required additional processing before they could be utilised. On the other hand, the relative amounts of fruits in size classes 1 (301-400 g/fruit) and 0 (401-500 g/fruit), which attract higher market prices, were 49.7 % and 23.4 %, respectively, when PRD had been applied. Thus, the achieved fruit size distribution was actually slightly superior to that of trees with sufficient water supply (22.1 % in class 0 and 44.3 % in class 1).

Table 3.19: Influence of irrigation techniques on the yield of mango trees (SPREER and KÖLLER, 2005).

Treatment	**Irrigation**			**Yield**		**Water use efficiency** [a]
	mm	**m^3 / tree**	**n** [b]	**kg / tree**	**σ** [c]	**kg / m^3**
MI_{Con}: Full irrigation	270	4.32	73	12.78 ab	1.09	2.96
MI_{CDI}: Controlled deficit irrigation	135	2.16	48	9.19 b	0.84	4.26
MI_{PRD}: Partial root-zone drying	130	2.08	49	12.26 ab	1.23	5.80
MI_{0V}: No irrigation	---	---	22	5.78 c	1.23	---

[a] according to DOORENBOS and KASSAM, 1979
[b] number of trees per variant
[c] standard error

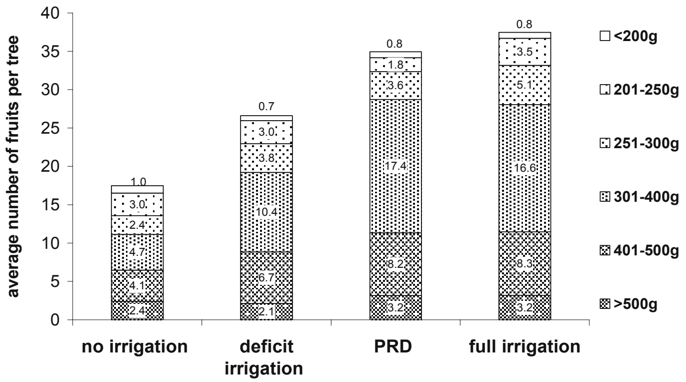


Figure 3.13: Effects of water-saving irrigation techniques on the fruit size distribution of mangoes (SPREER and KÖLLER, 2005). Legend: Size class in g / fruit.

During the dry season stomatal resistance was higher than during the rainy season (reference: no drought stress) in the trees of all variants, even in the fully irrigated ones (MI_{Con}). Especially during the afternoon hours, stomata of drought-stressed trees (MI_{0V}) closed more due to high irradiation and temperature. This reaction could not be observed for the mango trees subjected to the PRD treatment (MI_{PRD}). Consequently it could not be proved that an additional drought stress was induced by PRD. There is evidence for the assumption that irrigation water was more efficiently used due to the drippers applied in MI_{PRD}.

3.5.3.4 Root Development of Longan Trees

As shown in Table 3.14, the longan trees on the two plots used for the irrigation experiments had been subjected to different irrigation practices by the farmers *before* starting the scientific experiments outlined in 3.5.2.2. While water supply had been limited during the dry seasons by using sprinkler irrigation on plot `IrrLS´ (deep red loamy soil), flooding in the dry season resulted in excessive water supply throughout the year on the plot `IrrSS´ (deep white sandy soil).
In the loamy soil of the plot `IrrLS´, where the trees had been previously subjected to limited mini-sprinkler irrigation, the active

roots were concentrated near the trunk, where sprinklers overlapped, up to a depth of 60 cm and at the top layer from the midpoint between the trunks and the canopy rim, where fertilisers were applied (Figure 3.14). Two distinct zones of higher root activity were also observed in a similar study on mango trees, where the highest activity occurred close to the trunk at a depth of 15 cm and the second peak was near the periphery (BOJAPPA and SINGH, 1974). In their study on avocado, AVILAN et al. (1984) found the highest concentration of roots in the upper 20 cm of the soil halfway between the trunk and the edge of the canopy. By analogy, studies on annual crops suggest that fertilisers stimulated root length in the area of their application (DURIEUX et al., 1994; PERSAUD et al., 1977).

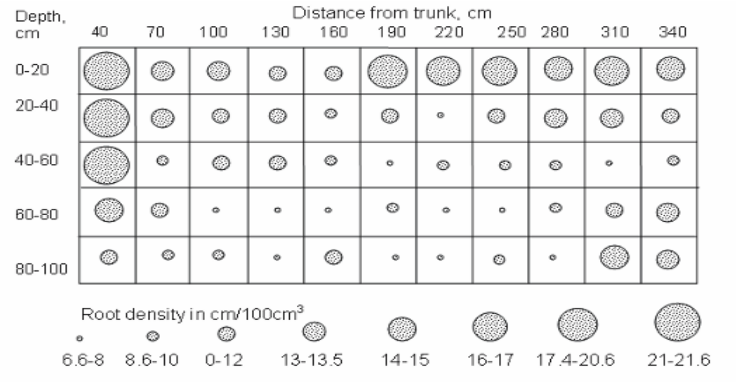


Figure 3.14: Root density pattern of longan trees based on the root length: relative active (white) root density in the loamy soil of plot \`IrrLS´ after limited sprinkler irrigation and sufficient fertigation.

Unlike plot \`IrrLS´, the sandy soil of plot \`IrrSS´ was always kept wet under the canopies to a depth of more than 100 cm, even in the dry season, due to the farmer's former excessive flood-irrigation. In addition, these trees had been previously exposed to higher levels of fertiliser application. Consequently, the active roots of the trees had responded to such excessive levels of water and nutrients by concentrating the roots both at the top layer and in deeper layers at 60-100 cm (Figure 3.15). According to MARSHALL and GILMAN (1997), the roots with diameters of 5-20 mm in field-grown live-oak at were similarly concentrated in sandy soil at the depths of 0-25 and 75-100 cm.

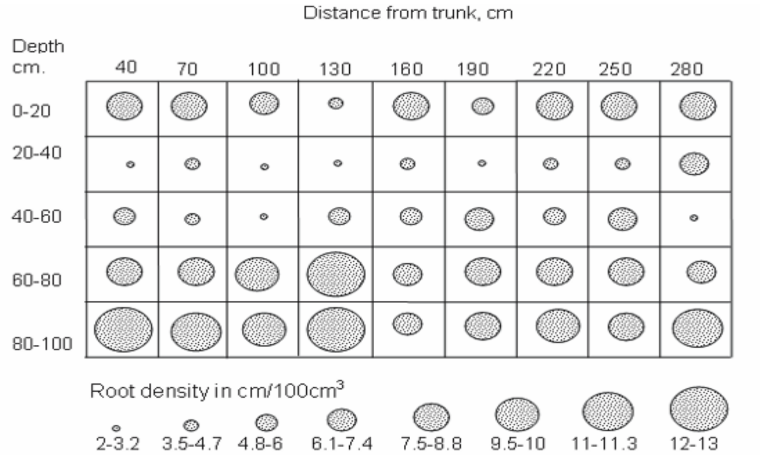


Figure 3.15: Root density pattern of longan trees based on the root length: relative active (white) root density in the sandy soil of plot `IrrSS´ after both excessive flooding irrigation and fertigation.

As expected, no effect of irrigation on the mass distribution of dry (brown) roots was observed (data not shown), as the root mass is greatly influenced by the number of large, strong roots needed for anchorage.

3.5.4 Conclusion

The results presented here on yield response of longan and mango to irrigation are based on one irrigation season only and are to be further tested during the next two crop years. However, essential preliminary conclusions can be drawn.

Concerning the fertiliser dosage, longan trees receiving sprinkler fertigation at 1.5 times the annual nutrient requirement tended to give better yields than those receiving the 1.0-fold amount, but these yields were obviously not worse than those resulting from a conventional soil drench containing twice the annual nutrient requirement. Regarding the technique of fertigation, yields obtained after low-cost fertigation were comparable with those obtained after standard fertigation procedures.

Partial root–zone irrigation of longan trees restricting the relative water supply to 66 % did not reduce the fruit yield of the trees, whereas deficit irrigation with a relative water supply of only 50 % partly resulted in significant reduction of the fruit yield.

The length of active roots indicated a level of root activity in longan trees consistent with the observation that increased root density, derived from the root lengths, occurred in parts of the soil with high access to water and fertiliser. The distribution of these high-access areas depended on the applied irrigation and fertigation modes.

Drought stress induced by the use of PRD was not observed in the mango experiment. However, as described in other reports, a considerable increase in water-use efficiency was found without the significant yield loss observed under deficit irrigation. These evident differences in yield of both deficit irrigation treatments have to be demonstrated in the coming irrigation seasons, correlated more closely with the type of emitters used (sprinklers vs. drippers).

As a practical conclusion, PRD can be considered an interesting alternative for a drought stress tolerant crop such as mango, if water availability is a limiting factor of production. Apart from the plant response to drought stress, the influence of application methods of irrigation water has to be further examined, since low evaporation losses, enhanced by a higher infiltration rate of the dry soil, might be the main reason for the differences between the tested methods. Intensive research on the influence of irrigation techniques on the success of deficit irrigation will be emphasised in future experiments.

3.6 The Control of Postharvest Ripening Processes and its Implications for the Productivity of Mango Processing

Sybille Neidhart, Ana Lucía Vásquez-Caicedo, Busarakorn Mahayothee, Isabell Pott, Werner Mühlbauer, Pittaya Sruamsiri and Reinhold Carle

3.6.1 Introduction

The production of high-quality food depends not only on an appropriate processing technology but also on the selection of proper raw materials. This experience, well known among food manufacturers, can be exemplified in the case of mango processing.

In fruit processing, climacteric fruit species may be distinguished from non-climacteric ones as regards the handling of the raw material. Non-climacteric fruit species, such as lychees (*Litchi chinensis* Sonn.) and longans (*Dimocarpus longan* Lour.), have to be processed directly after harvest to maintain optimal fruit quality (see Chaper 3.7). In contrast, climacteric fruits, like mangoes (*Mangifera indica* L.), have to be harvested at their mature-green stage with subsequent postharvest ripening to reach optimal ripeness for eating or processing. The climacteric phenomenon is characterised by a rise in respiratory gas exchange. Whereas most climacteric fruits display this respiratory trend on or off the tree, some mango varieties present notable exceptions, because they do not ripen when attached to their parent tree (LESHAM et al., 1986). Detachment usually stimulates the emergence of the respiratory peak and ripening. Proper physiological maturity at harvest and control of postharvest ripening are thus decisive factors in the production of high-quality mangoes at consumption.

The aim of this contribution is to review our recent research on adjusted strategies for the utilisation of mangoes within or related to The Uplands Program. Various process technologies are presented which could enable exploitation of the whole crop, when combined with methods of diversified fruit processing and realised in parallel with fresh fruit marketing. Apart from a fundamental knowledge of the quality-related characteristics of the raw material, the realisation of these concepts requires that there should be a reliable supply of raw material, which is independent of fresh fruit markets, and effective methods of sorting the fruit that provide a product of appropriate quality specifically for the intended purposes.

3.6.2 The Importance of Postharvest Ripening in Mango Processing

As Thai mango cultivars have been scarcely considered in international literature, VÁSQUEZ-CAICEDO et al. (2002) comprehensively characterised the quality profiles at full fruit ripeness of nine varieties cultivated in the northern Thai region. However, different mango cultivars are generally consumed or processed at different maturity stages, since their specific sensory profiles result from the differential development postharvest of their major properties. These include softening, formation of yellow-orange pigments, sugar accumulation and acid degradation (Figure 3.16). The carbohydrate and organic acid metabolism result in an increasing sugar-acid ratio (TSS/TA).

Proceeding ripeness is indicated by increasing sugar-acid ratio (TSS/TA). Hue angles decreasing from 135° to 45° imply a colour change from greenish-yellow to orange, with a hue angle of 90° indicating pure yellow.

Therefore, the postharvest ripening behaviour of these nine mango cultivars was studied in detail (VÁSQUEZ-CAICEDO et al., 2004) to complete the previous characterisation of cultivars at full ripeness. On the basis of the cultivar-specific postharvest ripening characteristics, the authors suggested options for processing mangoes at well-defined, appropriate ripeness for different applications. For example, cultivars suitable for puree production, such as `Kaew´, `Nam Dokmai #4´ (Figure 3.16) or `Maha Chanok´, were characterised by fast softening and pronounced yellow-orange pigmentation even at moderate sugar-acid ratios. Processing of the same varieties into cut-stable solid foods, such as canned fruits in syrup, frozen or dried fruits, imply that they should be used at a relatively early stage of ripening, while the fruit is still sufficiently firm (MAHAYOTHEE et al., 2004a). However, the utilisation of cultivars less prone to softening, such as `Chok Anan´, might be more appropriate for these applications because they have a better colour after longer ripening (VÁSQUEZ-CAICEDO et al., 2004).

With respect to the nutritive value of mango fruits, the provitamin A level of their mesocarp is of great interest. It depends on the extent of β-carotene biosynthesis during ripening and on the natural distribution of β-carotene stereoisomers (Table 3.20). Compared to the all-*trans*-stereoisomer, efficiency of β-carotene conversion into vitamin A is only 53% and 38% for 13-*cis*- and 9-*cis*-β-carotene, respectively (ZECHMEISTER, 1962). High provitamin A levels when the fruit is ripe enough for consumption are the result either of elevated total β-carotene contents (e.g., `Nam Dokmai #4´ in Table 3.20) or of low percentages of *cis*-β-carotene isomers (e.g., `Kaew´ in Table 3.20).

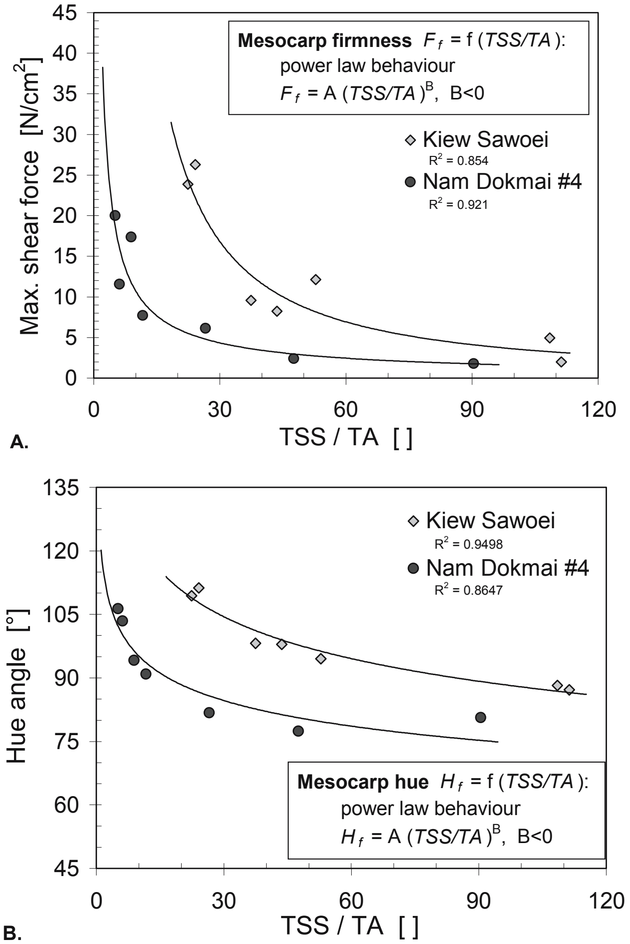


Figure 3.16: Postharvest ripening behaviour of selected varieties among nine Thai mango cultivars studied (VÁSQUEZ-CAICEDO et al., 2004): **A.** mesocarp firmness; **B.** mesocarp colour.

Table 3.20: Extent of β-carotene biosynthesis during postharvest ripening, natural distribution of β-carotene stereoisomers, and resulting vitamin A values of the mesocarp in selected Thai mango cultivars (according to VÁSQUEZ-CAICEDO et al., 2005).

		β-carotene				
Cultivar	TSS/TA[a]	Total [µg/100g DW[c]]	All-trans [%]	13-cis [%]	9-cis [%]	Vitamin A[b] [RE/100g DW]
Cultivar examples[d] with strong postharvest β-carotene biosynthesis:						
Kaew	9.0	1190 ± 75	86.7	13.3	n.d.	186 ± 13
	26.9[e]	5912 ± 231	85.8	8.8	5.4	912 ± 34
	50.2[e]	8249 ± 14	82.5	9.6	7.8	1246 ± 2
Chok Anan	9.8	536 ± 6	100.0	n.d.	n.d.	89 ± 1
	27.6[e]	5053 ± 64	65.9	17.3	16.8	686 ± 7
	49.9[e]	6544 ± 21	66.3	17.6	16.1	892 ± 1
Nam Dokmai #4	8.9	1658 ± 12	73.4	12.2	14.4	236 ± 1
	26.6[e]	5513 ± 30	68.8	15.4	15.8	762 ± 2
	47.6[e]	11249 ± 939	70.5	14.8	14.7	1573 ± 140
Cultivar examples[d] with poor postharvest β-carotene biosynthesis:						
Kiew Sawoei	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	24.1[e]	673 ± 30	100.0	n.d.	n.d.	112 ± 5
	52.8	1544 ± 68	74.2	12.7	13.1	221 ± 10
	111.3	1831 ± 33	73.5	13.9	12.6	261 ± 5
Okrong Thong	14.5	289 ± 10	100.0	n.d.	n.d.	48 ± 2
	23.4	329 ± 12	100.0	n.d.	n.d.	55 ± 2
	65.1[e]	1977 ± 39	66.5	17.4	16.1	270 ± 6
	114.1	2538 ± 62	66.0	18.1	15.8	345 ± 8

[a] TSS/TA, sugar-acid ratio; [b] vitamin A values in retinol equivalents (RE) calculated according to ZECHMEISTER (1962); [c] DW, dry weight; [d] among nine Thai cultivars studied by VÁSQUEZ-CAICEDO et al. (2005); [e] TSS/TA at typical consumption ripeness of this cultivar; n.a., not analysed; n.d., not detectable. Analytical methods as described by VÁSQUEZ-CAICEDO et al. (2005). Increasing TSS/TA ratios indicate proceeding postharvest ripening.

β-Carotene is also among the predominant carotenoids in this fruit (POTT et al., 2003a; CHEN et al., 2004), and it is this pigment which is amongst the most important for the development of the natural mesocarp colour as the fresh mango fruit ripens (Figure 3.17). When the CIELAB colour space formed by the L*, a*, and b* coordinates (HUTCHINGS, 1999) was used for the description of mesocarp colour, the green-red colour coordinate a* and the corresponding hue angle H° also correlated with the all-*trans*-β-carotene content (r = 0.89 and –0.83, respectively), as shown by general correlation analyses of the total data set irrespective of mango cultivar or fruit ripeness (VÁSQUEZ-CAICEDO et al., 2005). Mango fruits that developed a bright yellow-orange colour (Figure 3.16B) were particularly rich in β-carotene at full ripeness, such as the cultivars `Maha Chanok´, `Kaew´, and `Nam Dokmai #4´ (Figure 3.17).

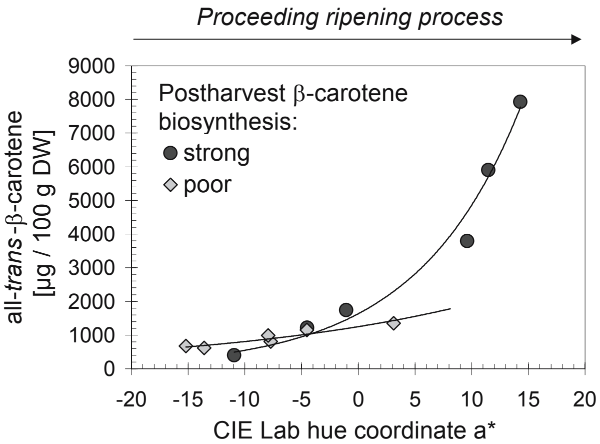


Figure 3.17: Colour development in the mesocarp (CIELAB hue coordinate a*) by cultivar-specific postharvest β-carotene accumulation (according to VÁSQUEZ-CAICEDO et al., 2005), exemplarily illustrated for cultivars with strong and poor postharvest β-carotene biosynthesis (`Nam Dokmai #4´ and `Kiew Sawoei´, respectively).

As already indicated in Table 3.20, the cultivars under study were classified according to their postharvest ripening behaviour in carotene-rich and carotene-poor cultivars. As a consequence of the established correlation between mesocarp hue and vitamin A value, useful "nutritive indicators" could be derived from the regression equations describing the postharvest development of the red colour component (CIELAB hue coordinate a*) of the mesocarp for this cultivar classification. Used along with the vitamin A values, these indicators facilitated simple and rapid identification of carotene-rich varieties for processing by simple determination of mesocarp colour and fruit ripeness (VÁSQUEZ-CAICEDO et al., 2005).

In addition to the quality attributes shown in Figure 3.16, postharvest ripening of mangoes is associated with further changes that affect sensory perception and processability such as increasing susceptibility to enzymatic oxidations and browning after tissue disintegration (VÁSQUEZ-CAICEDO et al., 2004). The nine cultivars studied differred in their proneness to enzymatically induced discolouration during processing owing to the cultivar-specific rise in activities of enzymes, such as polyphenoloxidase, that cause enzymatic browning. Cultivars with pronounced postharvest biosynthesis of oxidative enzymes, such as `Kaew´, should be processed either at early ripening stages when they still provide sufficiently low enzyme activities (MAHAYOTHEE et al., 2004a) or when they are treated to contribute to the early inactivation of these enzymes (KLOOS, 2004; POTT et al., 2005).

As the manifold impact of the cultivar-specific postharvest ripening behaviour on processability and on the nutritive and sensory quality of products has been clearly shown by the cited examples, the importance of the proper selection of cultivars and degree of fruit ripeness has been well documented. However, in postharvest ripening practice, mangoes have frequently been roughly evaluated by rule of thumb, as half ripe, fully ripe and overripe. Thus, quality comparison among cultivars or even fruit batches has often been difficult. Reported cultivar specifications have been subject to broad variations and uncertainties regarding the underlying physiological ripeness of fruit. Consequently, sorting according to ripeness has required visual inspection and it has been found difficult to handle commercially relevant amounts of fruits. Automation of sorting processes is of particular interest when sorting is part of continuous processing lines on an industrial scale. Under these conditions, sorting contributes to the maintenance of sensory and nutritive quality by directing fruit either to the processing line or back to the postharvest ripening chamber thus ensuring fast processing of fruits of uniform ripeness.

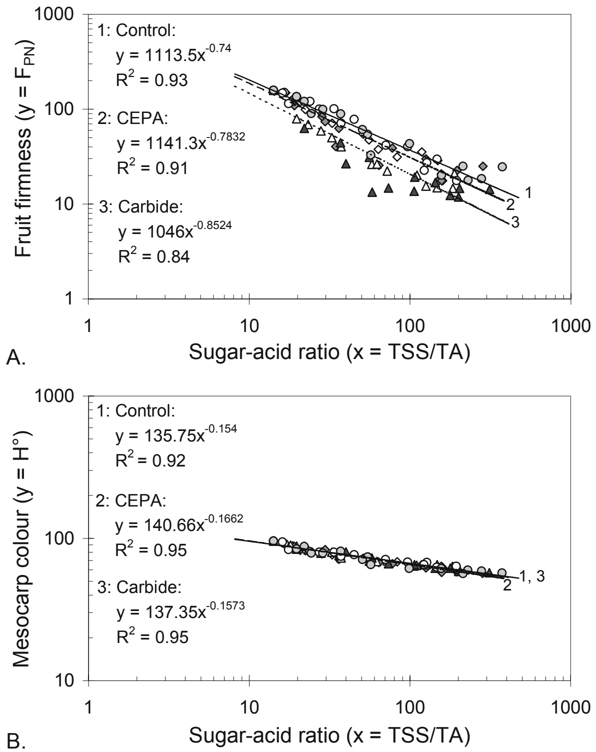


Figure 3.18: Influence of various postharvest ripening conditions on the simultaneous development of quality attributes (MAHAYOTHEE, 2005), exemplified for mango cultivar \`Chok Anan´.

After division of a fruit batch into six portions, different temperatures (open symbols, 25°C; filled symbols, 35°C) and treatments with ripening accelerators (1: control without accelerating agent [circle]; 2: 2-chloroethyl-phosphonic acid (CEPA) [rhomb]; 3: calcium carbide [triangle]) were applied in postharvest ripening.

VÁSQUEZ-CAICEDO et al. (2004; 2005) modelled the postharvest ripening transformations of the nine Thai mango cultivars to investigate the interactions between the changing quality parameters. As a consequence, we were able to establish a ripening index (RPI) in our parallel studies (MAHAYOTHEE, 2005) that was introduced for the specification of postharvest ripeness in the assessment of provitamin A in mango cultivars (VÁSQUEZ-CAICEDO et al., 2005). The index comprises several of the most characteristic physical and chemical qualities that define ripeness. In particular, connecting fruit or mesocarp firmness with the sugar-acid ratio relates the index to the sensory perception of texture and taste. In formulating the index, the different influences of various postharvest ripening conditions on firmness and sugar-acid ratio (Figure 3.18A) had to be taken into account. By contrast, the development of mesocarp colour was unaffected by the conditions under which the fruit ripened (Figure 3.18B), so no adjustment had to be made.

Owing to its linear correlation with postharvest ripening time (MAHAYOTHEE, 2005; VÁSQUEZ-CAICEDO et al., 2005), the RPI is a good method for predicting the ripening period needed under a particular set of conditions until utilisation of the fruits. It does this by exploiting the initial RPI-time data sets after warehousing. At the same time, the novel RPI has potential for automated sorting of mangoes according to fruit ripeness, as shown by our calibration experiments using near infrared (FT-NIR) spectrometers (MAHAYOTHEE, 2005).

Application of FT-NIR spectrometry requires extensive calibration with suitable attributes, which are accessible by conventional analyses. FT-NIR spectrometry was shown to be a useful tool in non-destructive monitoring of the overall quality changes during postharvest ripening, as clearly demonstrated by the high correlation of spectral changes with ripening time rather than with particular quality attributes (MAHAYOTHEE et al., 2004b). For ripeness prediction, calibration with the RPI is consequently the most appropriate approach rather than previous attempts which relied on the determination of individual quality attributes (MAHAYOTHEE, 2005), since the index is derived from several principal properties that undergo characteristic changes during ripening.

Since conventional observation of the ripening process by means of all required analyses is often restricted by a lack of time, manpower, funds, and poor levels of replication (FOLEY et al., 1998), FT-NIR spectrometry provides a rapid and non-destructive alternative to control fruit maturity during postharvest ripening. By use of the novel RPI, fruit maturity could even be estimated for samples with unknown ripening history. After extensive calibration and validation of instrument and method, one mango fruit could be investigated in less than one minute without sample preparation or use of chemicals. In addition, routine analyses with calibrated NIR instruments could be performed by non-skilled operators, even in semi-automatic systems by combining NIR spectrometers with step-wise cell conveyors (SCHMILOVITCH et al., 1999). Furthermore, NIR spectrometry may be integrated into on-line process control, in sorting and grading systems (SCHMILOVITCH et al., 1992). For broad application in industries, packing houses and orchards, the robustness of the calibration models has to be considered for the cultivar to be utilised.

In our studies, the RPI was found to be useful for precise classification of mango cultivars with respect to their proper ripeness for various processes, such as drying, canning or puree production. From a knowledge of the cultivar-specific postharvest ripening behaviour (VÁSQUEZ-CAICEDO et al., 2004), specific technological measures and an appropriate order of treatments during processing could be chosen as a first step towards optimisation of the process and product quality.

Finally, a detailed knowledge of the interactions between quality attributes that alter during postharvest ripening favoured the design of improved postharvest ripening processes for mangoes. The efficiency of ripening accelerators, which release ethylene or ethylene-acting analogues, could be evaluated on this basis by considering their effects on fruit quality (Figure 3.18; MAHAYOTHEE, 2005).

3.6.3 Process Technologies for High-Quality Mango Products

With respect to processing options, we focused on the appropriate utilisation of carotene-rich cultivars. The influence of processing on provitamin A levels in mangoes was studied for various process variables in driers of the solar and conventional over-flow types (POTT et al., 2003b; MAHAYOTHEE et al., 2004a) and in juice production (KLOOS, 2004).

Generally, modern industrial year-round mango drink and nectar production is mostly from puree intermediates produced during peak harvest seasons. Enzymatic puree liquefaction may be applied to standardise viscosity by controlled pectin degradation for technological and sensory reasons, since otherwise, the highly viscous mango pulp will often display inappropriate flow properties (JANSER, 1997). Therefore the fruit component in the final nectar may have been subjected to up to four heating treatments in the form of steam peeling, thermal inactivation of endogenous enzymes prior to enzymatic pulp liquefaction, and pasteurisation of puree and nectar (DUBE et al., 2004). Owing to severe cell rupture during pulping, the β-carotene in the disintegrated tissue matrix might be more prone to oxidative degradation and isomerisation than in solid mango products. Nevertheless, thermally induced degradation and isomerisation of β-carotene was found to be very limited at pasteurisation temperatures (KLOOS, 2004). It was shown by using stepwise process control in a pilot-plant that mimicked established industrial processes, that pasteurised nectars in which the β-carotene content of the processed fruit was largely preserved, could be produced in fast processing lines that consequently limited oxidative degradation. This implies that unnecessarily long holding times at elevated temperature must be strictly avoided particularly in the presence of oxygen, and that corresponding protective measures during filling and sealing should be applied (KLOOS, 2004). In modern industrial production of typical liquid mango products, the application of several heating steps at pasteurisation temperatures can be deemed to have little harmful effect on provitamin A preservation, but equally, it is hardly likely to contribute to a reduction in the allergenic potency of these fruits caused by some heat-stable allergenic proteins (DUBE et al., 2004).

In fruit drying, technologies were devised to avoid sulphitation or other pretreatments such as blanching and osmotic dehydration. Sulphitation is still widely applied in common mango drying practice to protect the fruits from browning and microbial spoilage. However, without precise process control, sulfite contents may exceed trade specifications and the product may not reach the quality demanded by the consumer. Sulphitation has been under critical consideration with respect to the allergen labelling of foodstuffs implemented by EU-Member States in November 2004 (Directive 2003/89/EC). Consequently, sulphur dioxide and sulphites at concentrations of more than 10 mg/kg or 10 mg/L, expressed as SO_2, are amongst those ingredients which have to appear on the label. The sale of products that do not comply with this directive has been prohibited within the European Union since 25 November 2005. Therefore, the process for non-sulphited dried mango slices (POTT et al., 2005) based on the concept of high-temperature drying is of the utmost significance for the international marketing of dried fruit products. As thoroughly discussed by the authors (POTT et al., 2005), the proper choice of fruit cultivar and fruit ripeness contributes to the minimisation of browning caused by the Maillard reaction, and to the early inactivation of browning enzymes by the application of sufficiently high drying temperatures. As a particular economic benefit of the suggested drying concept, productivity of fruit drying is improved by shorter process times that result from the shortened drying processes and the absence of pretreatments no longer needed.

Due to the low moisture content of dried fruit products, dried mango slices were shown to be good provitamin A sources in spite of β-carotene degradation and isomerisation caused by the drying processes (Table 3.21). In solar drying of mango slices, higher β-carotene losses were observed than in high-temperature, short-time processes. As lower drying temperatures were reached in solar drying, drying times of 7-8 h had to be applied (POTT et al., 2003b), causing prolonged exposure of the drying good to heat and light. Apart from thermally induced degradation, light-induced isomerisation to 9-*cis*-β-carotene considerably reduced the vitamin A value of solar-dried mango slices (Table 3.21). However, although shorter drying processes of 3 – 3.5 h without exposure of the drying good to light have to be recommended, solar drying of carotene-rich raw material could still yield mango products of high provitamin A content.

Table 3.21: β-Carotene isomerisation during various drying processes, and resulting provitamin A values of dried mango slices (according to POTT et al., 2003b).

	β-carotene				
Sample	all-trans [µg/100g DW [a]]	9-cis [µg/100g DW]	13-cis [µg/100g DW]	cis-isomers [b] [%]	Vitamin A [c]RE/100g
Over-flow dryer at 75°C for 3-3.5 h to a final water activity of a_w = 0.6 (cv. Tommy Atkins)					
Fresh fruit	3650	n.d. [d]	940	25.8	114
Dried product	2510	traces	930	37.1	431
Solar drying for 7-8 h to a final water activity of a_w = 0.6 (cv. Nam Dokmai)					
Fresh fruit	3650	traces	990	27.1	121
Dried product	2400	810	730	64.2	425

[a] DW, dry weight; [b] calculated as percentage of all-*trans*-β-carotene; [c] vitamin A values in retinol equivalents (RE) calculated according to ZECHMEISTER (1962); [d] n.d., not detected. Drying processes and analytical methods as described by POTT et al. (2003b).

3.6.4 Concluding Remarks

Various technologies have been elaborated for mangoes at different processing levels and would be available for optimising production capacity and management. Suggested processing options are applicable to both small-size and large-scale industrial processing, using fruit drying and pulp processing, respectively, as examples. Each of the suggested processes would largely maintain the vitamin A value of the mango fruit. The mango fruit is also an ideal example for demonstrating the interactions between quality of raw material, postharvest handling and final process technologies and the way they can all be manipulated to optimise product quality.

3.7 Innovative Strategies for Sustainable Lychee Processing

Sybille Neidhart, Piyatip Hutasingh and Reinhold Carle

3.7.1 Introduction

Litchi chinensis Sonn. is a non-climacteric fruit cultivated in many subtropical areas around the world (KADAM and DESHPANDE, 1995). In accordance with its main usage as fresh or canned fruit, most studies on the utilisation of lychees describe aspects of cultivars such as their nutritional parameters (MENZEL and SIMPSON, 1991; KADAM and DESHPANDE, 1995), the discolouration of the pericarp during marketing of fresh fruits (UNDERHILL and CRITCHLEY, 1995; HOLCROFT and MITCHAM, 1996; RAY, 1998; SARNI-MANCHADO et al., 2000) or the risk of pink discolouration of the fruit flesh during canning (WU and FANG, 1993; WU and SHEU, 1996). In view of increasing export markets, recent research has focused primarily on the postharvest biology and technology of lychee fruits, with the aim of producing light-coloured, chemical-free fruits without disease or insect infestation (JIANG et al., 2003). The fruits are appreciated for their fine flavour. The nutritional value of lychees is based on vitamin C which is found in its edible aril generally at levels of 40-90 mg/100 g (KADAM and DESHPANDE, 1995). However, this value is subject to great variation, depending on the cultivar, cultivation area, storage and processing conditions, and can be significantly lower in some cases (RAMMA et al., 2003).

As may be seen from the research topics mentioned above, lychees are highly perishable fruits that are prone to flavour and colour changes after picking, or during processing and storage. This was convincingly demonstrated in an interdisciplinary study on lychee canning, where the influence of heating on the immunological activity of lychee antigens was contrasted with the effects of heat on the sensory properties of the product such as firmness and colour (HOPPE et al., 2006). When the effects of heat treatment of lychees on fruit softening, pink discolouration and reduction in overall allergenic activity were compared, it was found that the respective activation energies increased in the same order. As has previously been shown in the case of conventional mango processing into pulp-containing products (DUBE et al., 2004), the usual canning of lychees ($P_{T_{ref}=93.3°C}^{z=8.9°C}$ = 5-10 min) did not suffice to eliminate allergenic activity completely. Pasteurisation only reduced the activity of some allergens with molecular weights of 25, 28, 32 and 35 kDa without significant reduction in the overall allergenic potency. Harsher heat treatments were not useful due to sensory damage and the high thermostability of particular lychee allergens.

To achieve the desired sensory quality and marketability of the products, careful process control is particularly required for this fruit species. However, when considering the productivity of fruit processing, the annual variation of the crop has to be taken into account. These variations include not only the total amount of the harvest but also the seasonal variation in fruit grades and internal quality.

In general, fruits are graded primarily according to their size (see Chapters 3.3 and 3.5). The influence of fruit size on product yields is self-evident. However, fruit size also determines machine runability, the types of pretreatments necessary, and the adjustments of process parameters. Because of trade specifications, fruit processing into solid products mostly requires the utilisation of particular grades. In contrast, the production and utilisation of fruit pulp is less dependent on pre-sizing of the raw material.

The aim of this contribution is to review our recent research into the adjusted strategies for the utilisation of lychees (*Litchi chinensis* Sonn.) within or related to The Uplands Program. Various process technologies are presented which, altogether, could contribute to complete utilisation of the whole crop, when combined with concepts of diversified fruit processing. In this way, fresh fruit marketing could be amended by the conversion into high-quality products of excess amounts of upper-grade fruit and those fruits, which are not adequate for fresh fruit marketing (e.g., owing to their low grade). Such options for diversification may involve well-established technologies as well as innovative approaches. Altogether, this concept is considered a primary prerequisite for sustainable fruit processing. The whole process aims at:

(1) avoiding fruit losses by spoilage due to seasonal overproduction and
(2) processing fruit as far as possible continuously throughout the whole year for various domestic and international markets.

In this chapter, the technological possibilities of processing fruits of any calibre is exemplified by lychees. The significance of so-called industrial cultivars, offering outstanding processing properties with respect to quality profiles and machine runability, should also be taken into account.

3.7.2 Particularities of Present Industrial Lychee Processing in Northern Thailand

Owing to the very short harvest periods, which were specified for northern Thailand in Chapter 3.3, and limited fruit production in the Thai highlands (see Chapter 3.1), industrial lychee processing is still largely restricted to canned fruits in syrup, mainly for export markets. As part of the participatory research, the present situation was analysed by means of interdisciplinary interviews at local fruit processing companies in the extended region around Chiang Mai in 2001 (STEMMER, 2002; CARLE et al., 2003). These interviews focused on the economic and technological aspects. Among numerous lychee cultivars and the botanically related longans (*Dimocarpus longan* Lour.), only lychee cv. `Hong Huey´ and longan cv. `E-Daw´, respectively, were processed. According to international trade specifications, the edible part of the fruit is mainly preserved as whole, peeled fruit without seed (e.g., DEUTSCHE LEBENSMITTELBUCH-KOMMISSION, 2004). Therefore, manufacturers usually compete with fresh fruit markets for large-sized fruits. Profitable processing has been possible only in crop years when upper-grade fruits were available at low prices. Thus, lychee processing has been of only minor importance for canneries and has not involved the permanent employment of personnel or the use of dedicated equipment. During their harvest period, lychees (as well as other seasonal fruits) have been processed mostly in small multi-purpose processing lines in parallel with permanent lines for year-round products such as selected vegetables. In the companies interviewed, average seasonal production ranged from 5 to 25 t of raw fruit / d for lychees or longans. Maximum capacities could reach up to 40 t of raw fruit / d. In contrast to permanent lines, the necessarily multi-purpose arrangement of canning lines for seasonal products became particularly evident as did the lack of investment in specialised equipment for operations specific to individual fruit species. Preparation of the raw lychees for canning is the most striking example: Instead of using mechanical peelers, destoners and fillers specifically adjusted to the raw material to be processed, labor-intensive manual peeling and simultaneous destoning of the fruits, followed by manual filling, is performed by a large number of seasonal workers.

In 2001, a case study was made of the quality of industrially canned lychees and longans (STEMMER, 2002; CARLE et al., 2003). Among a broad range of chemical and physical parameters, the study focused on the vitamin C content which was analysed as total ascorbic acid after reduction of dehydroascorbic acid (DHAA), as well as ascorbic acid (AA), according to the HPLC method described by HUTASINGH (2004). Samples of canned lychees in syrup (samples A to F from 6 different companies) and canned longans in syrup were obtained from four Thai manufacturers or purchased on domestic markets in Thailand. Little was known of the product histories of the canned samples, apart from the fact that the lychee samples directly provided by the manufacturers had been stored at ambient temperature over approximately one season, whereas the longan samples were produced during the harvest season in the year of the study (2001). The characteristics of the lychee samples are summarised in Table 3.22.

Table 3.22: Characteristics of industrially canned lychee fruits in syrup (CFS) investigated.

Samples	pH	Total soluble solids [°Brix]	Titratable acidity (citric acid, pH 8.1) [g/100g]
CFS A	3.88	20.30	0.03
CFS B	3.91	22.20	0.13
CFS C	4.28	21.60	0.07
CFS D	4.03	19.50	0.12
CFS E	3.95	20.90	0.04
CFS F	3.36	20.90	0.29

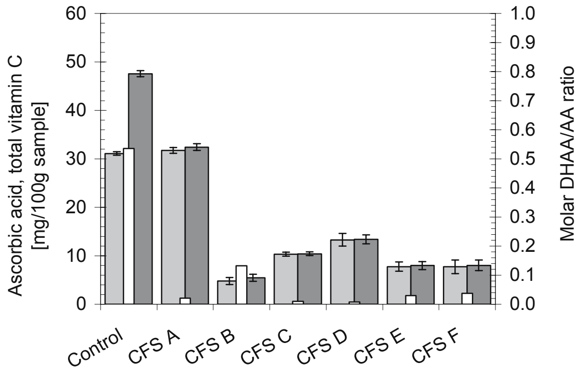


Figure 3.19: Contents of AA and total vitamin C, and molar DHAA/AA ratio in industrially canned lychee fruits in syrup (CFS) determined by HPLC after storage at ambient conditions for approximately one year. Control: fresh lychee fruits. ν, AA; ν, total vitamin C; □, molar DHAA/AA ratio.

The industrially canned fruits in syrup differed markedly in their absolute vitamin C contents, and DHAA/AA ratios (Figure 3.19). Only sample A reached the range of AA contents reported for fresh fruits and values were generally low ranging from 5.46 and 13.39 mg/100 g of canned fruit depending on the quality of the fruits and the conditions of processing and storage. The DHAA/AA ratios were also low possibly due to degradation of DHAA during the long storage of the cans. Strikingly high AA contents in some of the canned fruits may have been the result of the addition of AA as an antioxidant to the syrup to compensate for the losses of natural vitamin C during thermal processing. Conversely, CHAKRABORTY et al. (1974) reported the use of lychees with only 18 mg of AA / 100 g for canning, without investigation of potential AA losses during canning or product storage. With the exception of one sample (50.23 mg/100 g of canned fruit), total vitamin C contents of canned longans in syrup (four samples from production year 2001) ranged between 24.54 and 28.33 mg/100 g of canned fruit. The elevated molar DHAA/AA ratio of approximately 0.5 characterising the fresh lychee fruits is in accordance with their moderately acid pH around 4. A similar situation was found in tomatoes by GÖKMEN et al. (2000). DHAA therefore makes a significant contribution to the vitamin C activity of fresh lychees, contrary to the situation in the more acid citrus fruits.

The contribution of canned lychees and longans to the vitamin C supply of the local population seems to be insignificant, since residual total ascorbic acid was shown to be generally low in the products studied, and production is predominantly directed to export markets. Therefore, the economic potential of canned fruits in syrup is due to the possibility of reducing postharvest losses, and to the 'add on' value of the product in the cultivation region rather than to any increase in the nutritional value of the local diet.

3.7.3 Novel Options in Lychee Processing

It has been emphasised that lychees are strongly prone to colour and flavour changes during processing and storage. Apart from manual peeling, available peeling technologies, such as mere mechanical, lye or thermal peeling, are hardly recommended for such delicate fruits either because of poor peeling efficiency or because of the resulting loss of sensory qualities.

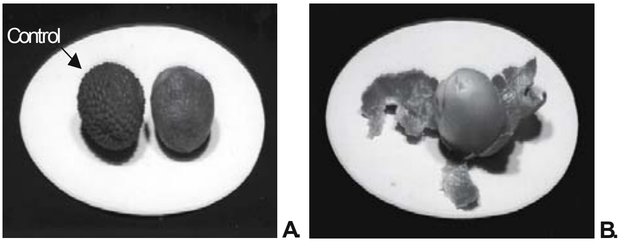


Figure 3.20: Mechanical-enzymatic peeling of lychees cv. `Hong Huey´: **A.** Pretreated fruit after enzymatic digestion of the peel for 30 min at 30°C; **B.** Peeled fruit after the mechanical-enzymatic peeling process (MEPP).

On the basis of our investigations on the composition and enzymatic degradation of cell wall polysaccharides in peels and the aril of lychees, the applicability of enzymatic peeling to lychees was evaluated (NEIDHART et al., 2001). After mechanical preparation of the peels for vacuum-infusion with the peeling enzymes, the peels were removed from the edible aril by enzymatic degradation of the peel cell walls, and the aril was subjected to a jet of water (Figure 3.20). No differences in the sensory properties of the fruit nor in its firmness were found when this peeling procedure was compared with manual peeling (Figure 3.21).

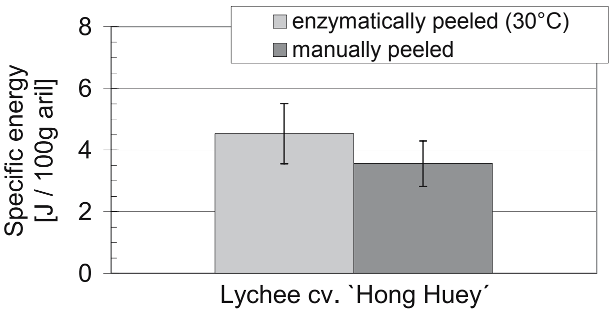


Figure 3.21: Mechanical-enzymatic peeling process (MEPP) for lychees: Comparison of aril texture after MEPP and manual peeling (control).

Subsequently, a mechanical-enzymatic peeling process (MEPP) was developed and integrated into the semi-continuous processing of lychees into cloud-stable lychee juices (HUTASINGH, 2004). The pulp-containing end product is shown in Figure 3.22 (variant LNP). The intensity of cloudiness in this lychee drink, containing 30% of lychee puree, was much higher than that of the lychee drinks usually offered in Thailand or sold on the export markets. Moreover, the pulpy cloud particles were less prone to sedimentation. Owing to the stabilised pulp particles and the increased pulp content, the product was organoleptically characterised by a better mouth-feeling and a particularly intense aroma typical of this fruit. Like pineapples or passion fruit (NEIDHART et al., 2002; MATTES and ENDRESS, 2000), lychees on their own are devoid of any cloud-stabilising potential and yield completely clarified drinks (variants HN and LN in Figure 3.22) unless they are subjected to additional cloud stabilisation technology, such as the addition of pectins as stabilising agents (Figure 3.23).

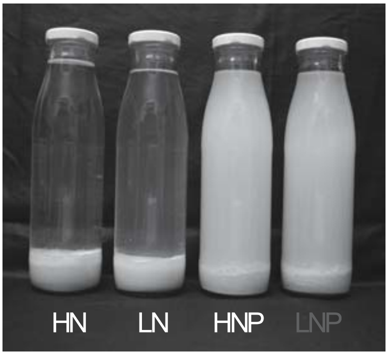


Figure 3.22: The use of MEPP in the production of liquid lychee products: a pulp-containing lychee drink with 30% of fruit (variant LNP). Manual peeling of fruits in production of control variants HNP and HN. Control products without cloud stabilisation (variants HN and LN) completely clarified during 6-months storage.
Products: pH 4.0; total soluble solids (TSS): 12 °Brix.

However, lychee cultivars differed in their technological suitability for MEPP owing to the specific physical characteristics of their peel structure. This resulted in differential accessibility of the cell wall polysaccharides to the enzymes throughout the peel, despite the fact that the composition of the cell wall polysaccharides is similar (NEIDHART et al., 2001). Therefore, specific cultivars with particular processability were preferred for juice production (Figure 3.23). Contrary to the situation with canning, it was thus possible to simultaneously process fruits of any calibre for conversion into high-quality liquid and viscous products.

At the same time, it is evident that the selection of an adjusted peeling technology for a specific conversion and preservation process is necessary to provide both optimal quality and profitability. When MEPP is applied for peeling, the intact seed is automatically removed later on during mechanical pulping of the peeled fruit in a passing machine for puree production. A separate destoning step is not necessary in this process (Figure 3.23). Removal of the red peel during pulping would cause discolouration of the white puree by peel anthocyanins. Therefore, it is essential to peel the fruit before it is pulped during puree production from lychees.

In industrial practice, MEPP would be thus advantageous in puree and juice production rather than in conventional canning of whole aril pieces. The latter requires peeling and destoning with minimal destruction of the fruit flesh. Owing to the shape of the fruit, these operations are presently performed by combined manual peeling and destoning. In batch processing with a high percentage of manual operations, decay by microbial contamination and biochemical transformations would be limited, if total process time was shortened both by the use of sufficient manpower and restriction of processed lot sizes. Given this prerequisite, the presently prevalent combination of manual peeling and destoning ideally matches the canning process owing to the flexible use of available manpower for various seasonal products.

However, as throughput is limited, this peeling procedure would be disadvantageous in semi-continuous juice production.

Therefore, in cases where lychee crops of selected cultivars suitable for industrial processing are abundant, the following processing concept is suggested: Both process options, that is, canning of limited quantities of fruit with sufficiently high assignment of personnel and highly automated, semi-continuous juice production on a large scale, could be managed in parallel to enhance and diversify lychee utilisation.

In the canning of fruits in syrup, as a direct kind of food processing, the edible part is preserved after slight preparation of the fruits without any conversion step. The final product is destined for direct consumption, and the process is limited to harvest seasons.

Contrarily, puree production would offer further possibilities for diversification of lychee processing. During the peak harvest season, puree may be partly processed into final beverages and partly preserved as intermediates for sale or further processing during off-season periods (Figure 3.23). Lychee purees may be produced not only for juice production, but also for the production of pastries, ice-cream, dairy products and baby food. Thus, fruit purees have market potential as intermediates in a diversified food industry on a domestic or at an international level. Unlike canning, processes as envisaged in Figure 3.23 would be characterised by nearly year-round production, semi-continuous processing with high throughput, and a high degree of automation ensuring short process times. They would also be independent of fruit size.

3.7.4 Concluding Remarks

As discussed in Chapter 3.6 on the mango fruit (*Mangifera indica* L.), various technologies have been analogously proposed for lychees at different processing levels with the aim of optimising production capacity and management. So far, the focus has been on the utilisation of the fruits irrespective of their heterogeneity in size and quality by adjusting the selection of raw materials and process technologies. The application of these technologies in a specific region, such as northern Thailand, would ultimately depend on the scale of fruit production for industrial fruit processing and on the desired orientation of industrial food production.

3.8 Synthesis: Food Safety, Productivity and Environmental Awareness as Key Objectives in Sustainable Fruit Production and Processing Systems

Sybille Neidhart and Pittaya Sruamsiri

Research discussed in this chapter provides basic knowledge on characteristics of local fruit cultivars and the quality of products thereof. Participatory research approaches were extensively used and valuable in identifying constraints and research needs, but also limited as cooperation and openness of interview partners differed widely. The three fruit species of interest, mangoes (*Mangifera indica* L.), lychees (*Litchi chinensis* Sonn.) and longans *(Dimocarpus longan* Lour.), were investigated in parallel. Experimental research focused on:

(1) Stabilising and extending the availability of fruits by overcoming alternate bearing of the fruit trees,

(2) Adjusting utilisation strategies for the above fruit species, aiming at diversification to meet natural heterogeneity in fruit size and quality.

Both in fruit production and processing, basic technical solutions were developed and partly even introduced into practice. At each level of the food chain, the natural peculiarities of mangoes, lychees and longans had to be taken into account and resulted in different scientific progress among the three fruit species. Mostly, the suggested solutions could not be simply transferred from one fruit species to the other, even not among the *Sapindaceae* fruit crops. Specific investigations on each species or even cultivar are necessary, as highlighted in the various reports. This equally applies to fruit production and processing, to flower induction (Chapters 3.3 - 3.4) as well as to mechanical-enzymatic peeling (Chapter 3.7). Special issues may have to be considered additionally, such as postharvest ripening in mango utilisation (Chapter 3.6), which is not relevant for lychees and longans.

Concurrently, it has become evident that the existence of elaborated techniques and the scientific knowledge of their potentials do not yet guarantee their sustainable application. New

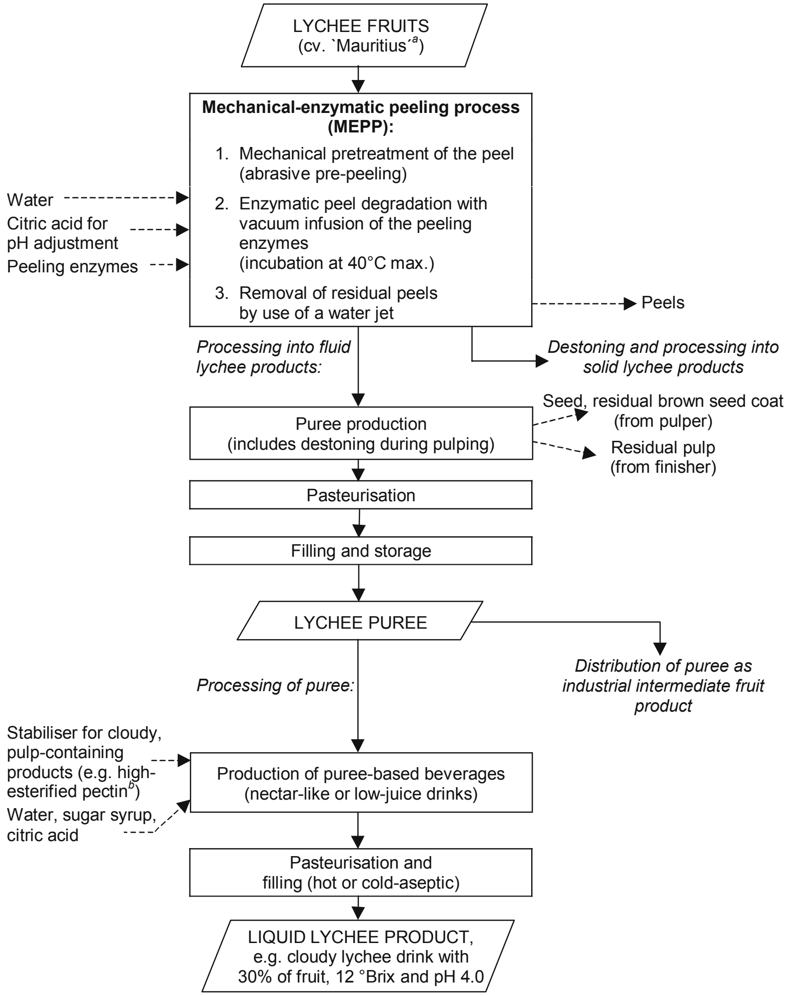


Figure 3.23: Alternative ways of lychee processing on the basis of a mechanical-enzymatic peeling process (MEPP) with particular focus on naturally cloudy lychee fruit drinks.

[a] syn. `Hong Huey´ (Thailand), `H.L.H.´ (South Africa), `Tai So´, `Big Crop´ (Australia), `Kwai Mi´, `Charley Tong´ (USA) (MENZEL and SIMPSON, 1991; ARADHYA et al., 1995); [b] e.g., industrially recovered from apple pomace or citrus peels.

challenges may be generated, as shown by off-season longan production. The initially prevailing use of this technique to increase regular in-season yields instead of off-season fruits has caused disadvantages in price levels and water demands. Time is obviously needed to pave the way for the originally intended sustainable applications of such techniques. After the development of any technique, its thorough validation with respect to effects in various domains, possibly followed by further adjustments, may characterise subsequent research. Successful implementation requires interdisciplinary approaches in order to weave the developed technique into sustainable conceptions for production management along the whole food chain. As the various components of the food chain often develop with different speed due to the peculiarities of each fruit species or other influences, basic techniques may still have to be improved on one level of the chain, while existing techniques used on another level might already be validated. Hence, verification of integrated utilisation concepts from fruit production to processing and marketing can occur only in future research periods.

Implications for future research are manifold (Table 3.23), but become increasingly specific for each of the three fruit species. Proceeding on each level of the food chain, mangoes, lychees and longans might often be no longer investigated in parallel as to a common problem because of increasing complexity of issues at each level. At the present stage, each fruit species presents its own challenges in research on sustainable fruit utilisation.

Table 3.23: Research fields for the evaluation of off-season fruit production and sustainable fruit utilisation.

Evaluation of off-season fruit production	
1.	Control mechanisms and production management (Induction of flowering, irrigation and plant nutrition, canopy management, cultivar performance)
2.	Long-term productivity of trees and fruit quality, particularly under improved use of scarce resources
3.	Specification of target physiological maturity at harvest
4.	Environmental risks (ecological impacts and food safety)
5.	Economic viability of fruit production and fruit utilisation (regional cultivar base, microclimatic effects on orchard viability, profitable fruit-growing and adjusted postharvest management, product differentiation)
6.	Stability and balance between fruit availability and demands
7.	Social acceptance of techniques in fruit-growing and postharvest handling in the presence of arising trends
8.	Regional transfer of knowledge
Fruit processing	
1.	Process management and institutional conditions of raw material supply chains
2.	Minimisation of processing waste (material recycling and recovery of value-adding by-products)
3.	Up-scaling of technical developments

Table 3.23 reveals the increasing complexity and the challenges at various levels of the food chain, even for a single fruit species. In addition, the particular situations in Thailand and Vietnam have recently been reviewed in more detail for fruits in general (RERKASEM, 2005) and the *Sapindaceae* fruits in particular (SETHPAKDEE, 2002; HAI and DUNG, 2002; CHOO, 2002; MENZEL, 2002; MENZEL and WAITE, 2005). Manifold implications for research beyond the initiated studies outlined in Chapter 3 can be anticipated. Food safety, productivity, and environmental impacts

may be the key objectives in validation of production techniques previously developed (Table 3.23). The efficiency of fruit processing techniques has been shown to be strongly dependent on the amount of fruit available (e.g., Chapter 3.7). It may prove a major task in the near future to estimate what target amounts are optimal in regional fruit production as regards profitability for farmers, traders and manufacturers as well as ecological aspects. The necessity of an interdisciplinary approach becomes increasingly evident as we proceed to validate the application of the concepts mentioned here to the utilisation of fruit. However, research requires sufficient time for developing viable solutions, while local developments are often subjected to other dynamics as shown by the example of the *Sapindaceae* fruits in Thailand (SETHPAKDEE, 2002), despite the country's long history of these fruit crops. In view of the increasing complexity of the investigated problems, prioritisation is increasingly needed in research. In priority selection, the challenge would be to find a sound balance between considering the dynamics of local developments and the promotion of concrete production and utilisation concepts. Last but not least, it should be considered in this context that it is up to the scientists to lay the foundations for the responsible use of an innovative technique after its elaboration.

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4.0 Livestock Production Systems

4.1 Introduction

Anne Valle Zárate

1) How does a chapter on livestock link to the topic of "sustainability"? Among animal science researchers, the term is as widely used and defined as in other disciplines. However, the common ground is usually (like in other disciplines mentioned in the general introduction to this volume) the definition resulting from the Brundtland Commission and covering the preservation of species and ecosystems with focus on distribution across generations (WCED, 1987). The extension of the focus performed by the UN Conference on Environment and Development in Rio de Janeiro (1992) to fair intra-generational distribution between the developed and developing countries, however, is not yet to be regarded as common ground and has rarely been addressed by animal scientists as e. g. by HODGES (2005). Little attention is given from the animal science discipline to the concept of sustainability per se, but in the last decade, issues related to the concept of sustainability have received increasing attention. For example, GAMBORG and SANDOE (2005) summarise prominent values, which define sustainable forms of animal breeding, namely: environmental production, animal health and disease, animal welfare, animal integrity, biodiversity, consumer safety, good quality, competitiveness, and common welfare. Among those, in industrialised societies and specifically by animal scientists from Western Europe, the issues of animal welfare and animal integrity have received increasing attention, whereas for tropical animal breeding, biodiversity has gained the most attention in recent years. Both research communities have addressed the issues of environmental protection, animal health and diseases and competitiveness in the past, but give presently more attention to consumer safety, food quality and human welfare, comprising all sectors of society, particularly trying to initiate dialogue between different stakeholders for deriving overall-accepted breeding goals and husbandry practises. This chapter addresses selected topics of relevance for the concept of sustainability in the livestock production systems context, which are expected to be of particular interest within the interdisciplinary research approach of The

Uplands Program in Southeast Asia: productivity and competitiveness of livestock breeding and technologies, contribution of livestock to food security, biodiversity as well as animal health as related to consumer safety and food quality.

2) All contributions assembled in the following chapter refer to research conducted in northern Vietnam, where livestock in general and pig husbandry in particular play a decisive role within different integrated crop-livestock smallholder farming systems.

Most of the research was carried out in Son La province attempting to cover a variety of production intensity levels, following a commonly agreed approach of selecting villages and conducting analysis along a gradient in altitude, corresponding with distance to town from urban to remote conditions, along with predominance of different ethnic groups, accessibility and orientation to markets as well as poverty conditions of farmers.

This approach is presented in the first article by DOPPLER et al., which gives an overview on the spatial and temporal differentiation of prevailing systems. The past role of livestock and its future potential are addressed, with special emphasis on the contribution of livestock to food security.

The second article by LEMKE et al. reports on research work partly overlapping in research sites with the first contribution and focussing on the most important livestock species, the pig. Suitability of local pig breeds as compared to improved introduced pig genotypes is compared for production systems along the gradient and classified to their characteristics regarding "demand driven" versus "resource driven" systems. Management of pig production is described, and results on input- and output-parameters presented, leading to a comparison of breeds and systems according to production efficiency.

The third article of THUY et al. follows a broader approach looking on the variety of livestock species in northern Vietnam, at the same time focussing on local livestock genetic resources. Assuming a specific relevance of local breeds for the sustainability of land use in remote areas and a sustainable management of autochthonous animal genetic diversity, overview is provided on characteristics and population trends of all domestic animal genetic resources.

In the fourth article, research results of THUY et al. are presented, which again focus on pigs. Based on the evaluation of 10 microsatellite markers, genetic distances have been estimated, comparing the genetic diversity of Vietnamese pig breeds to exotic, high-yielding breeds.

Economic valuation of local genetic resources attempts to simultaneously address the contribution of local breeds to biodiversity, the immediate use of livestock for the farmer as triggered through animals performance under extensive smallholder conditions, as well as potential future utilities through the existence of specific rare genes in livestock breeds, leading to superior characteristics in secondary traits. Of specific interest in this context are disease resistance traits; however, while their genetic foundation in local populations has been much assumed it has rarely been proven.

The article by ROMIG et al. reports on first results of research intended to document genetic differences in animals' resistance against parasites. As a first necessary step, a survey for selected livestock parasites in Son La has been conducted. Besides the aim of identification of resistance characteristics in local breeds as an intrinsic genetic quality, effects on product quality and meat safety have to be considered as well, if livestock production systems to be further developed shall sustainably contribute to health, wealth and social welfare of the human population.

4.2 The Contribution of Livestock to Sustainable Development of Mountain Farming in Northern Vietnam

Werner Doppler, Nguyen Thi Thanh Huyen and Do Anh Tai

4.2.1 Introduction

Living standards and food security in the mountain zones of Southeast Asia are largely determined by the availability, quality and use of resources in rural farming families, by the accessibility of markets and by the education and cultural behaviour of the indigenous ethnic groups. Changes in production conditions, degree of market orientation and socio-economic conditions of the families can be found as one progresses from urban to remote zones. Research has been carried out in Son La Province in Vietnam by LENTES (2003), TAI (2004) and HUYEN (2004) to investigate and analyse the variations in the principal development parameters and to determine the driving forces behind them. Livestock production is an important component of farming systems and has played a significant role in their spatial and temporal differentiation throughout the area. This paper deals with such research questions as the role that livestock has played in improving living standards and food security within the framework of rural development in the past, and what strategies should be applied to minimise differences in the level of development of farming systems in different locations. in the future.

4.2.2 Objectives

To answer the above questions, the following targets were set for the research programs carried out over the last five years:

1. To understand and explain the situation regarding availability and use of family resources in different farming systems in which animal production is a component.

2. To analyse the contribution of animal production to the living standards of farm families in different environments over time.
3. To predict the impact of future strategies in livestock production on the improvement and sustainability of family living standards.

4.2.3 Principal Concepts and Methods

Study area and classification of systems: A study area was selected in the Mai Son area, which represents a closed watershed with remote high mountain zones, sloping areas in the intermediate section and an urban centre in the lowland part as presented in Figure 4.1. The area is characterized by an increase in the importance of livestock the further one travels from the urban centre, but the level of intensity of livestock production is the opposite (Table 4.1). The farms and families were classified, according to their relation to the market, into Market Related System (MRS), Intermediate System (IS) (the mix between extensive and intensive animal production) and the Remote Area System (RAS). The market related system is close to the urban centre with high purchasing power and the cultivated land is flat with high production potential. The well-educated Kinh people live there and keep relatively few livestock. In the Intermediate System production conditions are good, but there is already a problem with soil degradation on sloping farmland when it is incorrectly used. Agriculture provides subsistence as well as produce that can be sold in the market for cash. The dominant ethnic group is the Black Thai. Livestock production is widespread and based on home fodder production as well as feed purchased from the market. In the Remote Area Systems livestock density is not as high as in the Intermediate Systems, but contributes more to income than in any other system.

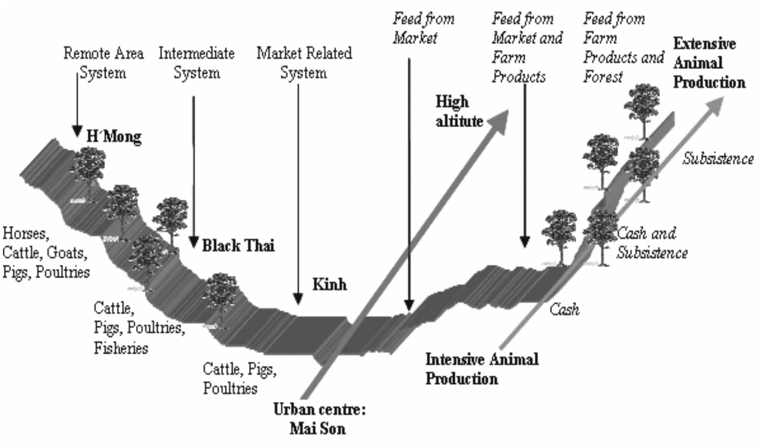

Figure 4.1: Transect of a valley showing typical production zones and areas of different development potential.

Table 4.1: Average numbers of animals per family in the different farming systems and locations from the study in Mai Son, Vietnam, in 2001.

System	Market related systems	Intermediate Systems			Remote area systems
Village	Bac Quang (n=25)	Na Huong (n=25)	Bo Duoi (n=22)	Ban Un (n=25)	Pa Dong (n=25)
1. Oxen	0.00	0.24	1.36	1.26	0.72
2. Cows	1.00	1.60	0.86	0.33	0.96
3. Pigs	2.52	5.88	2.50	4.88	3.12
4. Poultry	23.28	42.56	30.55	16.36	20.00
Tropical livestock Units TLU	1.51 (0.46)	2.79 (1.5)	2.86 (1.93)	1.72 (1.25)	2.43 (2.83)
Animal density (head/hectare)	0.75 (0.34)	1.34 (0.54)	1.07 (0.87)	2.30 (2.24)	1.61 (1.84)

Source: LENTES, 2003, TAI, 2004, HUYEN, 2004.

Figures in parenthesis are standard deviations. Significant difference in numbers of TLU and animal density among five villages were assessed using the Kruskal – Wallis test at a probability of 99%

Information base: The information available came from a primary survey in 1999 and 2002 and remote sensing data (LENTES, 2003). All family surveys are based on random sampling of families in each village. Villages were randomly selected and in each village 22 to 25 families were chosen for the two surveys, giving a total of 222 families (TAI, 2004; HUYEN, 2004). Standardized questionnaires were applied in the interviews during all surveys. In addition, a key person survey using 50 cases spread over the study area provided additional information from persons with specific information, experiences and views in the area (LENTES, 2003).

4.2.4 Analysis of Current Situation and Past Development

Resources and resources use: The comparative analysis shows that family resources become increasingly scarce along a gradient from Market Related to Remote Area Systems. Families are large in the Remote Area System with many young children. As communities become more remote, their members tend to have fewer capital assets, the intensity of production and the quality of the infrastructure is lower, and market sales, education level and all kinds of services (schools, health care, veterinary services) decrease. As a consequence, the knowledge of families living at higher altitudes becomes increasingly based on indigenous experiences rather than on knowledge transfered from the outside world. This can be seen in the case of feed for livestock. With increasing remoteness more feed is home grown rather than being bought from the market. The fluctuations between the two years of the study show that the the relative proportion of the two sources of feed is not fixed, but can vary between the seasons according to the level of production of by-products and fodder growth on the farm and the transportation costs and prices of feed at the markets. Farmers respond flexibly and this is usually an indicator of a general readiness to adjust their livestock operations according to the availability of resources and economics. The feed situation is influenced not only by the amount of grazing land used at high altitudes but also by crop production. In the whole area, the quality of the land is low according to the responses of more than 76% of the farmers (in the Remote Area System and in the Intermediate System) who claimed that crop yields tended to decrease over time. The practice of using manure for increasing or at least maintaining soil fertility was unknown to these families. Forest land had also become degraded over time diminishing the opportunity for using forestry products, which had consequences for income and especially for food supply and security. The extent of access to markets and services has an impact on the use of veterinary services and hence on the intensity and efficiency of the livestock sector. In general, the use of veterinary services decreases with increasing remoteness, but shows fluctuations over time indicating that families respond to different administrative and economic circumstances.

Farm and family income: Farm income decreases from urban zones to remote areas (Table 2). Since off-farm income also decreases, the family income is lowest in the high altitude zone for the H'mong people. The contribution of livestock to farm revenue is highest in the Intermediate System (up to 29% of the total farm revenue) because the herd size is largest here and the stocking rates highest. The next greatest contribution is found in the Remote Area System (15% of the total farm revenue). Both the production levels of individual animals and the total herd size on a farm affect farm income. On farms that have a lot of good quality land, crop production is intensified and dominant and the relevance of livestock decreases. On farms that have very little land or that have a lot of land but of low quality, the contribution of livestock to the farm income increases. Non-cropped areas offer opportunities for increasing income through increasing herd size as long as this does not also involve cutting down forests or overusing forest land. Results from regression models indicate the importance of animal production to income and living standard of farmers in the Intermediate and Remote Systems areas. A small change in the animal sector has a great impact on income and living standards. This means animal production has a high potential for the future development of farming systems and offers opportunities for the development of mixed farming systems.

Food security: The farm and family income per member of the family provides the economic basis for assessing the levels of family consumption and household supply. Generally, the income available for the family is about four times higher in the Market Related Systems than in the Remote Area Systems (Table 4.2).

There is a significant difference in farm and family income among five villages according to the Kruskal – Wallis test at a probability level of 99% but no significant difference in off – farm income among villages according to Kruskal – Wallis test at a probability level of 90%.

Table 4.2: Family income in relation to the resources used by different farming systems, Mai Son 2001.

Systems	Market Related Systems	Intermediate Systems			Remote Area Systems
Villages	Bac Quang (n=25)	Na Huong (n=25)	Bo Duoi (n=22)	Ban Un (n=25)	Pa Dong (n=25)
Farm income (1000 VND)	17487.4	23469.0	18292.0	8380.1	6915.6
- Per ha of cultivated land	8319.3	11565.0	6771.4	9708.9	4565.9
- Per family member	3999.0	4305.5	2900.1	1411.5	963.3
- Per family labor unit	7391.2	8570.3	6020.3	2850.9	1935.8
- As % of family income	80.3	92.3	86.5	74.9	81.8
Off farm income (1000 VND)	5559.2	2494.2	3013.5	2276.6	1103.3
- As % of family income	19.7	7.7	13.5	25.1	18.1
Family income, (1000 VND)	23046.6	25963.1	21305.6	10656.7	8019.0
- Per family member	5206.3	4685.2	3357.5	1814.5	1141.9
- Per family labor unit	9672.9	9302.0	6983.1	3662.4	2292.8

Source: LENTES, 2003, TAI, 2004 and HUYEN, 2004.

Livestock contributes to the living standard of the families. The value of the food consumed by the families is lowest in the remote areas (Table 4.3). The value of the goods consumed by the H'mong people is only about 65 % of that consumed in Market Related

Systems. Averaged over the year, there is no food deficit but, as was found by LENTES (2003), there are food shortages in certain periods of the year in some farming systems (Figure 4.2). There is a clear relationship between temporary food deficits and how far people live from towns. In Market Related Systems and in Intermediate Systems the danger of a temporary food deficit is much lower than in remote areas. From a nutritional point of view, people in remote areas consume more high energy crop produce and have protein deficits over longer periods. It is in these areas that livestock could contribute greatly to the improvement of the nutritional situation. In remote areas, the production of livestock products such as beef, pork, chicken and eggs greatly exceeds home consumption; these products are sold on the market to provide the limited cash earnings of these families.

4.2.5 Assessment of the Likely Impact of Future Strategies

On the basis of analyses of past development and the current situation, the most limiting factors in the past have been determined and modified to define future development strategies. Programing models have been developed, tested and applied to measure the likely future impact of such strategies on farm and family income, on food security and on the overall living standards of the families in different farming systems, locations and ethnic groups (HUYEN, 2004). One group of strategies attempts to increase limited resources, especially herd size which depends on the capacity of farmers´ stables. Another group focuses on the intensification of livestock production by improving feeding regimes and herd management and by providing more comprehensive veterinary care. The results can be summarized as follows.

Table 4.3: Food supply and consumption of livestock products in an average family per year in different farming systems and locations in the Mai Son study area, 2001.

Livestock products	Market Related Systems	Intermediate Systems			Remote Area Systems
	Bac Quang	Na Huong	Bo Duoi	Ban Un	Pa Dong
Value of food in 1.000 VND	8266.2	10187.0	10030.9	5826.1	5360.6
Subsistence in 1.000 VND	1114.8	3756.7	4204.9	3998.6	2330.9
From market in 1.000 VND	7151.4	6430.2	5826.0	1827.5	3029.7
Bought from market in %	86.5	63.1	58.1	31.4	57.7
Thereof livestock produce %	39.3	37.5	41.9	61.6	16.1
Total meat consumed, kg	101.9	83.6	95.0	75.1	48.5
Total meat produced, kg	122	161.4	91.6	130.4	204.7
Balance of meat (kg)	+ 20.1	+ 77.8	- 3.4	+ 55.3	+156.2
Consumed chicken in no.	27.6	47.2	63.8	21.6	18.8
% own chicken production	64.9	95.5	91.8	89.4	34.0
Eggs consumed in no.	345.0	227.7	359.0	114.8	17.1
% own egg production	74.1	53.7	80.3	76.7	73.2

Source: LENTES, 2003, TAI, 2004 and HUYEN, 2004.

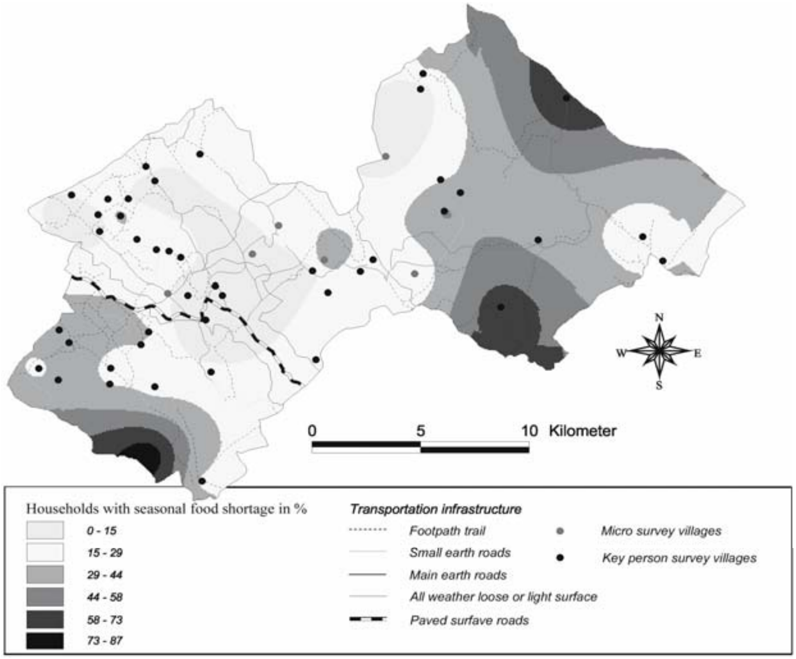

Figure 4.2: Spatial distribution of seasonal food shortages in the study area Mai Son, Vietnam, covering all farming systems, 2001.

Market Related and Intermediate Systems: Increasing herd size through increasing the capacity of stables and increasing the number of animals by natural regeneration would lead to a higher turnover of the livestock sector in the Market Related and Intermediate Systems. More resources would be needed. Some such as labor are available, but others such as capital investment are not. Supporting programs which provide credit for extending the capacity of stabling would enable an increase in farm and family income of between 6 % and 10 %. The highest increase would be in the Intermediate System because it would allow better use of crop residues and non-agricultural land. Increasing herd size would be followed by a reorganization of the cropping system and labor economy.

Remote Area Systems: In the remote areas, intensification would the future strategy based on extension work in two directions *viz* the introduction of new ideas in feeding and herd management and improved veterinary care. Cost free extension services would aim at an improved feeding regime and health care service with low external cost. Free input from the veterinary sector would allow families in the remote zones to reduce their losses by 10 % and increase the family income by between 2.4% to 3.1%. This seems low, but there has been no strategy found which is realistic and contributes to a greater increase in income. This clearly indicates that improving income in such remote zones is very difficult.

4.2.6 Conclusions

Livestock production is an important element in farming and socio-economic development in the mountain zones. It is still at a low technological level and only partly linked to markets. The role it plays differs in rural areas depending on their location and distance from markets. This role also varies according to the purchasing power, knowledge, education, values, and objectives of the people and ethnic groups involved in the production system and to their degree of access to the outside world. Livestock production clearly complements crop production and forestry. Livestock systems are unlikely to compete with crop production when the latter is efficient, but when conditions for crops are unfavourable livestock production will prevail. Animal products also help to ensure an adequate and nutritionally balanced diet for rural populations. Traditional livestock production systems have positive ecological effects which might, in the future, help to overcome the ever increasing problems of soil and land degradation. Keeping livestock has traditionally provided farmers with experience in making their own economic decisions and managing their own capital assets. This could be a way of introducing them to a new era of economic thinking and decision-making.

4.3 Suitability of Local and Improved Pig Breeds for Different Smallholder Production Conditions

Ute Lemke, Anne Valle Zárate, Brigitte Kaufmann, Javier Delgado Santivañez, Le Thi Thuy, Le Viet Ly, Hoang Kim Giao and Nguyen Dang Vang

4.3.1 Introduction and Objectives

The commonly developed gradient concept introduced in the presentation of DOPPLER et al. was again utilised in the present investigation. However, while DOPPLER et al. followed a three tier system of high mountain zones, sloping areas in the intermediate zone and urban centres in the lowland, this study focused mainly on the intermediate zone and the lowland areas near towns.

The mountain valleys and areas near towns are densely populated and therefore affected by a high land pressure. The infrastructure is relatively well developed. Pig production is conducted on a semi-intensive level and can be characterised as demand driven (STEINFELD and MACK, 1997). Farmers almost exclusively keep high-yielding pig genotypes, namely Vietnamese improved breeds, imported pig breeds and their respective crossbreds. The variety of genotypes kept is the result of a breed replacement process that started in the 1950s (NIAH, 1997).

On hillsides and hilltops, population density and hence land pressure are lower. The infrastructure in the area is poorly developed. Pig production is conducted on an extensive level and can be characterised as resource driven (STEINFELD and MACK, 1997). Local pig breeds are still predominant, though they are subject to an ongoing process of breed replacement by high-yielding genotypes coming from the lowland regions (THUY, 1999b). By keeping high-yielding genotypes, farmers may receive a higher revenue from pig production but may on the other hand undergo financial stress and economic risk, due to the required purchase of feed and animals, as well as the higher care intensity and the more complex veterinary care for the high-yielding pig breeds. In the first phase of the research program, the focus was on pig production as the most important enterprise within the livestock production system.

Sustainability in animal production has been defined as the extent at which animal breeding and reproduction contribute to the maintenance and good care of animal genetic resources for future generations (GAMBORG and SANDØE, 2005).

Thus, the objectives of this study were formulated as follows:

- To assess the suitability of local pig breeds and improved introduced pig genotypes for smallholders in the research area in Son La province,
- To identify the potential and limitations for future sustainable development of the existing pig production systems.

These objectives led to a comparison of the Vietnamese improved breed "Mong Cai" in a demand driven production system with the Vietnamese local breed "Ban" in a resource driven production system and thus to the central question: Is it reasonable to integrate the Ban breed in a breeding and marketing program in the resource driven system, or is it better to replace the local breed by higher-yielding genotypes?

4.3.2 Material and Methods

For this study, four villages of ethnic Black Thai, located in Son La province in the districts of Son La and Mai Son were selected according to the levels of intensity of their pig production systems, their distance from the nearest town and their altitude (figure 4.1). Villages are located along a gradient of production intensity that correlates with distance to town and village altitude. Demand driven pig production systems prevail in the densely populated mountain valley, while in the remote, less densely populated hillside areas, pig production systems are less intense (table 4.4). The villages Na Huong and Bo Duoi were shared as a research area with the working group of DOPPLER et al.

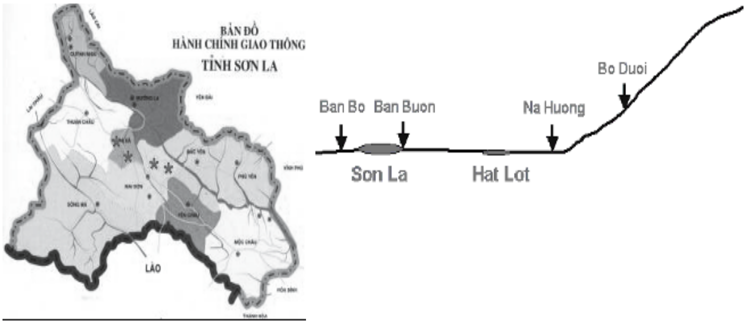

Figure 4.3: Location of selected villages in the Son La province (left, villages marked by red stars); schematic representation of distance of villages to town and altitude of villages. The sequence of marked villages in the left hand map corresponds with the gradient in the schematic view.

Table 4.4: Characterisation of villages selected for the study.

Village	Ban Buon	Ban Bo	Na Huong	Bo Duoi
Geographic location	District Son La capital Nearer to town Mountain valley		District Mai Son Farer from town Hillside	
Production system	Demand driven		Resource driven	
Predominant pig breed	Vietnamese improved: Mong Cai, MC crossbred		Vietnamese local: Ban breed	
Origin of pig breed	Red River Delta		Upland region, NW Vietnam	
Interviewed households (n)	17	16	16	15

Fieldwork was conducted from February to July 2001 and from January to August 2002, starting with a situation analysis (10 days in 2001) in the four selected villages. Based on the findings from the situation analysis, structured interviews were conducted in 64 households in the four villages. Each household was visited four times (twice per year). Household interviews covered socio-economic parameters, livestock production in general, pig production including reproductive and productive performance, and seasonal changes in pig production between the current and the previous interview. Additionally, communication tools following a rapid rural appraisal (RRA) approach were used for in depth-assessment of special topics, such as feeding strategies in different seasons of the year or farmers' appreciation of pig breeds (CHAMBERS, 1992; DHAMOTHARAN, 2001). Performance of pigs was recorded by repeated weighing (in total 731 individual measurements). Research results were discussed with farmers both individually and in feedback seminars conducted in the year 2002. Results were used to describe the two pig production systems. Suggestions for interventions based on the system description were made and communicated to farmers in training courses and to local authorities with the aim of initiating an immediate improvement in pig production.

4.3.3 Results and Discussion

Pig production shows considerable differences in the resource and the demand driven system. These differences are described starting from the impact of pig production on the household economy via the production performances and the pig production output up to differences in feed input requirements.

The impact of pig production on the household economy is higher in the demand then in the resource driven system. In the demand driven system, cropping, off-farm activities, animal production and pig production make roughly the same contributions to the annual cash revenue of the household (figure 4.4). The annual revenue from pig keeping is nearly four-times higher than in the resource driven system (demand driven system Ban Buon 3.9 million VND; Ban Bo 4.6 million VND; resource driven system Na Huong 1.1 million VND; Bo Duoi 1.4 million VND).

In the resource driven system, farmers get the highest cash revenue from cropping (Na Huong 23.1 million VND, Bo Duoi 15.2 million VND). Off-farm activities, husbandry of pigs and other livestock make only minor contributions to the total household cash revenue.

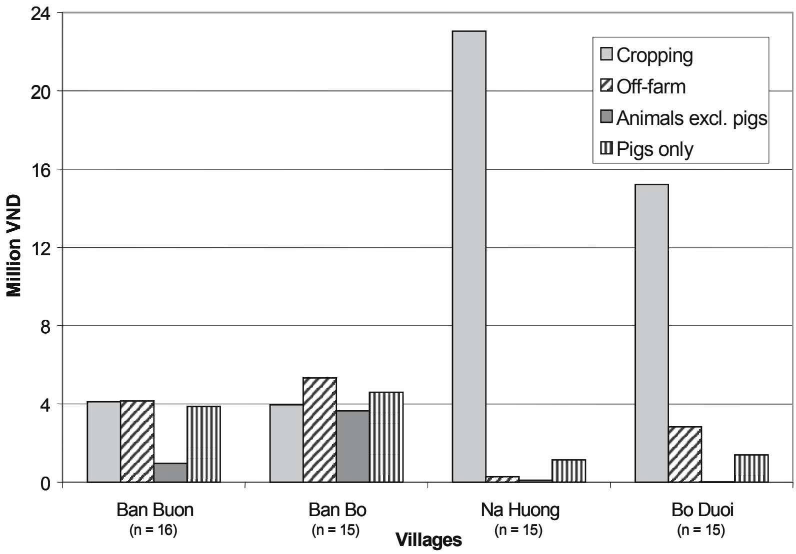

Figure 4.4: Average cash revenue/household/year (million VND), weighted by percent of farmers getting the respective type of revenue, by village. Household interviews 2002. VND = Vietnamese Dong, 1 USD ~ 15,500 VND (approximate exchange rate 2002).

From the different contribution of pig production to the annual household cash revenue it can be assumed that pig keeping fulfils different functions in the two production systems. These different functions are derived from farmers' answers to the question "Why do you keep pigs?" (table 4.5).

Results show that in both the demand and the resource driven system, pig keeping is perceived as an income generating activity. However, the proportion of farmers, who gave "income generation" as their main reason for pig keeping, was considerably higher in the demand driven system. In addition, in the resource driven system, pigs/ pork are necessary to fulfil social obligations and are used in connection with local customs and for special occasions like weddings, funerals, worshipping ancestors, etc. In the demand driven system, the proportion of farmers giving socio-cultural reasons for pig keeping was negligible.

Table 4.5: Farmers' answers to the question "Why do you keep pigs?", by village.

Production system	Demand driven		Resource driven	
Village	Ban Buon	Ban Bo	Na Huong	Bo Duoi
Interviewed farmers (n)	15	15	15	15
Answers (n)	21	15	34	33
Reasons given by farmers (%)				
Get income	71.4	93.3	26.5	42.4
Saving	13.3	0.0	0.0	0.0
Pork (consumption, worshipping, feasts)	4.8	0.0	61.7	48.5
Pay hired workers	0.0	0.0	11.8	3.0
Others	9.6	6.7	0.0	6.0

Note: Multiple answers were possible. Household interviews 2002.

It is known both from literature and from own results that the utilization of pigs in North Vietnam has more aspects than mentioned in Table 4.5 (e.g. PETERS, 1998). In the study area, pigs are used as a source of manure for cropping and as a source of pork for consumption. They can be given away as gifts, and pigs are also kept simply because it is customary to do so. Farmers did not explicitly mention these functions as reasons for pig keeping, which might have been due to the fact that they are not the primary reasons or that farmers take these functions for granted.

The differences in total cash revenue from pig production in the two systems can be partly explained by the different reproductive and growth performances of the predominant genotypes. Growth and reproductive performance are presented in figure 4.5 (reproductive performance) and figure 4.6 (growth performance).

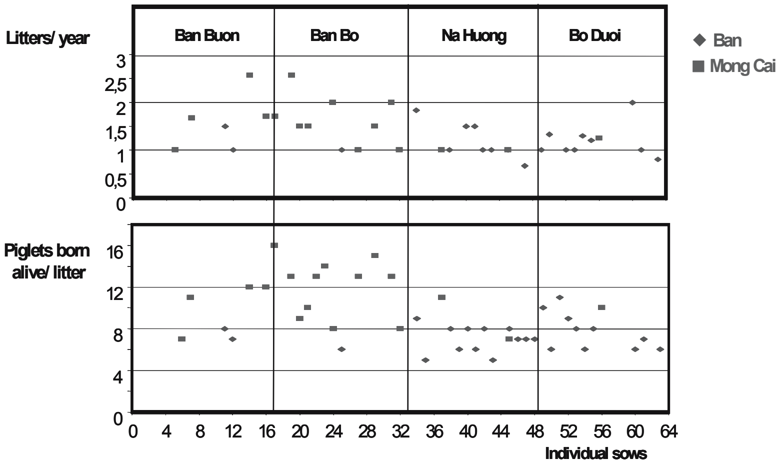

Figure 4.5: Reproduction data of currently kept sows by genotype and village. Litters/ year = Total number of litters/ age of sow at interview (age-at-first-litter not considered) Household interviews 2001.

The average reproductive performance of Mong Cai (MC) in the demand driven system is higher than the performance of Ban (B): While Mong Cai sows yield 1.8 ± 0.7 litters/ year (n = 15 sows) with 11.2 ± 2.7 piglets born alive (n = 18 litters), Ban yield only 1.2 ± 0.3 litters/ year (n = 20 sows) with 7.3 ± 1.5 piglets born alive (n = 26 litters). However, figure 4.7 shows a high variation within breed for both performance parameters (number of litters/ year; litter size), suggesting that there is also a considerable effect of management conditions on performance.

Reproduction data were collected in structured interviews; validation by data recording is currently being carried out in on-farm trials.

In each household visited, the growth performance of the offspring was recorded in addition to the reproductive data of the dams (figure 4.6). Data for Ban and Large White x Ban crossbreds (LW x Ban) were collected in villages of the resource driven system, data for Large White x Mong Cai (LW x MC) were only available in villages of the demand driven system.

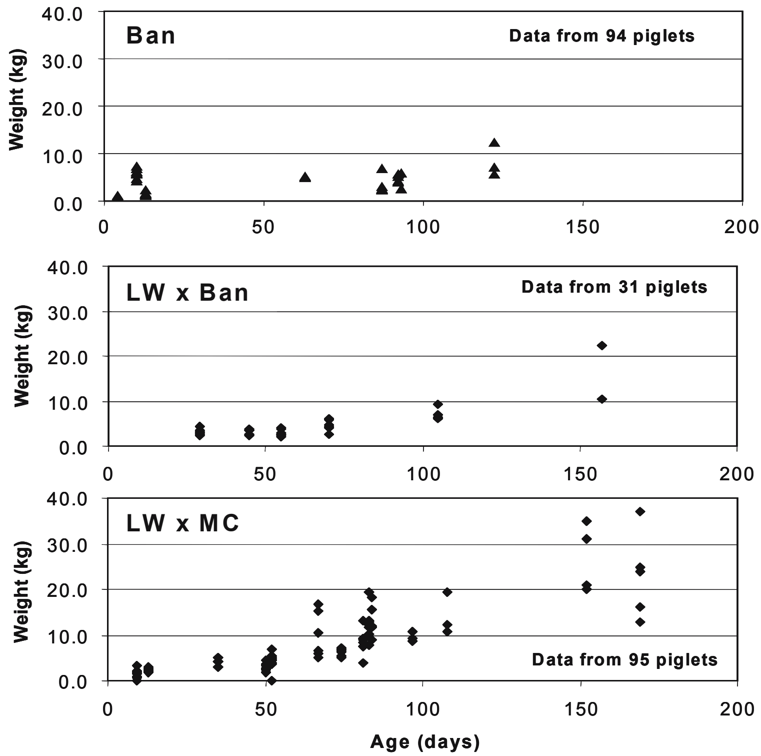

Figure 4.6: Growth performance of different pig genotypes. Weighing 2001.

Among the three pig genotypes, the LW x MC offspring shows the highest growth performance reaching up to 20 kg live weight at 100 days of age. LW x Ban crossbreds show a medium growth performance and yield about 10 kg live weight at 100 days. Ban shows the lowest performance with about 5 kg live weight at 100 days. Due to the low sample size, the recorded data give only preliminary growth performance values. Data recording with a bigger sample size is presently being conducted in on-farm trials.

Different performances of individual pigs result in a different total output from the pig herd per year and allow different extraction levels (figure 4.7). The total annual extraction from the pig herd per household is in the demand driven system with 342.2 kg pig live weight/hh/year in Ban Buon and 538.3 kg in Ban Bo higher than in the resource driven system with 297.8 kg pig live weight/ hh/year in Na Huong and 162.9 kg in Bo Duoi. But there are also large differences in the extraction level between the two villages of each system. Extraction from the pig herd in Na Huong is nearly as high as in Ban Buon (Na Huong 297.8 kg, Ban Buon 342.2 kg live weight/hh/year), hinting at the potential performance of pig production in the resource driven system.

In the demand driven system, pigs are almost exclusively sold. In the resource driven system, pigs are also sold, but slaughtered on farm to a greater extent than in the demand driven system.

The total amount of pigs sold seems to be very low in the resource driven system as compared to the demand driven system. However, the data show a trend towards increasing market orientation. A market for pigs only became available in this region as late as 1997. Since that time the number of farmers selling pigs and the number of pigs sold have been increasing continuously.

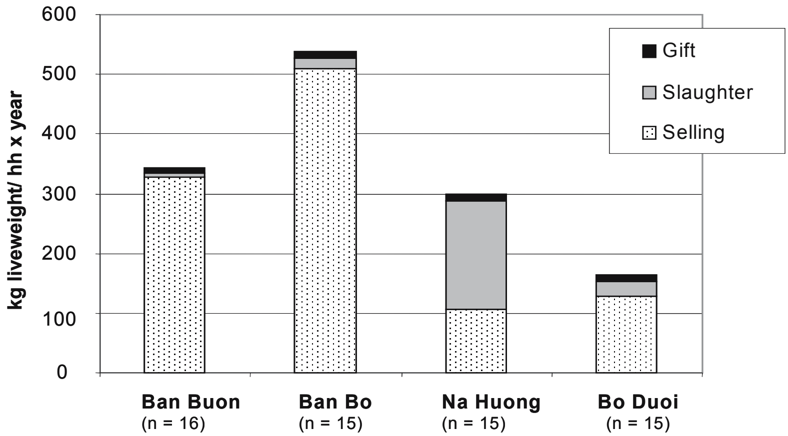

Figure 4.7: Average pig extraction/ household and year, weighted by percent of households selling/ slaughtering/ giving pigs as a gift, by village. Household interviews 2002.

In addition to differences in the total extraction from the pig herd, different extraction patterns (here selling patterns) can be observed in the two systems (figure 4.8).

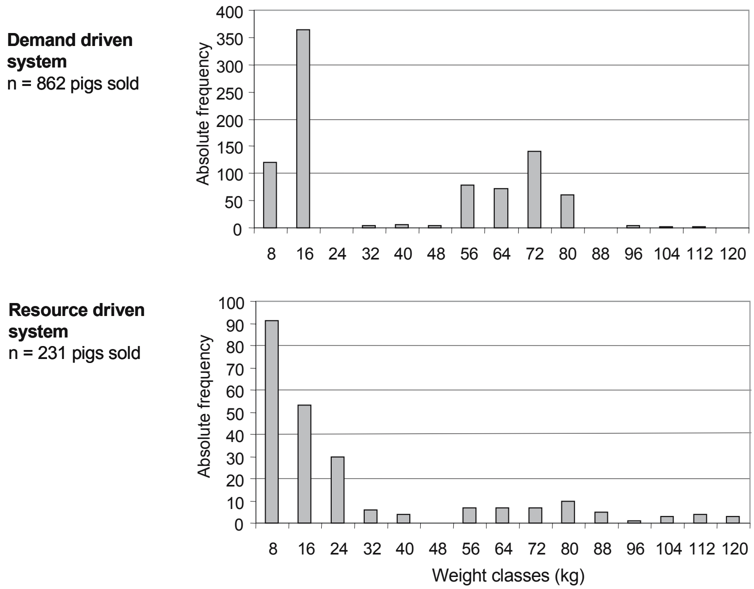

Figure 4.8: Selling management – weight distribution of pigs sold, by production system (household interviews 2002).

The selling strategies of the farmers demonstrate typical characteristics described for demand and resource driven systems (STEINFELD and MACK, 1997). In the demand driven system, pigs are sold in two more or less clearly defined age/ weight periods, namely directly after weaning to other farmers for fattening or breeding purpose and as fatteners to dealers, following the requirements of the market. This is shown by two peaks in the frequency distribution. In the resource driven system, pigs are mainly sold directly after weaning, and to a smaller extent as fattening pigs. However, in several cases they will be sold regardless of age and weight when the household is lacking feed or cash (figure 4.8).

For the calculation of production efficiency, output and input parameters are required. Since feeding has a strong influence on the production efficiency, comparative data are presented for feeding strategies and feed costs in times of feed abundance and feed shortage, respectively (table 4.6). Data for the "time of abundance" were collected in March/ April, when households still had sufficient feedstocks[1] from the last harvest. Data for the "time of shortage" were collected in June/July, just before the harvesting season, when most households had finished stocks.

The main feed components (concentrate feed, maize, cassava, rice bran, vegetables and dried fish) are used in both production systems but the composition of feeding rations and feeding strategies in time of feed shortage differ. The described feeding strategies again reflect characteristics of demand driven versus resource driven production systems (STEINFELD and MACK, 1997): In the demand driven system, resources are made available or are reserved in order to achieve a desired production level. This is shown by the purchase of feed in times of shortage, taking up credits for feed purchase, and keeping home grown maize for feeding. In the resource driven system, production is adjusted to the utilisation of the available resources. When feed resources are finished, energy-rich high-quality feed (maize) is replaced by any feed of lower quality and energy content that is still available on the farm (vegetables, cassava).

1 "stocks" refers mainly to maize as main high-energy feed component fed by all interviewed farmers

Table 4.6. Farmers' feeding strategies for different feed components in times of relative feed abundance and shortage.

		Demand driven system	Resource driven system
Concentrate	Feed abundance	- Higher amount/ day/ pig - Regular purchase	- Higher amount/ day/ pig - Irregular purchase
	Feed shortage	- Purchase by more farmers - Use of credits for purchase	- Purchase by more farmers, but less than in the demand driven system - Almost no credits used
Maize	Feed abundance	- Higher amount/ day/ pig - Produced maize mainly for feeding	- Lower amount/ day/ pig - Produced maize mainly for selling
	Feed shortage	- Buy additional maize - Use of credits for purchase	- Replace by vegetable, cassava, rice bran
Cassava	Abundance	- Lower amount/ day/ pig	- Higher amount/ day/ pig
	Feed shortage	- Same or smaller amount/ day/ pig - Purchase by few farmers	- Increase amount/ day/ pig (replacement) - No purchase

Description derived from household interviews, communication tools 2001, 2002.

The described feeding management is also reflected by data for the daily feed costs per household and their variation in times of feed abundance and shortage (figure 4.9).

In the demand driven system, the daily feed costs per household are higher than in the resource driven system (figure 4.9). In both systems, daily feed costs increase in times of feed shortage. However, in the resource driven system, daily feed costs remain lower than costs in the demand driven system (Ban Buon 5667 VND and Ban Bo 4151 VND/ hh/ day versus Na Huong 1126 VND and Bo Duoi 597 VND/ hh/ day).

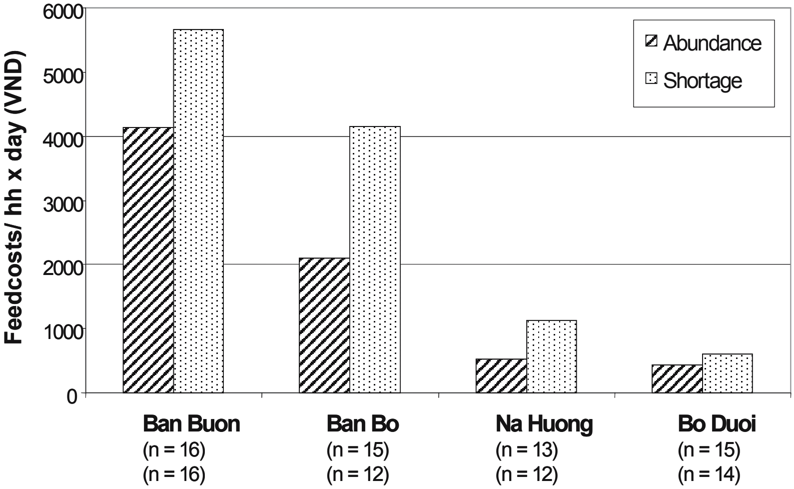

Figure 4.9: Average daily feed costs/ household in times of feed abundance and shortage, weighted by percent of households buying feed, by village. (n_1 = n households in time of abundance, n_2 = n households in time of shortage). Household interviews 2002 1 USD ~ 15,500 VND (approximate exchange rate 2002).

In order to assess the future role of the local Ban breed in the resource driven production system, the opinion of farmers also regarding their appreciation of the Ban breed has to be considered (table 4.7).

Most farmers of the demand driven system had already given up keeping Ban. Ninety one percent of interviewed farmers would consider to keep again Ban pigs, if Ban would have a higher production performance, or provided economic incentives could be granted (e.g. governmental subsidies). The main argument of non-Ban keepers for rejecting Ban was “the too low output from Ban”. Farmers of the resource driven system still keep Ban. They either do not want to keep another breed (51.7% of farmers) or intend to change to a higher-yielding breed but would consider continuing keeping Ban with economic incentives being granted (44.8% of farmers). The main argument for retaining Ban was that “input in non-Ban-breeds is too high”. It can be concluded that prospects for Ban in the demand driven system are rather negative, but still positive in the resource driven system.

Table 4.7: Appreciation of the local Ban breed by farmers, by production system.

Production system	Demand driven	Resource driven
Sample	23 Non-Ban keepers	29 Ban keepers
Keep Ban, no incentives required (%)	0.0	51.7
Keep Ban, but higher performance or economic incentives required (%)	91.3	44.8
Keep Ban under no circumstances (%)	8.7	3.4

Household interviews 2002.

4.3.4 Conclusions

Two pig production systems in the mountainous areas working at different intensity levels were investigated and compared. In the demand driven system, pig production aims at income generation; in the resource driven system, pig production has more diversified functions including income generation, consumption and social functions. The systems differ in the management strategies applied. Development strategies in pig production have to be adapted to the respective characteristics of the production system. The pig genotypes under study show different production performances in the two systems. The improved breed, Mong Cai, in the demand driven system yields a higher output but also requires a higher production input. The local Ban breed yields only a lower output but requires a lower input for pig production. There are indications that there are differences in production efficiencies of the genotypes under the applied management strategies but this still needs to be verified in larger samples.

Exogenous and indigenous influences (ongoing breed introduction, increasing market-orientation, market-influence) may lead to a further replacement of the Ban pig despite its importance for and preference by smallholders in the resource driven system. Only through the development of special breeding and marketing strategies may the continued keeping and utilisation of Ban pigs be warranted. Interactions with other livestock species have to be taken into account, building on the proven approach presented here of comparing demand and resource driven systems.

4.4 Local Livestock Genetic Resources in Northern Vietnam

Le Thi Thuy, Nguyen Dang Vang, Hoang Kim Giao, Le Viet Ly, Anne Valle Zárate and Ute Lemke

4.4.1 Introduction

In spite of being relatively small, Vietnam is one of the 15 richest countries in the world in terms of genetic resources. This wealth is a consequence of its natural and socio-cultural circumstances.

North Vietnam is located in the tropical zone, but has cold winters due to the influence of the monsoon. As a result, the climate has sub-tropical features and the high, mountainous areas may be considered to have a temperate character. The topography of northern Vietnam is varied and complex. Mountains with steep slopes cover three quarters of the area. This variety in climate and geography is one of the main causes of the biodiversity in agro-forestry in this region.

There are 54 different ethnic groups in Vietnam but most of them are located in the north. The particular ways in which plants and animals are farmed, the techniques used for agriculture and the different uses to which the products are put by the different ethnic groups contribute to the remarkable biodiversity of the region's agro-forestry. The tremendous store of ethno-botanical knowledge is particularly noteworthy.

During more than 20 years, thanks to agricultural development and cultural exchange, numerous commercial animal breeds have been introduced into Vietnam. They have tended to have a negative impact on animal conservation programs as a result of which many of the local breeds are facing extinction or are endangered. Very often the growth, food conversion efficiency or lean meat percent of the local breeds are much lower than those of imported breeds so Vietnamese producers have become unwilling to keep them.

However in the north, a mixture of exotic and local breeds is still predominant and there is a lower degree of intensification of livestock production compared to other regions. Some local breeds are still kept with specific traits that can satisfy the demands of local markets (e.g. H’mong chicken, Ri chicken, Mong Cai pig).

4.4.2 Characteristics of Agro-Ecological Systems in North Vietnam (North West and North East)

In contrast to the delta regions, this mountainous area is characterised by a large land area, isolated hamlets, poor transportation facilities, poor market access, poor living standards and a low level of formal education. Poor communication facilities and irrigation systems are limiting factors in this region. Barren hills and small parcels of land with low output can be frequently observed. The mountainous region is considered an underdeveloped zone, with the exception of Quang Ninh and Thai Nguyen provinces, where there are some industries like coal and iron mines and tourism.

Buffalo production is well developed. Pigs and scavenging chickens are popular but the performance levels of local breeds are generally low.

4.4.3 Natural and Economic Characteristics of North Vietnam (North West, North East)

The average altitude of North Vietnam is 501.2 m. The average monthly temperature is lowest in January (15.7^{0}C) and highest in June (26.7^{0}C.). Average rainfall per year is 1701.5 mm. Humidity is lowest in September (75%) and highest in February (89.5%).

The population is 2,487,200 inhabitants. The total area of North Vietnam is 540,096,300 ha of which 1,305,300 ha is agricultural land. The main crops are paddy (703,100 ha), maize (311,000 ha) and cassava (83,300 ha).

The predominant domestic animals, breeds and genotypes are cattle (e.g. Yellow cattle, Lai Sindh, H’mong cattle, Holstein Frisian, crossbred), pigs (e.g. Ban pig, H’mong pig, Mong Cai pig, crossbred pig), chicken (e.g. Ac, H’mong chicken, Short leg chicken/Te, Ri chicken), ducks (e.g. Co duck, Ky Lua duck, crossbred ducks), goats (e.g. Co goat, Bach Thao goat, crossbred goat) and horses (e.g. Vietnamese horse, crossbred horse).

4.4.4 The Current Status of Animal Genetic Resources Northern Vietnam

Vietnam is considered to be one of the first areas in the world where animals were domesticated. The animals domesticated here include 12 species, namely pig *(Sus scrofa*), cattle *(Bos indicus),* goat *(Capra hircus),* sheep *(Ovus asies),* deer *(Cervus nippon, Cervus unicolor),* rabbit *(Oryctolagus cuniculus),* chicken *(Gallus gallus),* duck *(Anas platyrhynchos)*, Muscovy duck *(Carina moschata),* goose *(Anser anser)* and pigeon *(Columba livia).* In total, 62 local breeds can be found giving a density of 1.520 species/km^2 which is much higher than the global average of 0.098 species/km^2. In addition to being well adapted to local conditions and having specific resistance to local diseases, these breeds have other valuable characteristics. The quality of their meat and eggs is particularly suited to Vietnamese tastes as well as being marketable to foreign consumers. Furthermore, some breeds provide pharmaceutical materials that are much appreciated locally e.g. Black Chickens, White Horses, or deer.

Most local breeds are nowadays found in the north and are kept in traditional systems mainly by smallholders, who use local feedstuff. They are frequently crossbred with exotic breeds to improve performance in planned or unplanned crossbreeding programs. The next few paragraphs give an overview of the local animal genetic resources in North Vietnam by species.

Pigs: The pig is generally the most important species in livestock production. In the north there exist four local pig breeds: Mong Cai (Quang Ninh province), H'mong (Ha Giang province), Muong Khuong (Lao Cai province), Ban (Son La province). Mong Cai is an improved breed that is becoming increasingly widespread.

Cattle: Four native cattle breeds are kept: Yellow, H'mong, Coc, Lai Sindh cattle. Yellow cattle predominate. They are raised for draught purpose and meat.

Buffalo: There are two main types, small Buffalo (Re buffalo) and big buffalo (Ngo buffalo), They are kept for draught purpose and meat.

Horses: They are kept as pack and riding animals and include the Vietnam White and the Grey horse.

Chickens: Eight local chicken breeds are kept in the north: Ri, Te, Oke, H'mong Brown, H'mong White, H'mong Black, Choi, and the Fighting Chicken. About 85% of native breeds are Ri chicken. All native chickens are raised in backyard scavenging systems with household waste as feed base in the rural areas. They are characterized by broodiness. Their meat is said to be tastier than that of broiler breeds. Generally, they are given no health care and are said to be resistant to many diseases.

Ducks: There are five native Peking duck breeds in the north: Co, Bau Ben, Ky Lua, Hoa, Moc. Seventy five percent of all ducks are Co ducks . They are raised for eggs and meat.

Muscovy ducks: There are three native Muscovy duck breeds. They are named according to their feather colour, namely "Re" (white colour), "Trau" (black colour) and "Sen" (mixed white and black colour). They are raised for meat.

Goats: The most frequently found is the Co goat (grass goat). It comes in different colours: White, black, grey, mixed black and white. Another popular breed is the Bach Thao goat. Both breeds are raised for meat.

Geese: Two breeds of geese, De and Co are found locally.

Rabbits: Vietnam Black and Vietnam Grey are the local rabbit breeds. New Zealand and Californian Rabbit breeds have also been locally adapted. They are raised for meat.

Deer: The Sika deer is the most important deer genetic resource in the region and its biology has been thoroughly studied. The Samba deer is the next most important species. Both are kept for meat and velvet.

Pigeons: There is only one native Pigeon breed, which is kept for meat.

Turkeys: The only local breed, the Vietnamese Turkey, is kept for meat.

4.4.5 Roles of Animal Genetic Resource in Food Security and Poverty Alleviation

The contribution to poverty alleviation by animal genetic resources is triggered mainly through direct consumption and income generation.

Husbandry contributes to *income* through the sale of animals and their products (meat, milk, egg, manure, hides). It creates many jobs in rural areas, resulting in income generation for farmers. In crop production, animals are used for draught power, transport, and provide manure. Pet animals (e.g. fighting cocks, fancy chickens and birds) can also be a source of income.

The use of animal products *reduces production expenses* e.g. the use of chemical fertiliser in crop production is decreased by the use of manure, no large investment is needed for tractors and farm implements when draught animals are used, and the amount of petroleum needed for farm work is decreased.

Socio-economic benefits include the generation of a productive role for women, children, and elderly people e.g. in pig, poultry and goat keeping. Animals are used in religious or traditional ceremonies (e.g. chickens are sacrificed to worship the ancestors), in sports, shows or recreation (e.g. cock fighting, bull fighting). They contribute to the socio-economic status of a farmer, serve as loan collateral and are used for dowry or inheritance.

As a major component in crop production systems, livestock husbandry contributes indirectly to *food security*. For instance, in the case of rice production for family consumption, draught animals provide the power for land preparation and transportation and the manure for fertilisation. Crop residues can be utilised to produce more food from animals.

Animals provide a steadier supply of food on family farms: Backyard chickens provide daily meat and eggs, as do ducks. Goats provide meat. Preserved meat and traditionally processed animal products include salted duck eggs and dried beef or pork. These, and other animal products provide family food assurance in case of crop failure due to natural hazards such as flood, drought, crop pests or diseases. The sale of animals enables families to buy rice or other food. Farmers do not usually send crops directly (paddy, cassava, sweet potato etc.) to the market but use the surplus crops as animal feed to produce animal products for the market. The expenses for food, clothes, school fees, health care, medicines, weddings and funerals are covered to a great extent by the proceeds from animal husbandry.

Malnutrition is prevented, since the consumption of animal products helps to counteract the bad effects of protein-energy imbalance in local diets, especially those of pregnant and breastfeeding mothers and their children. It is crucial that meat and eggs should be available in all villages and households.

4.4.6 The Use of Native Breeds, Trends and Risks

Table 4.8 is an overview of native breeds in Vietnam showing their level of use, recent population trends and the risk that the respective breed becomes extinct. The following table (Table 4.9) focuses on the endangered breeds, their population trends, and the reasons for those trends.

Table 4.8: The use of native Vietnamese breeds, population trends and risks.

Breed	Origin/conservation site	Aim of utilisation	Level of use	Population trend
Pigs				
I	Nam Dinh, Thanh Hoa	Meat, crossing	Critical	Decreasing
Mong Cai	Quang Ninh	Meat, crossing	Not at risk	Decreasing/mixing
Lang Hong	Bac Giang	Meat, crossing	Critical	Decreasing
Ba Xuyen	MRD	Meat, crossing	Vulnerable	Decreasing
Thuoc Nhieu	Thuoc Nhieu	Narrow	Vulnerable	Decreasing/boar
Phu Khanh	Khanh Hoa	Wide	Extinction?	Mixing
Muong Khuong	Ha Giang	Wide	Normal	Decreasing
Meo	Nghe An	Wide	Normal	Decreasing
Soc	Dac Lac	Wide	Normal	Decreasing
Co	Nghe An		Extinction	Without boar
Son Vi	Phu Tho		Extinction	
Mini	Quang Tri	Meat	Vulnerable	Decreasing

Ban	NW Vietnam	Meat, crossing	Vulnerable	Decreasing
H'mong	NW Vietnam	Meat, crossing	Vulnerable	Decreasing
Cattle, buffaloes				
Thanh Hoa group	Thanh Hoa	Draught, meat, crossing	Normal	Decreasing (Zebuisation)
Nghe An group	Thanh Hoa	Draught, meat, crossing	Normal	Decreasing (Zebuisation)
Lang Son group	Lang Son	Draught, meat, crossing	Normal	Decreasing (Zebuisation)
Phu Yen group	Phu Yen	Draught, meat, crossing	Unknown	Decreasing (Zebuisation)
Ba Ria group	Vung Tau	Draught, meat, crossing	Unknown	Decreasing (Zebuisation)
H'mong	Ha Giang	Draught, meat	Normal	
Uriu	Nghe An	Draught, meat	Vulnerable	Decreasing (Zebuisation)
Ngo buffalo	Highland	MP	Normal	Increasing
De buffalo	Lowland	MP	Normal	Decreasing
Goat, sheep, horse, rabbit				
Co goat	Northern	Meat	Normal	Stable
Bach Thao goat	Ninh Thuan	MP	Normal	Increasing
Phan Rang sheep	Ninh Thuan	Meat	Normal	Increasing
Sika deer	Nghe An	Velvet, meat	Normal	Stable
Samba deer	Central Highlands	Meat	Normal	Increasing
White horse	Northern mountains	Fancy, medicine	Vulnerable	Decreasing
Coloured horse	Thai Nguyen	Draught, meat	Normal	Stable
Rabbit, black	Northern	Meat	Normal	Increasing
Rabbit, white	Northern	Meat	Normal	Increasing
Rabbit, grey	Northern	Meat	Normal	Increasing
Chicken				
Ri	Northern	MP	Normal	Decreasing/mixing
Ho	Bac Ninh	Fancy, meat	Normal	Increasing
Mia	Son Tay	Meat	Normal	Increasing
Dong Tao	Hung Yen	Meat	Insecure	Decreasing/mixing
Ac White	Vinh Long	Meat, medicine	Normal	Increasing
Ac Black	Vinh Long	Meat, medicine	Normal	Increasing

Oke	Ha Giang	Meat, medicine	Vulnerable	Decreasing
Te	Ha Giang	Meat, medicine	Vulnerable	Decreasing
Tau Vang	Southern VN		Normal	Decreasing
H'mong black	NW Son La	Meat, medicine	Vulnerable	Decreasing
H'mong white	NW Son La	Meat, medicine	Vulnerable	Decreasing
H'mong brown	NW Son La	Meat, medicine	Vulnerable	Decreasing
Van Phu	Yen Bai	Meat, egg	Extinction	
Tre		Fancy, fighting	Vulnerable	Decreasing
Choi	All regions	Fighting	Normal	Normal
Phu Lu Te	Ha Tay	Meat	Vulnerable	Decreasing
Turkey	Hung Yen	Meat	Vulnerable	Normal
Duck, muscovy duck, goose, pigeon				
Co duck	Ha Tay	Meat, eggs	Normal	Decreasing/mixing
Bau Ben duck	Hoa Binh	Meat, eggs	Critical	
Bau Quy duck	Nghe An	Meat	Critical	
Ky Lua duck		Meat	Vulnerable	Decreasing/mixing
Omon duck		Meat		
Nang duck	Lang Son	Meat, eggs	Vulnerable	Decreasing/mixing
Moc duck	Binh Dinh	Meat, eggs	Vulnerable	Decreasing/mixing
Trau musc. duck	All regions	Meat	Normal	Decreasing/mixing
De musc. duck	All regions	Meat	Normal	Decreasing/mixing
Sen musc. duck	All regions	Meat	Normal	Decreasing/mixing
Co goose	RRD	Meat	Normal	Decreasing/mixing
Native pigeon	All regions	Meat, fancy	Normal	Stable

Source: Vietnamese Country Report on Animal Genetic Resources (2003).

Table 4.9: Endangered Vietnamese livestock breeds.

Species	Breeds	Trends	Causes
Pig	I	Decreasing, critical	Low performance, inbreeding
	Co	Critical	Low performance
	Lang Hong	Critical	Low performance
Horse	White	Endangered	Poor reproduction
Duck	Co	Normal	Mixed
	Bau Ben	Endangered	Mixed, low performance
	Ky Lua	Endangered	Mixed, low performance
	Nang (Lang Son)	Endangered	Mixed
Chicken	Mia	Endangered, small pop.	Mixed, low performance
	Dong Tao	Endangered, small pop.	Mixed, low performance
	Ho	Endangered	Low performance, reproduct.
	Van Phu	Critical, extinction	Mixed, low performance
Buffalo	Murrah	Decreasing	Inappropriate

Source: Vietnamese Country Report on Animal Genetic Resources (2003).

4.4.7 Conclusion

Vietnam owns a great variety of domestic animal genetic resources. Local livestock breeds are the backbone of the smallholder animal production systems that dominate animal production in Vietnam. Local breeds have various functions within production systems that directly or indirectly ensure food security and contribute to the alleviation of poverty.

Local breeds are under increasing pressure from the introduction of and replacement by higher-yielding and higher-demanding exotic animal breeds which may jeopardise the food and economic security of smallholder households. Thus, both research and development efforts must aim on the further description and evaluation of local breeds and on investigating the possibilities for using these genetic resources in a sustainable manner under smallholder conditions.

4.5 Genetic Diversity of Vietnamese Pig Breeds[2]

Nguyen Thi Dieu Thuy, Melchinger, E., Andreas W. Kuss, Peischl, T., Heinz Bartenschlager, Nguyen, V.C., Hermann Geldermann

4.5.1 Introduction

Directed selection for economically desirable traits can lead to genetic erosion of individual breeds. A genetic base thus diminished is likely to limit the potential for improving production characteristics that may be vital for sustainable agricultural systems in the future. According to the FAO inventory 55% of the world's pigs are located in the Asian and Pacific region, representing 37% of the breeds listed by the FAO (SCHERF, 2000). A number of studies have been conducted on the genetic diversity of European (LAVAL et al., 2000) and Chinese pig breeds (LI et al., 2000) and a new international cooperation project has been started recently to evaluate 50 Chinese breeds in comparison with 59 European breeds (BLOTT et al., 2003). Polymorphic molecular genetic markers provide a means of assessing within and between breed genetic diversity. Micro satellite markers are recommended for studies of livestock diversity due to their abundant and even distribution throughout the genome, high polymorphism and comparative ease of genotyping. They have been used to characterise a wide variety of farm animal breeds in several species. This study is concerned with the evaluation of 10 micro satellite markers in five Vietnamese indigenous pig breeds with a diverse geographical origin, the assessment of their level of genetic diversity and the estimation of genetic distances among them. In comparison with the Vietnamese autochthonous breeds, two Vietnamese exotic breeds of European descent as well as three

2 The study was supported by the Deutsche Forschungsgemeinschaft (DFG) and the German Federal Ministry of Education and Research (BMBF).

European commercial breeds and Wild Boar were included in the study.

4.5.2 Material and Methods

Blood or sperm samples were collected from 317 animals belonging to 11 selected breeds. These included five Vietnamese local breeds Co, Meo (from Nghe An, a mountain area of central Vietnam), Mong Cai (from Hai Phong), Muong Khuong and Tap Na (from Lao Cai and Cao Bang respectively (two areas in the mountains of northern Vietnam)), two exotic breeds adapted to Vietnamese conditions Landrace and Yorkshire (from Hanoi), and the European breeds Landrace, Large White and Pietrain as well as the European Wild Boar (from Germany). The individual animals selected were considered to be characteristic of their particular breed according to local experts and farmers. DNA from blood and sperm was isolated according to standard protocols. The 10 micro satellites used in this study are listed in Table 4.10. A PCR reaction was carried out on 25 µl of DNA extract using the appropriate PCR conditions (table 4.10).

Table 4.10: PCR parameters for micro satellite markers.

Locus	$MgCl_2$ [mM]	T_A[1)] [°C]	Forward primer	Reverse primer
SWR345	3.0	60	AACAGCTCCGATTCAACCC	TACTCAGCCTTAAAAGGAAGGG
SW489	3.0	55	CAAGTGTGAAATTTGTGCGG	CGAAGTGCTAACTATAAGCAGCA
IFNG	2.1	58	ATTAGACCCCTAGCCTGGGA	GTTGGTCCTGTTCTCCAATAGG
SW2019	1.9	60	ATGATGCGAACCTGGAACTC	TATGTGTAACTTGGTCCCATGC
TNFB	2.1	60	CTGGTCAGCCACCAAGATTT	GGAAATGAGAAGTGTGGAGACC
SW1083	3.0	50	CCTTGCTGGCCTCCTAAC	CATACTCCAAAATTTCTATGTTGA
SW2410	3.0	56	ATTTGCCCCCAAGGTATTTC	CAGGGTGTGGAGGGTAGAAG
SW957	3.0	54	AGGAAGTGAGCTCAGAAAGTGC	ATGGACAAGCTTGGTTTTCC
S0215	2.5	58	TAGGCTCAGACCCTGCTGCAT	TGGGAGGCTGAAGGATTGGGT
SW2427	3.0	60	GCATGTTATTGAGTTGATGTGTAGG	TCGGAATTCCAGAAAATTGG

[1)]Annealing temperature

Fragment length analysis was performed on an Automated Laser Fluorescent Sequencer (A.L.F., Pharmacia, Freiburg) using 5 % Hydrolink gels for 150 min at 1500 V and 50°C, with 0.6 x TBE buffer. The actual fragment lengths based on internal and external length markers were determined by using the ”A.L.F. win/Instrument Control” and the “Allele Links” software (Pharmacia, Freiburg).

Selected micro-satellite alleles were separated by cloning with the use of the pT7Blue Perfectly Blunt Cloning Kit (Novagen, Freiburg) and then sequenced.

Statistical analyses: Genetic variability was measured for individual as well as grouped populations. Effective number of alleles (ENA) (KIMURA and CROW, 1964) and polymorphism information content (PIC) (BOTSTEIN et al, 1980) were calculated. The BIOSYS-2 software package was used for determination of deviations from Hardy-Weinberg Equilibrium (HWE), F-statistics and standard genetic distances (NEI, 1972). Standard genetic distances were submitted to 1000 bootstrap resamplings applying the BOOTDIST routine of BIOSYS-2 and subsequently used for the construction of UPGMA (Unweighted Pair Group Measure using Arithmetic Averages) dendrograms with the NEIGHBOR and CONSENSE routines of the PHYLIP software package (FELSENSTEIN, 1991).

4.5.3 Results and Discussion

Number of alleles: The number of alleles detected per locus varied widely, with as few as 9 at *IFNG* and as many as 18 at *TNFB,* the total mean number of alleles being 14.4. None of the population samples contained the whole range of alleles for any of the loci, and for locus *S0215* only one allele was found in the exotic breeds. The breed with the greatest mean number of alleles was the Meo with 9.5, and the one with the lowest was German Landrace with 4.0. Among the Vietnamese indigenous breeds, Mong Cai, which is kept at an experimental station, showed the lowest value for the average allele number which, at 5.7 comes close to the range of values for the breeds of European descent (4.1-5.1).

Table 4.11: Number of alleles per locus, breed and genetic group.

Breed	NS	NL	MNA	ENA
CO	31	10	8.9	4.91
ME	32	10	9.5	5.09
MK	32	10	9.4	4.96
TN	25	10	7.5	4.56
MC	32	10	5.7	2.89
LV	22	9	4.8	2.63
YV	17	9	4.2	2.61
LG	32	10	4.0	2.25
PI	32	10	5.0	3.17
LW	30	10	4.1	2.77
WB	32	10	5.1	2.82
VB	120	10	12.8	6.17
XB	39	9	5.4	2.77
EB	64	10	6.4	3.31

CO: Co, ME: Meo, MK: Muong Khuong, TN: Tap Na, MC: Mong Cai, LV: Landrace (Vietnam), YV: Yorkshire (Vietnam), LG: Landrace (Germany), PI: Pietrain (Germany), LW: Large White (Germany), WB: European Wild Boar, VB: Vietnamese breeds (CO, ME, MK, TN); XB: Exotic breeds (LV, YV); EB: European breeds (LG, PI, LW); NS: Number of samples; NL: Number of Polymorphic Loci (A locus was considered to be polymorphic if the most frequent allele was < 0.99); MNA: Mean number of alleles across all loci; ENA: Effective number of alleles.

Table 4.12: Heterozygosity, Hardy-Weinberg Equilibrium and F-statistics

Genetic group	PIC	H_E	H_O	NLE	F_{IS}	F_{ST}
VB	0.78	0.80	0.69	7	0.089	0.050
XB	0.50	0.54	0.51	9	0.022	0.028
EB	0.55	0.58	0.53	8	-0.005	0.097

VB: Vietnamese breeds (CO, ME, MK, TN); XB: Exotic breeds (LV, YV); EB: European breeds (LG, PI, LW); PIC: Polymorphism Information Content; H_O: observed heterozygosity (direct-count); H_E: expected heterozygosity (unbiased estimate); NLE: Number of loci in Hardy-Weinberg equilibrium (from 10 loci analysed); F_{IS}: Inbreeding coefficient of individual in subpopulation; F_{ST}: Genetic differentiation between subpopulations by genetic drift.

As can be seen in table 4.11, the group of Vietnamese breeds has at least twice the mean number of alleles compared with the breeds of European origin. The effective number of alleles (ENA) of the marker panel was also markedly higher in Vietnamese breeds than in the groups with a European background. Higher ENA values in Vietnamese indigenous breeds than in the breeds of European background mirror our findings for allele numbers and agree with the results of LI et al (2000), who found increased Polymorphism Information Content (PIC) and ENA values in four indigenous Chinese pig breeds as compared to one Australian breed. Low numbers of alleles (3.7 to 5.8) as found by FAN et al. (2002) for three Chinese indigenous breeds could be explained by the fact that only populations from livestock farms were investigated. This is supported by our finding for Mong Cai (5.7) which is also kept at an experimental station under controlled breeding conditions. Taken together, these results suggest that the Vietnamese indigenous breeds are still highly diverse while the other breeds seem to have a reduced allelic diversity due to selective breeding. This finding is supported by the fact that, while none of the population samples contained the whole range of alleles individually, only Vietnamese breeds as a genetic group contains all the observed alleles at four loci (*SW489, SW1083, SW2410 and SW957,* not shown).

Heterozygosity and genetic equilibrium: The PIC values, as shown in table 4.12, were closely correlated with the effective number of alleles.

The observed heterozygosities (table 4.13), were lower than expected in all the genetic groups. Vietnamese breeds showed a pronounced difference, having also the lowest number of loci in genetic equilibrium. It has been suggested, that reduced heterozygosities can be the consequence of size homoplasy at certain loci that cannot be detected by electrophoretic fragment length analyses (MAKOVA et al., 2000). An example of this has been found at locus *SW498* for which comparative sequencing (different individuals) of one highly frequency allele with equal length per locus revealed a 2 bp deletion in the 5'-flanking region of an allele with 16 repeats (not shown). The deletion caused this particular allele to appear as the 15 bp allele in fragment length analysis.

The number of populations for which significant deviation from Hardy-Weinberg equilibrium occurred was slightly more than would be expected had they all been randomly mating. For the Vietnamese local breeds, a certain degree of inbreeding due to a lack of management and poor infrastructural conditions can be expected. This is reflected by the inbreeding coefficient F_{IS} (Table 4.12), for which Vietnamese breeds showed the highest value (0.089) while the lowest F_{IS} value (-0.005) was observed in EB. As can also be seen from Table 4.12, Vietnamese breeds showed an intermediate F_{ST} (0.050) while F_{ST} was highest (0.097) in European breeds and lowest (0.028) in exotic breeds. These F_{ST} values are within a range between 0.005 and 0.15 which is considered to indicate moderate differentiation between populations (WRIGHT, 1978; HARTL and CLARK, 1997). Interestingly it is the group of European commercial breeds that shows the highest F_{ST} value. This could partly be the result of selection, since when genetic drift and gene flow are weak, the effects of other forces on the gene pool, such as mutation and selection, gain more influence (NEIGEL, 2002).

Genetic distances and phylogenetic tree: The genetic distances (NEI, 1972) between individual populations are represented in Table 4.13. The smallest genetic distances were found between the breeds Vietnamese Landrace and Vietnamese Yorkshire (0.06), Co and Meo (0.10) as well as Vietnamese Landrace and Pietrain (0.07). The UPGMA dendrogram for the eleven pig populations is shown in Fig. 4.10.

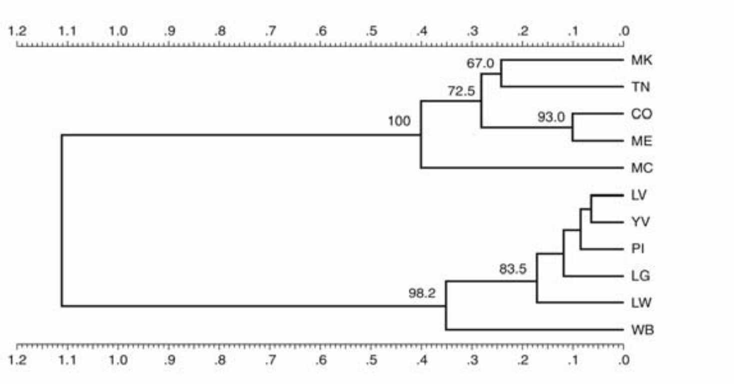

Figure 4.10: UPGMA dendrograms based on standard genetic distances (NEI, 1972).

CO: Co, ME: Meo, MK: Muong Khuong, TN: Tap Na, MC: Mong Cai, LV: Landrace (Vietnam), YV: Yorkshire (Vietnam), LG: Landrace (Germany), PI: Pietrain (Germany), LW: Large White (Germany), WB: European Wild Boar.

It can be seen that the eleven populations were divided into two branches. Within the branches the European based breeds Vietnamese Landrace, Vietnamese Yorkshire, Pietrain and German Landrace were very similar and bootstrapping values were below 60 %. The Vietnamese indigenous breeds were less homogenous than the European based breeds and all genetic distances had a high bootstrap support. The results clearly point to differences between the Vietnamese indigenous breeds which reflects their geographical distribution. The closely related Co and Meo for example originate from regions only 150 km apart in the Nghe An province while Muong Khuong and Tap Na, which also form a cluster, are both from the northern part of Vietnam and closer to each other than to any of the other populations. In addition to that, Mong Cai which have been kept at an experimental station show a slightly increased genetic distance from all the other local breeds.

Furthermore, our results clearly demonstrate significant distances between Tap Na (so far unlisted by the FAO) and the other tested breeds. With values below 60%, bootstrapping replicates of the trees did not however establish a precise topology among the commercial breeds of European descent. As the BOOTDIST routine of BIOSYS2 (SWOFFORD et al., 1989) resamples the locus specific genetic distances per population we consider this to be a consequence of the limited number of tested loci which should be overcome by increasing the marker number.

Table 4.13: Matrix of genetic distances according to NEI (1972) standard distance.

Population	Genetic distance										
	CO	ME	MK	TN	MC	LV	YV	LG	PI	LW	WB
CO	xxx										
ME	0.10	xxx									
MK	0.28	0.30	xxx								
TN	0.27	0.27	0.24	xxx							
MC	0.36	0.28	0.53	0.44	xxx						
LV	0.94	0.62	0.96	0.92	0.88	xxx					
YV	1.06	0.70	1.18	1.21	1.10	0.06	xxx				
LG	1.20	0.84	1.41	1.37	1.08	0.11	0.11	xxx			
PI	0.95	0.63	1.03	0.95	0.80	0.07	0.11	0.14	xxx		
LW	1.02	0.70	1.20	1.01	1.03	0.14	0.11	0.25	0.18	xxx	
WB	1.58	1.25	1.89	1.89	1.97	0.36	0.30	0.30	0.45	0.35	xxx

CO: Co; ME: Meo; MK: Muong Khuong; TN: Tap Na; MC: Mong Cai; LV: Landrace (Vietnam); YV: Yorkshire (Vietnam); LG: Landrace (Germany); PI: Pietrain (Germany); LW: Large White (Germany); WB: European Wild Boar; VB: Vietnamese indigenous breeds grouped (CO, ME, MK, TN); XB: Exotic breeds grouped (LV, YV); EB: European breeds grouped (LG, PI, LW).

4.5.4 Conclusion

This study is one of the first contributions to a genetic characterization of autochthonous Vietnamese breeds. It clearly demonstrates that these breeds harbour a rich reservoir of genetic diversity. The newly investigated Tap Na population can be considered to be an independent breed.

4.6 A Survey of Selected Livestock Parasites in Son La

Thomas Romig, Tina Jehle, Phan Van Luc and Ute Mackenstedt

4.6.1 Introduction

Endemicity of parasitic livestock diseases has a grave impact on the sustainability of farming systems. Depending on the species of parasite, this may be due to their impact on the quality and quantity of animal products, or due to their zoonotic potential as causative agents for human disease. This negative impact is less apparent in traditional farming communities with subsistence farming, where deficiencies of product quality or safety may not be recognized, or may traditonally be tolerated. With the onset of product marketing on a national or international level, this situation changes fundamentally, and small holder animal products may not be marketable, therefore reducing the possibility of cash generation by small holders.

Due to the complex life cycles of most parasites – which involve different host species and obligatory host changes – the locally prevailing conditions of animal husbandry, slaughtering facilities and marketing practises have a profound influence on the transmission intensity. Many parasitic diseases can be effectively controlled by improved slaughtering practises (meat inspection) and providing information on preventive behaviour to farmers and distributors. However, small scale farming usually favours disease transmission due to uncontrolled home slaughter with unsafe offal disposal and generally unhygienic conditions. Therefore, any changes in animal production systems and the introduction of new animal genotypes is likely to have an impact on parasite transmission and public health. To establish some baseline data in the first phase of the present investigation and as an aid to further project planning, a prevalence survey of various parasite species in livestock (pigs, cattle and buffaloes) was carried out, concentrating on the following parasites:

Sarcocystis spp. are non-zoonotic protozoan parasites, which has a cystic stage in the muscle tissue of e.g. pigs, cattle and goats. Meat quality is reduced, growth is impaired and heavily infected animals may die. Different species of *Sarcocystis* are likely to occur in the area, which are specifically transmitted to livestock by different species of carnivores (e.g. dogs and cats), and by man.

Taenia solium is a tapeworm of man which involves the pig in its cyclic transmission. The cystic stages in pig muscles (cysticerci) reduce meat quality, but of much more importance is its role as causative agent of human neurocysticercosis, a serious and often lethal disease affecting the central nervous system (brain, eyes). On a world scale, the parasite's presence is strongly associated with small-scale pig husbandry.

Echinococcus spp. are tapeworm species transmitted by canids (usually domestic dogs) to different species of livestock and to man. While different genotypes of *E. granulosus* mainly use pigs and goats for transmission, *E. ortleppi* is a parasite of cattle. In livestock and man the parasites cause hydatidosis, characterized by large fluid filled cysts developing in internal organs, mainly liver and lungs. In animals the parasite retards growth and at slaughter leads to the condemnation of internal organs, while in man untreated hydatidosis is often fatal. Pathogenicity to man is strongly associated with species and genotype of the parasite. While the presence of *Echinococcus* sp. is known from northern Vietnam, no information exists on genotypes and prevalence rates.

Trichinella spp. are nematode tissue parasites affecting carnivorous or omnivorous warm-blooded animals including man. The parasites are acquired by eating insufficiently cooked meat from infected animals (mainly pork). Acute infections with heavy doses can lead to death within a few days. Serious human infections often occur as outbreaks which can be traced to a common source, but sub-lethal infections are widespread in endemic areas where the cause of disease often remains unidentified.

4.6.2 Materials and Methods

Between October 2003 and October 2004, a total of 1244 animals from slaughterhouses were examined (977 pigs, 204 cattle, and 63 buffaloes). The majority of the slaughterhouses were situated in Son La town and several localities nearby.
For the diagnosis of *Sarcocystis*, tissue samples were collected from various muscles of each animal (tongue, diaphragm, skeletal muscles), and examined under 20x magnification. Positive samples were fixed in formalin and processed by standard histological techniques. Sub-samples were fixed for electron microscopy studies.

For cysticercosis and echinococcosis, tongue, skeletal muscles and internal organs (liver, lungs, spleen, kidneys) were visually examined. Suspected cysts or lesions were fixed in ethanol for further inspection in the laboratory, and for genetic analysis. Suspected metacestodes of *Echinococcus* were analyzed using a newly developed PCR system as described by DINKEL et al. (2004)

For trichinellosis, tissue samples of pigs (tongue, diaphragm, skeletal muscles) were artificially digested, and the resulting samples examined under magnification for the presence of larvae.

4.6.3 Results and Discussion

The preliminary results of the survey are summarized in table 4.14 and 4.15. The prevalences in the pig breed 'Lon Ban' were significantly higher for all parasite species except *Trichinella,* which was not found during this survey. All specimens of *Taenia solium* were obtained from 'Lon Ban', and the prevalence of *Sarcocystis* was 17%, as compared to 8% in "white" pigs.

Sarcocystis samples are not yet determined at species level. Tentatively, there was one species in pigs, 2-3 species in cattle, and 3 or more species in buffaloes.

The data obtained so far have not yet been analyzed according to spatial distribution and although a certain degree of clustering is apparent, at least with *T. solium* cysticercosis, no definite conclusions can presently be drawn on this matter. Neither can any conclusions be drawn yet on the reasons for the observed differences in parasite prevalence between different pig breeds. These may be due either to susceptibility of the pigs, or to husbandry conditions. If, during the ongoing project, more hygienic husbandry conditions for improved pig breeds can be identified as the reason for decreased parasite loads, this may have an impact on market acceptance of small scale farming products, and further support the sustainability of such systems.

Table 4.14: Summarized results of the slaughterhouse survey in Son La: *Sarcocystis* and *Trichinella*.

Species	n examined	Sarcocystis spp.		Trichinella spp.*	
		n positive		n positive	
Pigs (total)	420	42	10% (7-13)	0	0% (0-2)
Pigs (Ban)	105	18	17% (10-26)	0	0% (0-4)
Pigs (“white”)**	315	24	8% (5-12)	0	0% (0-2)
Cattle	204	88	43% (36-50)	n. d.	
Buffalo	63	42	67% (54-79)	n. d.	

* for *Trichinella*, a subtotal of 201 pigs was examined (57 Ban pigs, 144 “white” pigs)
** pigs of white colour are either of pure exotic origin (e.g. Yorkshire) or of crossbred origin (e.g. Mong Cai sow mated with Yorkshire boar)

Table 4.15: Summarized results of the slaughterhouse survey in Son La: *Taenia* and *Echinococcus*.

Species	n examined	Taenia solium		Echinococcus spp.	
		n positive	prevalence (95% CI)	n positive	prevalence (95% CI)
Pigs (total)	977	7	1% (1-2)	0	0% (0-1)
Pigs (Ban)	155	7	5% (2-10)	0	0% (0-3)
Pigs (“white”)*	822	0	0% (0-1)	0	0% (0-1)

* pigs of white colour are either of pure exotic origin (e.g. Yorkshire) or of crossbred origin (e.g. Mong Cai sow mated with Yorkshire boar).

4.7 Synthesis

Anne Valle Zárate

Livestock's present and future contribution to sustainable development of mountainous farming systems in northern Vietnam is specifically relevant for marginal production conditions in remote areas at high altitudes where the poorer farmersof different ethnic minorities live. Livestock in traditional systems in those areas shows a positive ecological effect, in complementing farming activities, in contributing to domestic animal biodiversity in different species and in substantially promoting soil fertility.

However, systems in transition between traditional/extensive and intensive production forms tend to concentrate on increased production and productivity with the primary aim of poverty reduction and increased supply of animal products to regional markets. The optimal allocation of natural and economic resources needs to be further addressed to ensure positive ecological contributions of the different lines of animal production (including aquaculture). More attention has to be paid to hygienic quality of animal products and their ability to meet consumer demands regarding nutritional quality, taste, flavour and health. Mere maximizing production and productivity in the short run will not sustainably contribute to food security, as it tends to increase the risk of production, specifically for the most vulnerable poor farmers in remote areas.

The rich biodiversity still predominant in the mountainous regions of northern Vietnam must be seen as an asset for small farmers, whose competitiveness in the national livestock sector will be considerably weakened if they give up to exploit their unique resources. Conservation of biodiversity through profitable utilization under farming conditions, where they have comparative advantages through special traits of adaptation, seems more viable and promising than waiting for international subsidies to be triggered into remote areas for the sake of preservation of global biological heritage.

Development of local pig breeds, identification of their specific rare genes and traits, with emphasis on disease resistance and product quality, and their incorporation in integrated programs of genetic improvement, improved management and marketing of high quality products have been identified as a prospective development path to combine the aims of food security and natural resource management in the research site of northern Vietnam. Further integrated research and development approaches will be in pursue of this aim.

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5.0 Farm Economics and Marketing Dynamics in Support of Sustainability

5.1 Introduction

Franz Heidhues

In Chapter 5 farm economics and market dynamics in support of sustainability are discussed. Understanding rural households` decision making, their economic constraints and their potential for action is a key precondition for formulating sustainability promoting measures in rural areas. In passing we might add that with all the attention in the development discourse given to macro conditions, such as structural adjustment programs, WTO trade issues and governance – as important as all these tropics are – looking at the micro level and understanding rural peoples` behaviour and decision making has received too scant attention. In their contribution (5.2) DOPPLER and DO ANH TAI address the decision making process and the economic environment of rural households along the gradient of tropical mountains watersheds: valley bottoms – middle hill sides – high mountain. Farmers in northern Thailand respond to the increasing pressures on land by intensifying crop production systems, particularly in using high doses of mineral fertilizers and pesticides with the resulting environmental damages to water and soils. ZEDDIES and SCHÖNLEBER in their paper (5.3) analyze nutrient balances of fertilizer use and levels of water contamination by pesticide application and assess the threat to the sustainability of farming in the area. PRANEETVATAKUL and SIRIJINDA (5.4) develop with multiple goal programming tools optimal farm plans of different ecological zones in a northern Thailand watershed, i.e. optimal under the aspect of sustainable farming systems. Longans and mangos are an important crops for small farmers in mountainous regions in northern Thailand. SOMPORN in his contribution (5.5) analyses the integration between the Bangkok and Chiang Mai whole sale markets for longan fruits, applying the co-integration model of Ravallion, Alexander and Wyeth. In their paper (5.6) HAU and VON OPPEN discuss the efficiency of the mango market in Thailand by testing linkages between the Bangkok wholesale market and regional and local markets in northern Thailand and measure the impact of trade and marketing on welfare. A synthesis discussion concludes chapter 5.

5.2 The Impact of Family Decision-Making on Sustainable Rural Livelihoods

Werner Doppler and Do Anh Tai

5.2.1 Problem and Objectives

Living standards and food security in mountainous zones of Southeast Asia are determined by a complex set of conditions, especially the availability and quality of resources and their use in rural farming families, the accessibility to markets, as well as education, ethnicity and cultural background. The degree of market orientation, production and socio-economic conditions of families changes as one moves from urban to remote zones. LENTES (2003), DO ANH TAI (2004) and HUYEN (2004) carried out research in Son La Province in Vietnam to investigate and analyse the variation of important development parameters and to determine the driving forces behind them. The objective of this research has been to understand farmers' complex decision-making behaviour and the impact of resource use and management on living standards and food security at the family and rural sector level. On this basis, future strategies for development can be proposed.

5.2.2 Principal Concepts and Methods

The research approach is derived from micro-level research dealing with families and their rural environment, combining the family and spatial levels in a watershed area characterized by different natural and man-made conditions. A study area was selected in the Mai Son area in Son La Province, which represents a watershed with remote, high mountainous zones, inclined areas in the intermediate section and an urban centre in the lowlands. Families were grouped into classes representing "market-oriented systems", "remote area systems" and "intermediate farming systems" respectively. The market-related system is close to the urban centre. It has high purchasing power and cultivates flat land with high production potential. The well-educated Kinh people live there. In the intermediate system, production conditions are good, but the cultivation of inclined farmland leads to soil degradation. Production serves for subsistence as well as market supply for cash income. The dominant ethnic group is the Black Thai. In the remote area system, subsistence production is dominant and the life of the people is very traditional and not much linked to urban areas. The information for this research project came from own family surveys in 1999 and 2002 and remote sensing data (LENTES, 2003). All family surveys are based on random sampling of the families in villages with 22 to 25 families per village comprising 222 families in total (DO AN TAI, 2004; HUYEN, 2004). Standardized questionnaires were used in interviews for all surveys. In addition, a key person survey with 50 cases spread over the study area provided additional information, based on the knowledge of persons in the area with specific expertise, experiences and views (LENTES, 2003). A package concept for questionnaires and data base systems has been designed and applied. Comparable family level analyses were carried out to define the driving forces of past developments; they were complemented by modeling future strategies and their impact on resource use. Furthermore, spatial analyses were carried out with the help of GIS and they were used for outlining future strategies of development as a complement to the family level modeling.

5.2.3 Analysis of Past Developments and the Current Situation of Rural Families

The comparative analysis shows that resources become increasingly scarce and unfavourable for agricultural production as one moves from the lowlands to remote mountainous areas. Farm size and cultivable land (table 5.1) are relatively high in the middle altitude villages Bo Duoi and Na Huong (2.91 to 3.65 ha) followed by farms in the high mountainous zones, where H'mong people live, and are smallest in farms in the intensive rice production areas of the lowland zone of Ban Un (1.69 ha). The quality of cultivated land is low in the entire study area, but particularly poor in the high and remote areas, where land resources are facing serious degradation problems. The tendency towards decreasing land quality or increasing degradation from farms in the lowlands to farms in the high mountainous zones is due deforestation and inappropriate land use. The changes in land quality run contrary to the rising human needs in the high mountainous zones. Thus, poor land quality coupled with small farm sizes is likely to increase problems of food insecurity in these high zones.

Forest resources are important to hill tribes. However, due to deforestation and forest degradation, forest use currently does not reflect its potential in the high mountainous zones. Nevertheless, forest resources have a high potential for the future development of the area. As the size of the family increases (>50% of the family are children) in the high mountainous zones so do the human demands in these remote areas, as compared to families in the lowland areas. A large but unskilled labor force people's poor health conditions, a low level of education, poor infrastructure and services as well as a scarcity of other resources limits the potential for economic development and higher living standards in the high mountainous zones. Families living in the area cannot solve these kinds of problems alone.

The results of the analyses show that the economy in this area is developing over time, but it is confronted with the problem of resource degradation due to overuse. The analysis also shows that there is unequal development in the living standards of families due to uneven resource availability and use by farms in the different zones, from lowlands to the high mountains. Farm income accounted for a majority share of the family income in all the villages (table 5.2). However, off-farm income also contributes a significant proportion to the total family income necessary to satisfy their needs, especially in the H'mong villages of the high mountainous areas. There is a tendency towards decreasing farm and off-farm income following the altitudinal gradient from lowland to highland families, and also from families with good access to land resources (Bac Quang and Tong Tai) to families with limited access to resources (Ban Un and Pa Dong). Concomitantly, living standards of farmers and levels of economic development follow the altitudinal gradient, with high economic development in the lowlands and low development in the highlands and remote areas, as well as high economic development and better food security in areas with high access to land resources.

Table 5.1: m size and crop production by system in the study area, 2001.

Items	Bac Quang (n=25)	Ban Un (n=25)	Na Huong (n=25)	Bo Duoi (n=22)	Pa Dong (n=25)	Tong Tai (n=25)
Farm size in ha	2.23 (0.24)	1.70 (0.41)	2.91 (0.32)	3.65 (0.80)	2.09 (0.29)	2.88 (0.45)
Land/ person in ha	0.49	0.18	0.38	0.49	0.25	0.43
1. Paddy Rice, %	0.00	56.41	4.74	3.86	2.11	0.00
2. Upland Rice, %	0.00	0.00	1.98	1.16	1.41	6.67
3. Maize, %	81.25	11.97	73.91	79.54	88.73	87.06
4. Beans, %	5.73	0.85	11.07	0.39	0.00	0.00
5. Sugar Cane, %	10.94	17.09	0.00	5.02	0.00	0.00
6. Cassava, %	0.52	11.97	5.14	9.27	7.75	6.27
7. Other crops, %	1.56	1.71	3.16	0.77	0.00	0.00
Total annual crop, ha	1.92	1.17	2.53	2.59	1.42	2.55
Total perennial crops, ha	0.26	0.22	0.12	0.51	0.12	0.14

Source: DO, 2003A, P. 31. 32, 58).

Note: Figures in parentheses are confidence limits of mean estimation (α =0.1). The assumption of no significant differences in the farm size and in the available land per person among the villages could be rejected according to the results of the Kruskall-Wallis test at a probability of > 99%.

Table 5.2: Farm and family income in different systems in the study area in Mai Son, 2001.

Items	Bac Quang (n=25)	Ban Un (n=25)	Na Huong (n=25)	Bo Duoi (n=22)	Pa Dong (n=25)	Tong Tai (n=25)
Farm income (1000 VND/year)	17487.4 (2670.9)	8380.1 (2299.2)	23469.0 (3777.2)	18292.1 (2052.8)	6915.7 (1525.9)	9459.3 (1488.5)
Per hectare of cultivated land	8319.3	9708.9	11565.0	6771.7	3358.9	3981.3
Per farm labor unit	7391.2	2850.9	8570.3	6020.3	2016.9	3288.3
As % of family income	80.3	74.9	92.3	86.5	81.9	79.5
Off-farm income (1000 VND/year)	5559.2 (3231.6)	2276.6 (747.8)	2494.2 (1270.9)	3013.5 (893.7)	1103.4 (155.0)	1733.5 (413.5)
As % of family income	19.7	25.1	7.7	13.5	18.1	20.5
Family income (1000 VND/year)	23046.6 (3784.9)	10656.7 (2569.2)	24149.2 (5011.0)	21200.3 (2455.3)	8019.0 (1568.6)	11192.7 (1699.1)
Family income per head	5206.3	1814.5	4372.5	3338.1	1141.9	1860.4

Source: DO (2003A, P. 82)

Note: Figures in parentheses are confidence limits of mean estimation ($\alpha = 0.1$). The assumption of no significant differences in farm income and family income between the villages could be rejected according to the results of the Kruskall-Wallis test at a level of probability > 99%. The assumption of no significant differences in off farm income between the villages could be rejected according to the results of the Kruskall-Wallis test at a level of probability of 86.5%.

A well-trained and educated farming family is important for the efficient and proper management of natural resources. The impact of education is seen in their attitudes and behavior as well as in the decision-making processes. Given the current level of education in the region, there is a need to train farmers in the management of their resources. This calls for extension services. As the regression analyses indicate, resource availability and use have a strong impact on living standards. However, given the limitations of natural resources for improving living standards, farmers need to increase the efficiency of their resource use by changing current practices to generate greater yields from a given resource. Increased living standards will also impact on the way resources are managed by farmers, e.g. in protecting them and avoiding degradation. The results of the regression models show the important role that livestock and forest resources play in the income and living standards of farmers in high mountainous zones. Food security is, as expected, positively correlated with the village income level, but a nutrient imbalance is prevalent in the entire study area. Therefore, farmers need to change their food use habits in order to have on adequate food and nutrient diet. The quantified results of living standard analyses are described qualitatively in Table 5.3. There is a clear tendency for living standards to decrease with increasing distances from the urban center which provides not only markets but also all kinds of services. Increasing distance is correlated with changes in and a greater diversity of ethnic groups as well as with increasingly unfavorable natural conditions for farming.

Future development strategies have been assessed by applying family models to estimate future development with and without the implementation of selected strategies. The difference between the criteria of success of a family (e.g. family income) in the with and without development is interpreted as the impact of the respective strategy. The applied family models are composed of the farm, the household and the off-farm sub-units (see DO, 2003a: 122). The external relations of the family were defined for the field of resources (e.g. land, water, capital, labor) and products (inputs and market products) as well as for the food, legal and social relations.

Mathematical programming was applied and a linear algorithm used to find the optimal allocation of resources under a given socio-economic goal. The objective function was to maximise family income (farm and off-farm) under the conditions, that the resources are not overused, the legal and social restrictions are not violated and the food and household supply of the family is insured. The models are dynamic in a way that a 10 year period is considered by defining a simultan eous matrix of 10 matrices each one representing a 12 months period (see DO, 2003a: 126) While each year was covered by an individual matrix and connected to the others (e.g. through ownership rights, cash and other obligations), the objective function was a multi-periodical one covering all 10 year at once. Risk was externally applied by a sensitivity analysis varying certain parameters under question. The model design, the structure and purpose of application as well as the validation of the various models for different classes are discussed and presented in DO (2003a: 119-139) and in HUYEN (2004:111 - 122).

Table 5.3: Final assessment of family living standards in different farming systems in the Mai Son study area in 2001.

Items	Bac Quang (n=25)	Ban Un (n=25)	Na Huong (n=25)	Bo Duoi (n=22)	Pa Dong (n=25)	Tong Tai (n=25)
1. Family income	High	Low	High	High	Low	Low
Farm income	High	Low	High	High	Low	Low
2. Cash, liquidity	High	Low	High	Medium	Low	Low
3. Independence from resource owner	Most	Less	Less	More	Least	More
4. Food supply and food security	High	Low	High	Medium	Low	Low
5. Supply of water, housing etc.	Very good	Normal	Good	Normal	Poor	Bad
6. Health conditions	Very good	Poor	Normal	Normal	Poor	Normal
7. Education and qualifications	High	Medium	Medium	Medium	Low	Low
8. Social security	Very good	Normal	Good	Good	Poor	Poor

Source: DO, 2003A. P.106.

The models have been applied for different strategies and classes (see DO, 2003a: 113-119) and in HUYEN (2004: 109 to 111). Strategies and classes considered here can be summarized as follows:

1. Measuring the impact of changing credit conditions on family income in the ethnic group of Black Thai under the condition of Ban Un.

2. Measuring the impact of changing land availability under the condition of Bac Quang in the flat valley close to urban areas, ethnic group of Kinh people
3. Measuring the impact of change in land quality in Black Thai and H'mong villages

Applying a strategy of reducing interest rates and increasing the amounts of informal loans in particular, given the situation of land scarcity in the Black Thai farms of Ban Un, provides only a small additional benefit. However, shifting to formal credits and thus reducing dependency on informal money-lenders produces a significant impact. The amount of credit will increase considerably (21% increase) and be used in the production of perennial crops such as longan and litchi. The strategy of reducing farm size by distributing land among children has a negative effect and lowers the average family income per year by up to about 9%, 16% and 25% depending on the respective level of reduction during the ten year-period of the model simulation. Decreasing the availability of farmland will destabilize the living standard and food security situation of farmers and aggravate social problems. The strategy of improving land quality through terracing will have a positive impact on farmers' living standards and food supply conditions, and increase incomes in the long-term. Terracing is a suitable erosion control measure for the maintenance of soil fertility in inclined areas. It will lead to increased yields and contribute significantly to farm and family income. The terracing strategy will have a greater impact on farms and families in the high mountainous zones (H'mong villages) where erosion is particularly serious. With terracing, the average income level of families will increase by between 32% and 35% per year compared to no terracing. Similarly, families in the middle altitude areas (Black Thai) are likely to increase their average incomes by between 15% and 38% per annum. The terracing program also indicates sustainable development through yearly income increases and the generation of employment for the benefit of the unemployed. This will increase the standard of living of farming families in particular and benefit the rural society in general. (For a detailed discussion see DO (2003a: 132-144)).

5.2.4 Spatial Analyses and Assessment of Future Strategies

In addition to family-based micro-level analyses, spatial analyses have been carried out by LENTES (2003). GIS has been applied for the analysis of past developments as well as for modeling future impact. Based on a variety of data sources, including remote sensing, satellite images interpretation and classification of the area mainly based on natural sciences data (e.g. geology, geomorphology and land cover information) was done. A digital terrain model (LENTES, 2003: 66ff) and a watershed classification constituted the bases of different types of models. Socio-economic data from the family survey were integrated in the following way (LENTES, 2003: 121-125):

a) The location of the interviewed families in the study area gave a first information about the socio-economic changes in the space of the region.
b) This was more specified by an interpolation either of or in the space between villages and houses
c) A key person survey for 59 villages in the area provided another source of spatial distribution of socio-economic parameters in the area.

Through this the family survey information was represented in the space as well as in the different zones of the region. By adding information on road infrastructure and market distances the relation between remote and urban areas have been investigated.

The results show the relevance of the spatial approach while basically confirming the micro-level results. The food security analyses revealed that there is not a general hunger problem, but rather seasonal food shortages, especially before new harvests. With increasing remoteness, the probability of seasonal food shortages also increases (Figure 5.1). This was expected and formulated in hypotheses. The lesson is that under such conditions, traditional systems are not able to solve problems without external knowledge and experience.

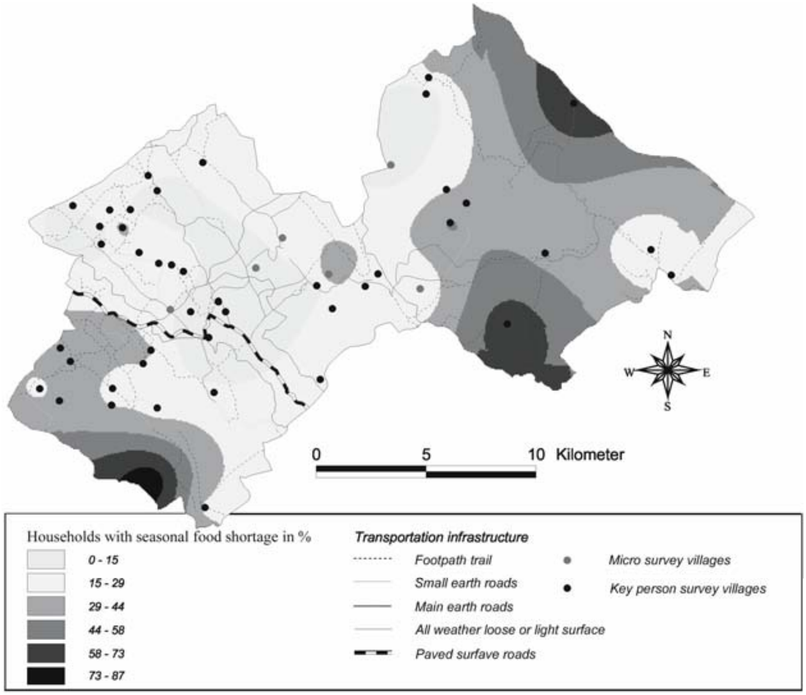

Figure 5.1: The distribution of seasonal food shortages in 2001 in the Mai Son study area.

Family income decreases with increasing distance from the market and altitude (Figure 5.2). Inadequate use of land leads to soil degradation and loss of production and hence a reduction in income. LENTES (2003) simulated future development under the assumption that past soil degradation will continue in the future and measured the loss of farm income for farming families under given conditions (Figure 5.3). Results show that the loss of income is highest precisely in those areas where the level of income is already low. The poorest people will be the losers due to overuse of land. Rural infrastructure plays a central role in rural development and livelihoods. Road infrastructure is often an important component in connecting people to markets, health and education services and external knowledge. The road-building strategy has been simulated (LENTES, 2003) and the results indicate its great relevance for income growth (Figure 5.4). The positive effects are higher in areas where people already have some links to markets and services. However, despite lower income growth in the more remote areas, it is still very important, since it contributes much more to an increase in income of the poorest. Rural development strategies implemented in a situation where livelihood levels in the area are very low often require combined efforts to achieve results over time. In areas such as the study region, improvements in land management through measures to avoid further soil degradation and bringing people closer to markets and services in urban areas by improving road infrastructure may have combined effects which are greater than any single action. Such a combined strategy has been tested (LENTES, 2003). The results clearly show the great benefit to families in the intermediate areas in particular, but most important is the contribution to income in the remote zones.

5.2.5 Conclusions

The research showed that it is possible to acquire good quality information in very traditional societies through a combination of in-depth interviews, participatory information gathering and remote sensing. Another methodological result was the combination of family level with spatial analyses modeling and GIS. It has been shown that micro-data can be used in GIS to transfer micro-level to spatial knowledge. This was complicated by the fact that families live in villages and not on the lands they cultivate. The approximation methods developed proved to be adequate in solving the problem.

In the empirical field, the research showed a close relationship between rural and urban areas. In most cases hypotheses were confirmed that with increasing remoteness, the socio-economic conditions of the families deteriorate, while ecological parameters and those related to social life in the families increase to a certain extent. Temporary deficits in food are prevalent and represent one of the most important problems for families. This becomes more pronounced the more people tend to live in remote zones that are not connected to markets. Agricultural production, storage and processing are one area on which problem-solving strategies could focus, but it has been shown that access to markets is central to this problem. Resources, especially natural resources, have a strong impact on living standards and food security. Families with better resource endowment in terms of quality and quantity, especially land resources, have higher living standards than those with fewer resources. Furthermore, the management and use of these resources play an important role in economic success in general and living standards and food security in particular. This is especially true of areas and settlements where natural resources are becoming increasingly scarce. The study revealed that the increasing scarcity of natural resources such as land has a negative effect on the economies of families, and that erosion control and land rehabilitation will have a positive impact on farmers' living standards.

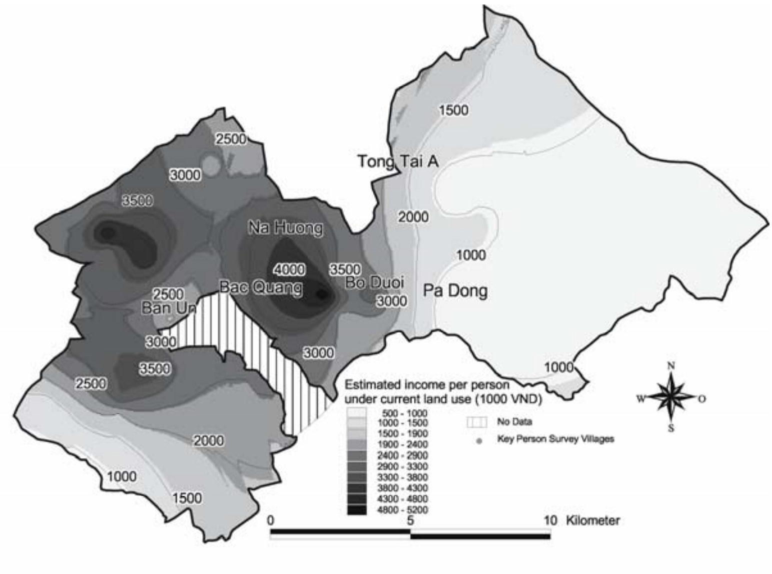

Figure 5.2: Spatial distribution of family income in the Mai Son study area under 2002 land use.

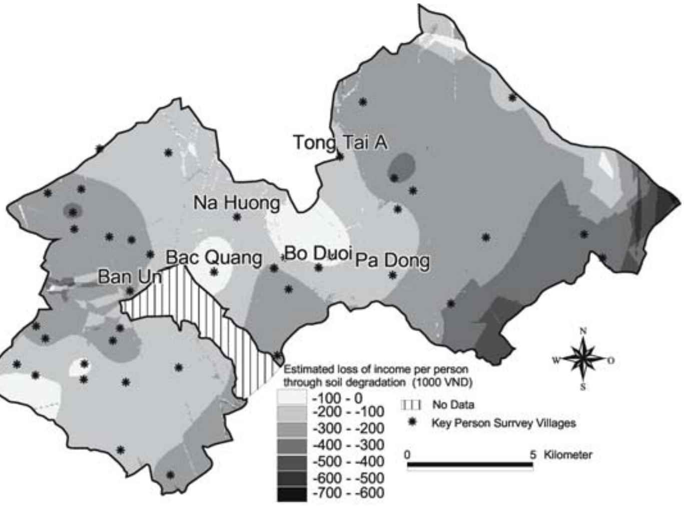

Figure 5.3: The impact of future soil degradation on loss of future farm income in the Mai Son study area.

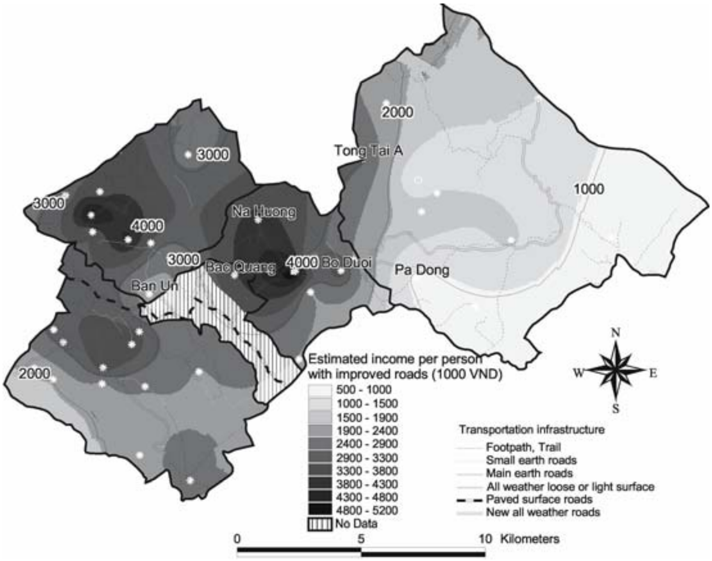

Figure 5.4: The impact of a future strategy for road improvement on income per person in the Mai Son study area.

Therefore, natural resource protection measures are vital for improving standards of living and the food security situation, especially for those in the high mountainous areas. Potential future strategies show the positive impact of investments in all areas, such as road infrastructure, resource availability for families, improved production techniques and the introduction of extension services. There are big differences among the strategies tested. The highest contribution to living standards comes from better access to markets and education/knowledge, from improved resource availability (in quantity and quality through measures against soil degradation) and from improved production techniques.

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5.3 Sustainability of Mountainous Farming Systems

Jürgen Zeddies and Nicole Schönleber

5.3.1 Current Situation

Various ethnic minority groups living in the mountainous regions of northern Thailand have been engaged in agriculture there for several decades. Over the last two decades, there has been a trend towards permanent settlements. Former opium growing farmers, such as the Hmong, have settled down permanently and have abandoned their traditional shifting cultivation system. Since the early 1980s, national programs have led to a crucial change in the area's agricultural structure. Traditional opium cultivation, which constituted the main source of peasant income in the region, was substituted with intensive land use systems in the form of cash crop cultivation, such as vegetables, fruits and cut flowers. Animal husbandry plays a minor role in generating income (FALVEY, 2000).

High population growth among the ethnic minorities together with the need to cultivate smaller fields has increased the pressure on intensification of land cultivation. In the long run, over-exploitation and lasting damage to the soil structure through erosion and leaching of nutrients and pesticides are the logical consequences. Due to the degradation of these resources, yields decrease and thus the income situation of farmers is appreciably worsened (see figure 5.5).

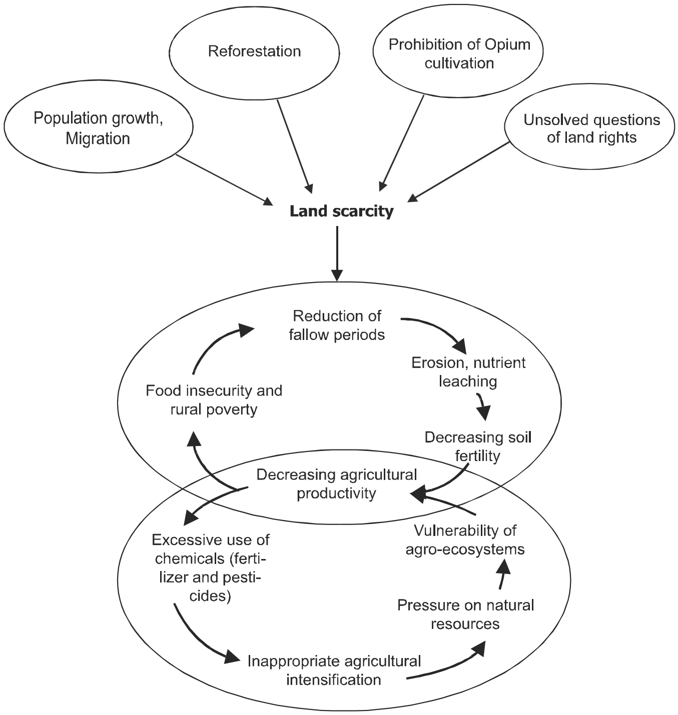

Figure 5.5: Vicious cycles of land scarcity involving negative external effects on the environment (Source: following The Uplands Program / SFB 564, 1999).

The sustainability of the land use system has to be restored in order to solve these problems. Thus, the objectives of the study are to analyse the sustainability of current land use with respect to economic, ecological and social indicators and to formulate policies appropriate for improving sustainable resource use. The investigation is based on household survey data and measurements of the chemical content of run-offs (SCHÖNLEBER, 2002; ZEDDIES, 2003).

5.3.1.1 Economic Situation

The farms' income situation is subject to extreme fluctuations. Socio-economic farming household data were gathered in 120 households (covering 8 % of the farming household population) in eleven villages in Chiang Mai province (Mae Sa Mai water catchment area).

Figure 5.6 illustrates the revenues from crop production (GM I[1]) of farming households in two of the villages investigated (Nong Hoi -NH- and Buak Chan -BC-) as well as farm profits (GM III). A line marks each farm's total cultivated area. The illustration shows that the farm profits of farming households vary enormously. The profit margin (GM III) ranges from 972,000 Baht/year (more than 22,800 €) to –89,000 Baht/year (a loss of approx. 2,100 €). Yet, taking a closer look, it becomes clear that the possible income is determined not only by farm size but also depends to a great extent on technical as well as marketing factors.

The average yearly per capita income was approximately 2,000 €. Many farming households in the research area earn farm incomes, which are much higher than these amounts. However, on a per capita basis, taking into account household size, it is less than the national per capita income of approximately 2,800 €.

1 The gross margin gained from a crop results from market revenues less variable costs, which can be assigned crop-specifically. The sum of all gross margins from a single crop production system results in GM I. GM I includes calculations of the total cultivated area as well as all vegetation periods within a year.

GM I minus variable costs which cannot clearly be assigned to a respective crop production system yields GM II.

The farm profit of a farming households is calculated by GM II less fixed costs and is named GM III.

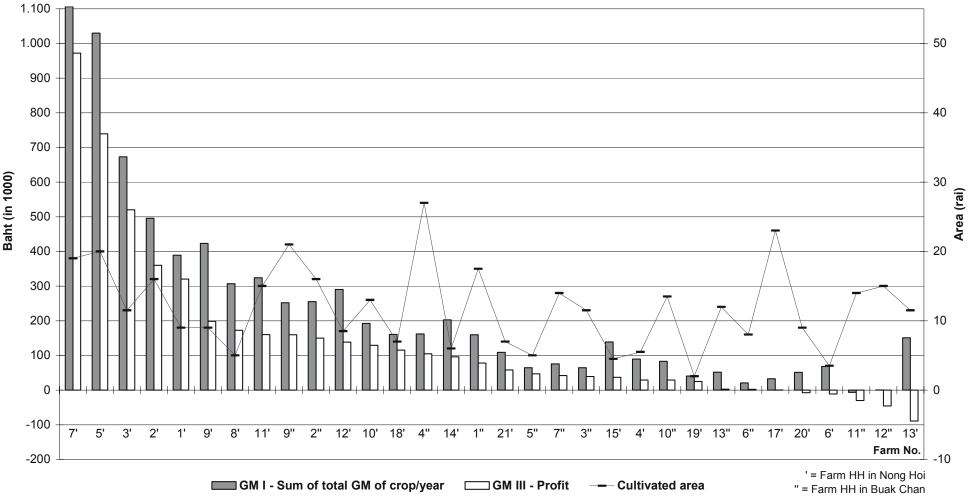

Figure 5.6: Income calculations of farming households investigated
Source: Schönleber 2002, survey data.

The economics of three cash crops - namely lychee, gerbera flowers and Chinese cabbage - are presented below. The following graphs illustrate yields as well as revenues, variable costs and gross margins of the farming systems examined in detail. All calculations refer to one rai (0,16 hectare). The results of vegetable and lychee production refer to one cropping season. The production of gerbera flowers refers to a vegetation period of one year.

The single calculated gross margins (GM) of lychee production vary between -1,440 and 25,414 Baht (Figure 5.7). The GM is mainly determined by variable costs, as well as by market prices, which are subject to quality and seasonal influences.

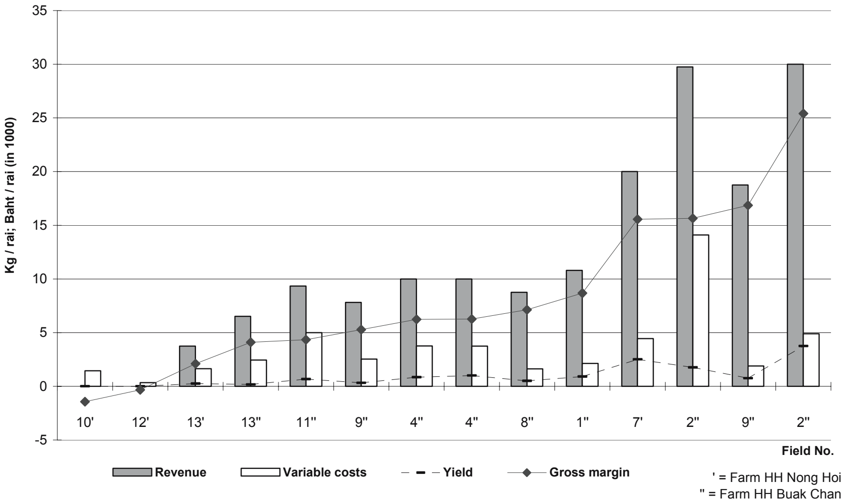

Figure 5.7: Gross margin calculations of lychee production (Source: Schönleber 2002, survey data).

Figure 5.8 depicts the profitability of gerbera flower production. Gerbera yield is at a level of 24,200 to 161,300 flowers per year/rai, and gross margins of –10,697 to 163,258 Baht/rai were obtained (see Figure 5.4). The strong fluctuations in yields could be explained by the effect of soil salinization.

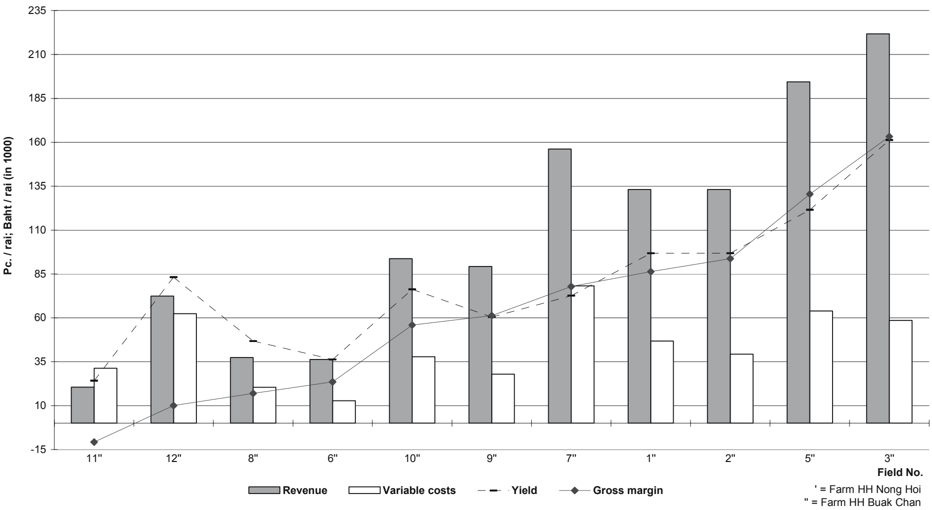

Figure 5.8: Gross margin calculations of gerbera production (Source: Schönleber 2002, survey data).

With Chinese cabbage production, gross margins of between -1,404 and 13,213 Baht/rai were achieved (see Figure 5.9).

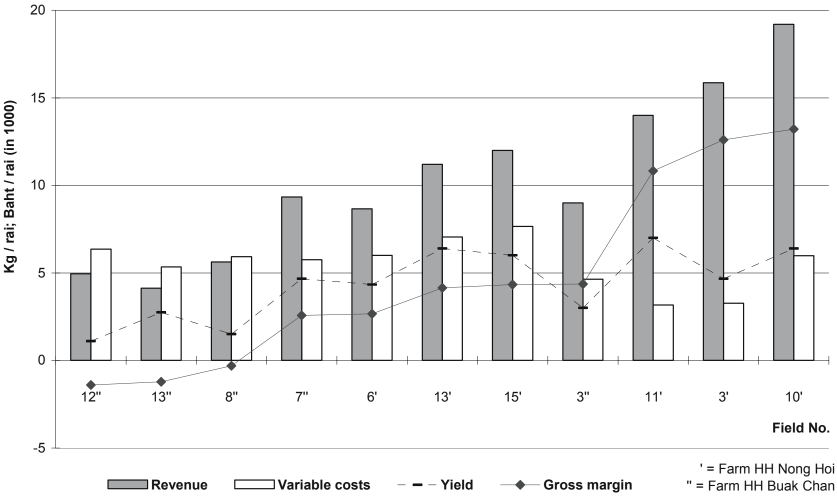

Figure 5.9: Gross margin calculations of Chinese cabbage (Source: Schönleber 2002, survey data).

The level of farm income depends only partly on farm size. A diversification of the cropping structure to minimise risks of yield and price variations is rather important for the amount of income. However, a lack of expertise and attempts to achieve high product quality for better market prices often lead to the excessive use of fertiliser and pesticides in some farms and thus to negative environmental effects. Extension on crop production by locally active institutions, e.g. Royal Project (RP) stations, proved to be beneficial and important. Within cooperating farm households, the excessive use of fertiliser and pesticides decreased.

Several cultivation periods a year can also lead to higher farm profits. It is very important to consider economic sustainability in farm planning and management. Yield or market prices are not always the only reasons behind low income; expenditures on production inputs are not necessarily related to the revenues achieved.

Farm planning and development are significantly affected by the financial situation. Access to credit is subject to some conditions, e.g. land titles as collaterals, which many farmers cannot offer. Lack of liquidity prevents optimal planning and development of farming systems. Access to credit is a requirement for farmers with small net incomes to improve their profit in the long run.

5.3.2 Ecological Situation

Ecological sustainability is endangered predominantly by the overuse of fertiliser and pesticides.

5.3.2.1 Fertiliser Application

The use of mineral fertilisers in Thailand has significantly increased. The rate of application has more than doubled, from 1.35 Mio. t. in 1986 to 3.31 Mio. t. in 1995 (LDD, 2002).

Excessive or inappropriately timed N-fertilisation, e.g. during the monsoon season, can lead to nitrate-nitrogen leaching into groundwater, particularly in permeable soils (detailed analysis has been done by sub-project B2). As a first step, only the application of nitrogen to selected cash crops was evaluated by calculating a simplified input-output balance. The balance was determined as follows:

N-Balance = Supply of nitrogen by mineral and organic fertilisation – Nitrogen extraction related to yield

In the following figures, the application rate of pure nitrogen for a single farming household's different crops was related to the actual nitrogen requirement for the yields achieved. It illustrates the extent to which the various plants are over or under-supplied with nitrogen. The calculated value serves as a parameter for possible environmental threats from fertiliser use. A nitrogen surplus is considered to be an indicator of environmental damage.

Chinese cabbage and carrots will be closely examined as examples of the vegetables cultivated. Climatic conditions and relatively short growing seasons as well as technical equipment allow multiple vegetable cropping. Consequently, a higher nitrogen level in the soil is required. Furthermore, the nitrogen balances of gerbera flower production systems are outlined. Gerbera flowers are biennial crops and are harvested all year long. Thus, a frequent and intensive input of fertilisers is required.

The single bars show the N-input and the actual N-requirement as well as the resulting difference between inputs and demands. The values are measured in kg per rai.

Figure 6 shows the N-balances of the carrot production systems investigated. A yield of 100 kg is assumed to require 0.2 kg N. Here, the yields differ greatly and lie within the range of 800 to 4,700 kg/rai. Thus, the N-demands account for less than 10 kg N/rai. However, the amount of nitrogen applied varies between 10 and 42 kg N/rai. More N is distributed to these fields than carrots need for optimal growth. The amounts of over-supply lie between 8 and 39 kg N/rai.

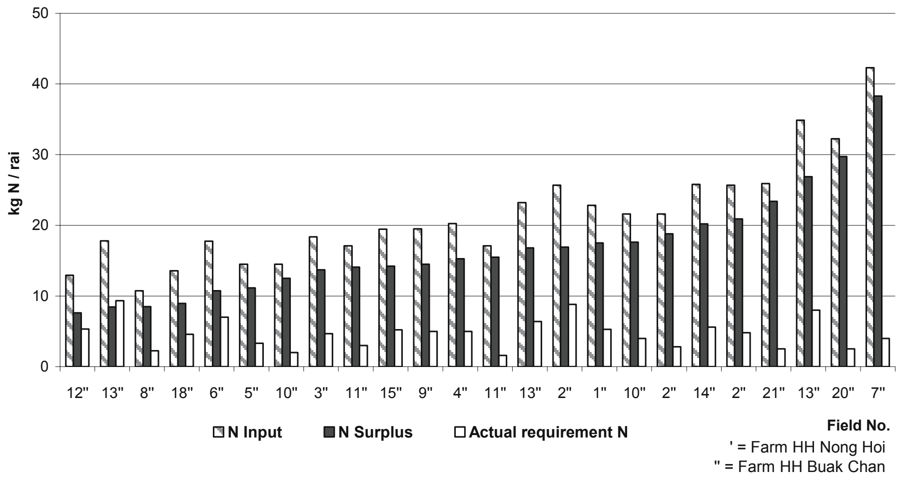

Figure 5.10: Nitrogen balance of carrots (Source: Schönleber 2002, survey data).

The next figure illustrates the values of nitrogen application rates examined within Chinese cabbage production systems. Yields of between 1,100 and 7,000 kg/rai were achieved in one growing season. 0.3 kg N/100 kg is indicated as the N-requirement of

Chinese cabbage. Figure 7 shows that all the differences calculated are in the positive range. An over-supply of nitrogen within the Chinese cabbage production systems is evident. The surplus of nitrogen lies between 9 and 96 kg N/rai.

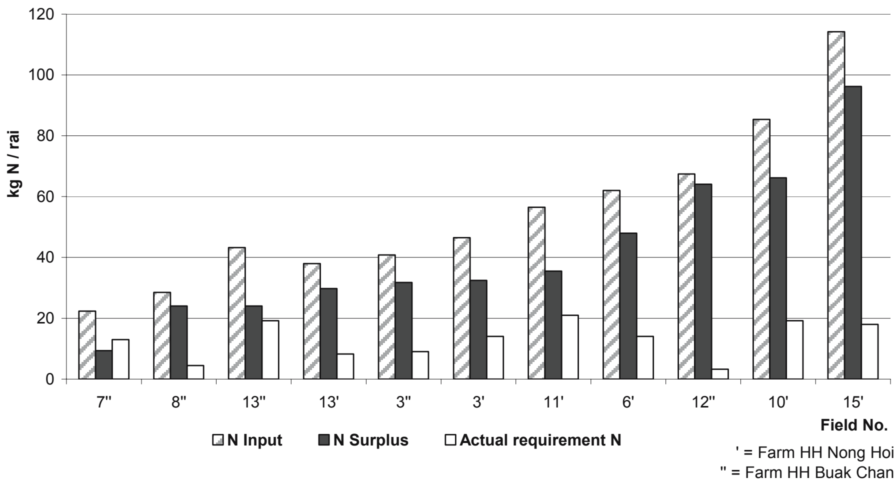

Figure 5.11: Nitrogen balance of Chinese cabbage (Source: Schönleber 2002, survey data).

High application rates as well as regular, partial N-applications are justified under permanent cultivation. The N-balance displayed for gerbera production represents only a very simplified approximation. The exact N-requirement of a single gerbera flower could not be assessed; an amount of 0.001 kg/m² per week was estimated as a reasonable requirement. Thus, the estimated amount is a fixed value referring to a unit of one rai and does not depend on the numbers of flowers harvested. A quantity of 83.2 kg N/rai/year results as the N-requirement.

The number of harvested flowers per year in an area of one rai varies significantly from 24,400 to 161,300. The amounts of pure nitrogen applied in gerbera production fluctuate greatly. Over one year, amounts of pure nitrogen ranging from 47 to 378 kg N/rai were applied to the cultivation systems examined (figure 5.12).

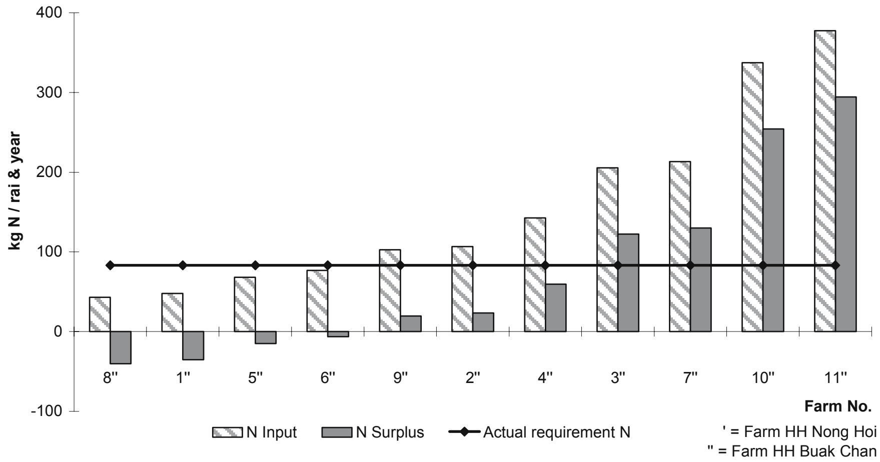

Figure 5.12: Nitrogen balance of gerbera flowers (Source: Schönleber 2002, survey data).

An over-supply of nitrogen was discovered in seven out of eleven gerbera production systems. An under-supply of nitrogen was found on four gerbera plots. The maximum values of nitrogen under and over-supply are –43 kg N/rai and +294 kg N/rai, respectively.

In conclusion, it can be said that the application rate of pure nitrogen is far too high in all of the vegetable production systems considered. Approximately a third of the farming households investigated use nitrogen fertilisers in excessive amounts.

5.3.2.2 Pesticide Application

The influence of hazardous pesticides was investigated based on an assessment of the amount applied on the one hand and by measuring river waters and rainfall on the other.

Table 1 depicts the amount of selected pesticides applied, with a ranking of how hazardous their active ingredient is. Percentages of WHO pesticide classification and E-Values were based on the total amount of active ingredients used in the main cash crop production cultures. The calculated vegetation period is one year for the perennial crops lychee and ornamental flowers, three cropping seasons for vegetables consisting of two crops during the rainy season and one in the dry season under irrigated conditions.

Table 5.4: Pesticide Ingredient Ranking (Source: Riedel 2003, survey data).

Type	Name & Active ingrdients Concentration	WHO	CROP TYPE ACTIVE INGREDIENTS INPUT [KG / YEAR / RAI] AND (%)			
			LYCHEE	FLOWERS	VEGETABLE	GREENH.
INSECTICIDES	Diazion 600g/l*	II	5 (3.8)	63 (11.8)	78 (9.8)	12 (3.5)
	Permethrin 235 g/l*	III	-	12 (2.2)	156 (19.7)	-
	Dimethoate 600g/l	II	9 (6.9)	62 (11.6)	34 (4.3)	56 (16.3)
	Methomyl 480g/l*	Ib	-	45 (8.4)	23 (2.9)	45 (13.2)
	Malathion 600g/kg*	III	8 (6.1)	23 (4.3)	124 (15.7)	38 (11.1)
	Cypermethrin 400g/l*	II	52 (40)	124 (23.2)	89 (11.2)	19 (5.6)
	Deltamethrin 325g/kg	II	12 (9.2)	56 (10.5)	130 (16.4)	68 (19.9)
	Alha-cypermethrin 100 g/l	II	-	58 (10.8)	26 (3.2)	-
	Lambda-cyhalothrin 25g/kg	II	28 (21.5)	89 (16.6)	72 (9.1)	-
	Esfenvalerate 50g/l*	II	4 (3.0)	-	28 (3.5)	25 (7.3)
	Thiobencarb 40g/kg**	II	14 (10.8)	-	29 (3.6)	79 (23.0)
	TOTAL INSECTICIDES		*130 (100)*	*533 (100)*	*789 (100)*	*342 (100)*

Type	Name & Active ingrdients Concentration	WHO	CROP TYPE ACTIVE INGREDIENTS INPUT [KG / YEAR / RAI] AND (%)			
			LYCHEE	FLOWERS	VEGETABLE	GREENH.
HERBICIDES	Glyphosate 360g/l	U	32 (43)	-	67 (26)	115 (26.4)
	Bentazone 870g/kg	III	-	-	84 (32.8)	-
	Ametryn 750g/kg**	III	-	-	72 (28)	34 (7.8)
	Alachlor 600g/l*	III	21 (28)	-	21 (8.2)	13 (3.0)
	Diuron 480 g/l	U	-	-	-	128 (29.4)
	Bromocil 870 g/kg	U	8 (11)	-	12 (4.7)	78 (17.9)
	Thiobencarb 750g/kg**	II	13 (18)	-	-	67 (15.4)
	TOTAL HERBICIDES		*72 (100)*	-	*256 (100)*	*435 (100)*

Type	Name & Active ingrdients Concentration	WHO	CROP TYPE ACTIVE INGREDIENTS INPUT [KG / YEAR / RAI] AND (%)			
			LYCHEE	FLOWERS	VEGETABLE	GREENH.
FUNGICIDES	Cyprodomil 250g/l	II	14 (22)	46 (10.3)	56 (14.4)	15 (4.5)
	Mancozeb 300g/l	U	8 (12.7)	89 (20)	-	59 (17.7)
	Mancozeb 750g/kg	U	17 (27)	43 (9.6)	38 (9.7)	12 (3.6)
	Cyprodinil 250g/l	II	12 (19)	89 (20)	58 (14.9)	36 (10.8)
	Propikanzole 125g/l	II	-	56 (12.6)	69 (17.7)	72 (21.7)
	Methalaxyl 50g/kg	III	5 (7.9)	73 (16.4)	12 (3.0)	90 (27)
	Methalaxyl 200g/kg	III	29 (46)	-	45 (11.5)	48 (14.5)
	Sulfur 800g/kg	U	-	49 (11)	112 (28.7)	-
	TOTAL FUNGICIDES		*63 (100)*	*445 (100)*	*390 (100)*	*332 (100)*

WHO = pesticide influence on health:
Ia extremely hazardous; Ib highly hazardous; II moderately hazardous; III slightly hazardous; U unlikely hazardous in use
Pesticide permission in GERMANY:
* Not permitted anymore; ** never permitted.

In general it can be stated that in the majority of farms and crops, pesticide input is extremely high and far beyond thresholds tolerable for sustainability. This was also verified by chemical analyses of run-offs.

BALLARIN (2004) examined the contamination of surface water through pesticide accumulation on the basis of pesticide measurements in river streams and rainfall within the project area. Eleven pesticides containing notable contaminating ingredients were selected (Chlorpyrifos, Endosulfan, Malathion, Mevinphos, Monocrotophos, Parathion-Methyl, Permethrin, Profenofos, Chlosthalonil, Metalaxyl and Atrazin). In nearly all samples of the base flow, Chlorpyrifos (occurring in 92-100% of the samples), Dicofol (84-92%), Endosulfan isomers α and β (88-96%) and DDT (92-100%) were detected, despite the prohibition of DDT since 1999. Endosulfan exceeded the EU-threshold for pesticides in drinking water (0,1 μgL^{-1}) in all three catchment areas. In particular, Chlorthalonil was found in the catchment area, predominantly used in flower production, and Metalyxyl in the area of vegetable production. The samples of rainfall measured contained the same pesticides in similar concentrations as the adjacent streams. Hence, it can be assumed that Chlorpyrifos, Endosulfan, Dicoful and DDT were present in high *background concentrations* in these regions, while the other pesticides were more likely to contaminate the river streams in the short term and were probably caused by *point sources*.

On occasions of heavy rain, pesticides were predominant in the main peak of river discharge, reflecting a first flush of pesticide run-off from surrounding streets and fields. In addition, there was a high proportion of pesticides bound to particles, exceeding 60% of the total amount during the sampled peak flow events. Mean sum concentrations in the two peak flow events reached 1,72 μgL^{-1} and 2,23 μgL^{-1}, as a sum of particle-bound and dissolved transport, and exceeded the average mean concentrations of the base flow (0,47 μgL^{-1} - 0,6 μgL^{-1}, only dissolved transport) in the catchment areas. The ratio of direct flow to base flow for the particular catchment is therefore particularly important for pesticide transportation.

Due to steep slopes and low forest acreage, the catchment area mainly devoted to vegetable production has the highest contamination ratios. Most pesticides had a short half-life period in the water phase ($\leq$ 5d) and thus might contribute little to downstream contamination. Only Metalaxyl, mostly used in vegetable production, was persistent, with a half-life period of 86 days. Hence, vegetable production systems rather than flower or lychee plantations seem to determine pesticide loads in the ecosystem examined.

5.3.3 Conclusions

In order to ensure lasting income security in farming systems, a diversification of plant production systems seems to be appropriate. A diverse cultivation structure prevents financial losses through diversification of harvest risks and market price fluctuations. Direct local support by national or international organisations is considered favourable for rural development. Farmers in Ban Nong Hoi who are members of the Royal Project have the opportunity to market their products locally; hence, farmers can save substantial costs for transportation and marketing. In addition, farmers can receive production inputs free of interest via a joint contract; they pay for the inputs with the delivery of harvested cash crops.

In order to improve farm management with the aim of sustainability, an increased agricultural extension service is necessary, particularly in economics and marketing. The offer of extension services in plant production methods seems to be relatively weakly defined.

In general, a surplus supply of mineral nitrogen can be found within all crop production systems examined as part of the farming systems investigated. To avoid an over-application of nutrients in the plant production systems, it would be beneficial to educate farmers in ecologically sustainable crop production methods. In particular, the resulting environmental problems as well as their possible solutions should be clearly explained to farmers in detail by the extension system, perhaps with the support of national and international organisations. In future, the development of ecologically and economically sustainable land use systems must be enforced in such a way that the long-term security of yield and income can be ensured within the farming systems.

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5.4 Sustainable Farming Systems Planning Using Goal Programming in Northern Thailand

Suwanna Praneetvatakul and Aer Sirijinda

5.4.1 Introduction and Problem Statement

An increase in highland population, immigration from neighboring countries and the expansion of infrastructure in the northern part of Thailand have resulted in non-sustainable use of natural resources. In many places, forests have been converted to agricultural land. In addition, the fallow period of land use has been shortened. Also, land has been used intensively for agricultural purposes and the use of chemical fertilizer and pesticides has increased tremendously. As a result, degradation of natural resources such as soil erosion as well as the accumulation of pesticides and fertilizer, toxic to water and soils, has occurred, with an adverse impact on human health and living conditions. Moreover, highland farmers' existing agricultural systems have changed in favor of market-oriented systems. Therefore, there is an urgent need to study the conditions of sustainable farming systems in the highland areas of Thailand.

5.4.2 Research Objectives

- To study farming systems in the highland areas of northern Thailand.
- To analyze economic, social and environmental sustainability indicators.
- To conceptualize sustainable farming systems in northern Thailand.

5.4.3 Research Scope

The Mong minority group in Mae Sa Mai village, Chiang mai province has been selected as the research area. The survey data period covers the cropping years 2000/2001 and 2001/2002.

5.4.4 Methodology

The research methodology includes the following data collection and analytical methods:

Data Collection

Primary data are the main source of information for the research. Farm household surveys were conducted in April-May 2001 and again in May 2002. Forty-two households were interviewed and socio-economic and crop production data were collected for 115 farms.

Analytical Methods

Both qualitative and quantitative analysis of the data took place.
– The costs and returns of each farming system are calculated.

The sustainability index and performance values are used to calculate the sustainability indicator. The methods follow those of the Thai Department of Land Development (1998). The indicators are defined as follows:

– Economic indicators are net cash farm income, farm size and net household income.
– Social indicators are types of land ownership, level of education and the degree to iohich farmen employ family labor or labor from within the village.
– Environmental indicators are cropping systems, the impact of chemical pesticides and biodiversity of the farm.

The Sustainability Performance indicators can be calculated using the following formula.

$$\text{Sustainability index} = \frac{\Sigma \text{ Sustainable score}}{\text{Maximum score}} \times 100 \qquad (5.1)$$

Goal programming (GP) is utilized to maximize gross margin and self-sufficiency, and minimize the social and environmental impact of farming in the research area. The objective function of goal programming is a simultaneous optimization of several goals, i.e. the deviations from the desired targets are minimized (ROMERO AND REHMAN, 1989: 31). The minimization process can be achieved by several methods. A weighted goal programming (WGP) model is employed, one of the best known and widely used variants of GP.

$$\text{Minimize } Z = \sum_{i=1}^{m} (di^{-} + di^{+}) \qquad (5.2)$$

Subject to $AX + di^{-} - di^{+} = B$

$X, di^{-}, di^{+} \geq 0$

Where

Z =deviational variables

di^{-} = negative deviational variables

di^{+} = positive deviational variables

X = farming systems production activities

A = coefficient relationship of inputs and outputs

B = constraints

5.4.5 Results

The study yielded characteristic socio-economic household information, agricultural land use and farming systems, costs and returns of crop production, sustainability indicators and a basis for sustainable farm planning.

Socio-Economic Information for Households in the Research Area

All the households interviewed are made up of Mong with a limited education level, living in relatively large families with fruit tree growing as the most important agricultural activity. Many household heads had no formal education (48%). The main occupation of the farmers interviewed is fruit tree planting (66%). Most households had lived in the village for more than two decades (21-40 years, 67%) and the average family size is 9 persons per household with about 3 persons working in agriculture.

Agricultural Land Use and Farming Systems in the Research Area

The average land area is 15.6 rai per household with 1.2 rai for residential use and 14.4 rai of agricultural land. Most farmers own their land but have no formal land title. The land use pattern is commonly permanent cropping; 60.7% with mono-cropping and 27% with multiple cropping. The main source of agricultural water supply is rainfall, that is, the area is largely rainfed. However, traditional irrigation does exist in some areas. The main land type is a slightly sloping (45%) and strongly sloping (40%). The rest is terraced or flat. Cabbage is the main vegetable crop in the area with an average of 2 rai per farmer. Lychee is the main fruit crop in the area with an average of 9 rai per farmer.

Costs and Returns of Crop Production in the Research Area

Four zones are classified according to typical cropping patterns for the analysis of costs and returns in the study area with the following major components.

Zone 1: Pa Ka with 8 cropping systems, including maize, different combinations of vegetables and lychee.

Zone 2: Mae Nai with 6 cropping systems, including potatos, vegetables and lychee.

Zone 3: Pang Ka Mu with 9 cropping systems, namely upland rice, maize, potatoes, vegetables and lychee.

Zone 4: lower village level with 19 cropping systems, including upland rice, upland maize, potatoes, vegetable combinations and lychee.

The individual crops and the detailed results in the four zones are shown in appendix 1. They show that the highest benefits in all zones are achieved in growing vegetables, i.e. in zone 1 from the cropping systems of cabbage-white cabbage, radish and cabbage-radish. Similarly, the most profitable ones in zone 2 are carrot-radish, carrot-garlic leaf, potato and carrot. In zone 3 they are potato, white cabbage-cabbage, white cabbage, cabbage-cabbage and cabbage. Finally, those in zone 4 are carrot-head lettuce, cos lettuce, radish, carrot-carrot, carrot-baby carrot, carrot-garlic leaf, baby carrot-carrot, baby carrot-cos lettuce, cos-lettuce- cos-lettuce-cos-lettuce, potato and lychee.

In sum, the highest gross margin (GM) in zone 1 is cabbage-white cabbage with a GM of 9,236 and 10,275 Bath/rai[2], while in zone 2 carrot-radishes leads with 2 GM of 34,282 and 5,575 Baht/rai. The best in zone 3 is potato with a GM of 40,317 Baht/rai and that in zone 4 is head lettuce with a GM of 44,685 Baht/rai, followed by lychee, which provided a high GM of 34,999 Baht/rai (7 year-old tree).

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2 1 US$ = 39 Baht and 1 ha = 6.25 rai

Sustainability Indicators of Farming Systems in the Research Area

Table 5.5 summarizes the results of calculating the sustainability indicators. The lower the value of an indicator, the larger the difference between actual practice and the most sustainable situation. Among the economic indicators, small farm size is the indicator that points to the most serious impediments to sustainable farming, while among the social indicators, the lowest score is shown for land type and ownership. Among the environmental indicators, high expenditure on chemical pesticides identifies pesticides as the main issue for sustainable land use (Table 5.5).

Table 5.5: Sustainability indicators of Mae Sa Mai village, Chiang Mai province, 2000-2002.

Indicators	Sustainability indicator year 2000/21	Sustainability indicator year 2001/22
Economic indicators		
1. Farm size	57.74	59.46
2. Net household incomes	59.52	64.86
3. Net cash farm incomes	86.31	93.24
Social indicators		
1. Land ownership	49.40	47.30
2. Education	60.71	62.16
3. Family labor	81.55	83.11
Environmental indicators		
1. Chemical pesticide	30.95	40.54
2. Biodiversity	47.62	47.30
3. Cropping systems	89.29	89.19

Among the nine indicators, the environmental indicators represent the most serious issue in the area. It was found that the impact from chemical pesticide use - measured by expenditures on pesticide spraying in farms - leads to the most non-sustainable agricultural practice in the research area. That means the reduction of chemical pesticide use in the area is urgently required and highly recommended for achieving sustainable farming systems in Mae Sa Mai village.

Sustainable Farm Planning

A base model derived by linear programming shows a representative result for farmers' practice and hence is validated for the use of sustainable farm planning. Goal programming was used to obtain a sustainable farm plan that meets the objectives of maximizing the gross margin and safety from chemical pesticide use, while minimizing dependency on labor hired from outside the village. The results, shown in table 5.6, indicate that the following cropping systems would present the best combinations of sustainability indicators: In zone 1 (vegetables, rainfall area in the upper part) farmers would optimize their cropping pattern if they would grow vegetables on 105 rai; in zone 2 (vacant rainfall area in the upper part) farmers should optimally grow vegetables on 35 rai; in zone 3 (fruit trees, irrigated area in the upper part) growing apricots on 210 rai would be optimal; in zone 4 (vegetables, irrigated area in the lower part) farmers should grow persimmon on 100 rai; in zone 5 (fruit trees, irrigated area in the lower part) growing lychee on 294 rai, apricot on 80 rai, persimmon on 392 rai and teak on 1,492 rai is recommendable. With an increase in credit, the optimal farm plan indicates that bamboo and avocado could be introduced into the sustainable plan (Table 5.6).

5.4.6 Conclusion and Recommendations

With the increasing intensification of agriculture in highland areas, which is likely to occur in many areas of northern Thailand, sustainable farm planning is useful. Sustainable farm planning modeling, as carried out in this study, suggests that most vegetable areas should still remain as currently practiced, and that tree crop areas can also be converted to vegetable areas. Most irrigated highland areas should be used for growing fruit trees. For sustainable farming, fruit trees in mono-cropping as is currently the case, should not be continued; the model suggests that diversified fruit tree cultivation, such as lychee, plum, persimmon, avocado, orange, teak and bamboo be introduced as an alternative. Hence, a policy supporting diversification of fruit tree systems would be recommendable for sustainable farming in the Mae Sa Mai village. In addition, lower use of chemical pesticides in highland agricultural systems are recommended. Future research should undertake sustainable farming system planning for other forms of highland agriculture, such as the production practices of the Karen and Lahu. In addition, regional agricultural systems planning for the entire highland area is needed.

Table 5.6: Results of base model and goal programming.

Study area		Base model results (Rai)	Goal programming results (Rai)	Impact of increasing credit (Rai)
Zone 1				
-	Vegetable	105	105	49.85
-	Bamboo			55.15
Zone 2				
-	Vegetable	35	35	35
Zone 3				
-	Lychee	210		57.05
-	Apricot		210	15.82
-	Persimmon			33.95
-	Orange			83.18
Zone 4				
-	Vegetable	100		100
-	Persimmon		100	
Zone 5				
-	Lychee	2,300	293.72	33.76
-	Apricot		80.16	
-	Persimmon		391.72	1,051.23
-	Orange			
-	Teak		1,492.12	1,050.92
-	Avocado			116.78
-	Bamboo			47.31

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Appendix 1 Costs and returns of vegetable and fruit crops in Mae Sa Mai village, 2000/01 crop year

(unit : baht/rai)

Items	Revenue	Variable cash costs	GM	Total costs	Profits
Zone 1: Paka					
Maize (local variety)	1,500.00	157.00	1,343.00	3,283.40	- 1,783.40
Cabbage	4,900.00	2,538.10	2,361.90	5,986.50	- 1,086.50
Radish	10,133.50	404.10	9,729.40	4,362.50	5,771.00
Cabbage (crop 1)	4,000.00	2,012.50	1,987.50	5,465.70	- 1,465.70
Cabbage (crop 2)	4,400.00	2,147.50	2,252.50	5,676.70	- 1,276.70
Cabbage (crop 1)	11,843.70	2,607.90	9,235.80	5,701.30	6,142.40
White cabbage (crop 2)	12,027.30	1,752.70	10,274.60	4,289.50	7,737.80
Cabbage (crop 1)	6,900.00	1,835.50	5,064.50	5,346.70	1,553.30
Head lettuce (crop 2)	792.00	455.50	336.50	2,584.30	- 1,792.30
Cabbage (crop 1)	2,160.00	1,685.80	474.20	4,345.40	- 2,185.40
Radish (crop2)	9,123.40	200.00	8,923.40	2,986.00	6,137.40
4 year-old lychee	-	30.00	30.00	2,824.70	2,824.70
14 year-old lychee	805.00	285.00	520.00	1,563.70	758.70
Zone 2 Mae Nai					
Potato (Spoonta variety)	23,400.00	6,631.60	16,768.40	9,875.70	13,524.30
Cabbage	5,761.80	1,767.80	3,994.00	5,268.50	493.30
Carrot	16,008.50	1,957.80	14,050.70	5,634.40	10,374.10
Carrot (crop1)	26,133.70	1,653.40	24,480.30	5,719.30	20,414.40
Garlic leaf (crop 2)	2,532.70	1,709.90	822.80	6,665.80	- 4,133.10
Carrot (crop1)	35,616.00	1,334.00	34,282.00	4,318.50	31,297.50
Radish (crop 2)	6,440.00	865.00	5,575.00	2,552.10	3,887.90
1 year-old lychee	-	705.70	- 705.70	1,904.20	- 1,904.20
2 year-old lychee	-	378.50	- 378.50	953.30	- 953.30

Appendix 1 (cont.)

Items	Revenue	Variable cash	GM	Total costs	Profits
		128.60	- 128.60	992.90	992.90
4 year-old lychee					
	4,444.00	18.50	4,425.50	1,392.50	3,051.50
5 year-old lychee					
	5,919.00		5,506.00	3,202.80	2,716.20
		413.00			
9 year-old lychee					
	9,706.90	599.50	9,107.40	3,628.90	6,078.00
18 year-old lychee					
	7,137.30	1,377.20	5,760.10	3,547.90	3,589.40
19 year-old lychee					
	585.60	83.20	502.40	2,341.10	- 1,755.50
20 year-old lychee					
Zone 3: Pang Ka Mu					
	868.20	193.40	674.80	2,373.10	- 1,504.90
Upland rice (local variety)					
	833.10	19.00	814.10	2,486.30	- 1,653.20
Maize (local variety)					
	47,910.00	7,593.10	40,316.90	11,192.80	36,717.20
Potato (Spoonta variety)					
	10,340.10	4,066.70	6,273.40	6,431.60	
					3,908.50
Cabbage					
	16,750.00	4,688.00	12,062.00	7,533.50	
					9,216.50
White cabbage					
	6,800.00	4,391.60	2,408.40	8,568.50	- 1,768.50
Potato (crop 1)					
	4,200.00	1,275.00	2,925.00	5,412.50	- 1,212.50
Cabbage (crop 2)					
	11,500.00	2,338.40	9,161.60	5,390.60	
					6,109.40
Cabbage (crop 1)					
	4,000.00	2,338.40	1,661.60	5,390.60	- 1,390.60
Cabbage (crop 2)					
	15,993.80	5,395.30	10,598.50	8,242.90	7,750.90
White cabbage (crop 1)					
	7,394.30	2,626.40	4,767.90	4,535.90	2,858.40
Cabbage (crop 2)					
		325.00	- 325.00	4,429.00	- 4,429.00
	-				
1 year-old lychee					
		100.00	- 100.00	4,117.20	- 4,117.20
	-				
2 year-old lychee					
		130.00	- 130.00	1,655.10	- 1,655.10
	-				
5 year-old lychee					
	1,669.50	99.00	1,570.50	4,656.20	- 2,986.70
8 year-old lychee					
Zone 4: Lower level of village					
	2,497.40	729.20	1,768.20	3,355.30	857.90
Upland rice (local variety)					
	14,371.20	3,404.00	10,967.20	7,675.90	6,695.30
Potato (Spoonta variety)					

Appendix 1 (cont.)

Items	Revenue	Variable cash costs	GM	Total costs	Profits
White cabbage	11,790.00	2,820.00	8,970.00	7,536.90	4,253.10
Carrot	12,490.50	3,144.90	9,345.60	8,321.90	4,168.60
Head lettuce	46,928.00	2,242.60	44,685.40	8,273.80	38,654.20
Cos lettuce	12,135.50	2,099.10	10,036.40	5,568.90	6,566.60
Radish	7,466.50	866.60	6,599.90	4,667.00	2,799.50
Garlic leaf	10,000.00	4,473.00	5,527.00	9,267.90	732.10
Upland rice (crop 1)	3,490.00	3,223.50	266.50	4,787.30	-1,297.30
Potato (crop 2)	38,940.00	6,899.10	32,040.90	8,623.50	30,316.50
Potato (crop 1)	9,720.60	2,203.00	7,517.60	7,560.40	2,160.20
Maize (crop 2)	1,380.40	15.00	1,365.40	2,363.90	-983.50
White cabbage (crop 1)	7,600.00	2,189.90	5,410.10	6,008.90	1,591.10
Carrot (crop 2)	7,600.00	3,303.40	4,296.60	6,543.80	1,056.20
Carrot (crop 1)	11,700.00	1,570.00	10,130.00	5,646.30	6,053.70
Carrot (crop 2)	4,950.00	1,055.00	3,895.00	5,493.90	-543.90
Carrot (crop 1)	9,192.00	3,005.70	6,186.30	6,381.20	2,810.80
White cabbage (crop 2)	4,933.40	2,092.70	2,840.70	5,512.80	-579.40
Carrot (crop 1)	29,600.00	4,428.00	25,172.00	7,212.10	22,387.90
Baby carrot (crop 2)	17,400.00	4,357.00	13,043.00	8,012.00	9,388.00
Carrot (crop 1)	5,800.00	2,020.00	3,780.00	6,989.60	-1,189.60
Garlic leaf (crop 2)	29,400.00	2,650.00	26,750.00	6,432.50	22,967.50
Baby carrot (crop 1)	14,390.00	4,357.00	10,033.00	7,787.00	6,603.00
Carrot (crop 2)	19,200.00	4,742.00	14,458.00	8,453.60	10,746.40
Baby carrot (crop 1)	40,737.60	3,395.60	37,342.00	7,496.20	33,241.40
Cos lettuce (crop 2)	4,404.00	1,843.40	2,560.60	5,573.40	-1,169.40
Cos lettuce (crop 1)	18,107.30	3,047.90	15,059.40	7,760.50	10,346.80

Appendix 1 (cont.)

Items	Revenue	Variable cash costs	GM	Total costs	Profits
Cos lettuce (crop 2)	18,170.30	3,005.00	15,165.30	8,023.30	10,147.00
Cos lettuce (crop 3)	11,191.80	3,005.00	8,186.80	8,023.40	3,168.40
1 year-old lychee	-	8.80	-8.80	3,559.40	-3,559.40
2 year-old lychee	-	29.70	-29.70	2,421.90	-2,421.90
3 year-old lychee	-	-	-	1,099.00	-1,099.00
4 year-old lychee	-	1,013.30	-1,013.30	3,184.70	-3,184.70
6 year-old lychee	11,452.70	706.20	10,746.50	3,583.90	7,868.80
7 year-old lychee	36,842.60	1,843.70	34,998.90	7,451.00	29,391.60
9 year-old lychee	14,013.80	1,277.60	12,736.20	5,211.90	8,801.90
11 year-old lychee	13,521.60	3,844.90	9,676.70	8,085.70	5,435.90
14 year-old lychee	32,652.30	1,697.70	30,954.60	8,110.60	24,541.70
19 year-old lychee	14,968.20	2,324.30	12,643.90	7,352.00	7,616.20

Note: GM = Revenue - Variable cash costs
Profits = Revenue - Total costs
Source: Center for applied economic research, 2003.

5.5 Fresh Longan Marketing and Reference Market: A Case of Longan Grown in Northern Thailand

Somporn Isvilanonda

5.5.1 Introduction

Longan plays an important role in developing sustainable production systems for the mountainous regions of Southeast Asia. It is a fruit grown at higher altitudes, mostly inhabited by poor farmers and ethnic minorities. In Thailand, 95% of an overall production area of 98 thousand ha is concentrated in the north, yielding approximately 212 thousand tons of longan in 2003. Despite its importance as the income source of northern growers, however, a short harvesting season and its highly perishable nature create a large, concentrated flow of supply to the market, depressing farm prices and farmers' income. Despite existing market links between production areas and consumers throughout the country, the influence of the central wholesale market in Bangkok plays a major role in dominating the wholesale markets in production areas. This paper sets out to examine the integration between wholesale markets in Bangkok and Chiang Mai. Focusing on price differences and variations, a daily recorded price of E-door variety, grade Jumbo longan in both markets between 16th July and 31st August 2002 was employed in this study. Following the introduction, the second section briefly reviews the marketing flow of longan grown in the north. The third section discusses price fluctuations in the two markets and marketing margins. The fourth section demonstrates the econometric results of market integration tests and the last section presents the conclusions.

5.5.2 Marketing Flow of Longan Grown in the North

Fresh longan grown in the north is supplied to both domestic and export markets. It is also supplied in fresh and processed forms.

OAE (1997) reported that fresh longan exports account for around 30% of the total supply. The major importing countries of Thai fresh longan are Hong Kong, Malaysia, and Indonesia. Domestic demand for fresh longan consumption represents around 33% of total production. The rest represents the demand for processed longan, particularly dry, canned and frozen.

Since longan growers are small farmers, they have relatively less bargaining power in selling their fruit. ISVILANONDA et al. (2002) found that few growers sell their fruit directly to either retailers or consumers. The majority of them channel their produce to either local or district assemblers. Farmers normally sell by weight in either mixed or separated grades. Sale by plot took place in the past, but has become less common in recent years. Contractual selling during flowering still occurs, particularly in remote areas where transportation is difficult. Except for sales by weight, where harvesting costs are deducted from the buying price, the assembler carries the harvesting costs.

Local assemblers mostly live in the village. They sometimes act as an agent for district assemblers. Having lived in the village for a long time, the local assemblers can monitor longan supply information from villagers or growers in the production area. They also negotiate with growers on their decision to sell. Since most local assemblers have a market network with district assemblers, they often check daily demand from the assemblers and arrange with them for delivering the supply. Some local assemblers may act as an agent for procuring supplies for processors or exporters. Many local assemblers receive credit from the district assemblers for collecting and procuring the fruit supply.

In practice, district assemblers collect the longan supply from local assemblers and their agents. Given their better market price information from upstream and downstream market links, the district assemblers arrange for collection of the supply with their agents by informing them of the daily buying price. They sometimes agree to support agents by paying transportation costs per kg of the amount supplied.

Re-grading is sometimes performed again at the district assembly market, particularly for those who are exporters or exporters' agents. At the market, four grades of fresh longan are commonly found; AA, A, B and C, which correspond to jumbo, large, medium, and small respectively. After re-grading and/or packing the fresh longan in a plastic basket with a net weight of 20 kg per basket, it is distributed to wholesale and retail markets. Nonetheless, some assemblers also channel fresh longan to processing plants, which are mostly located in the region.

The Bangkok wholesalers mostly have a marketing network with district assemblers in production areas. In recent years, a consignment contract between district assemblers and some wholesalers in final distribution centers, particularly at Talard Thai, Talard See Mum Muang and Paklong Talard - all located in Bangkok - was observed. Due to the contract, the wholesale price at the central market is quoted by the district assemblers when the fruit is sent out to the Bangkok markets. Bangkok wholesalers are responsible for selling the forwarded supply. In exchange, they receive a selling fee of 5 to 7% of the gross value from the assemblers. The transportation costs from origin to final market and the loading costs are paid by the assemblers.

The minimum selling unit at the central market is 20 kg (or one basket net weight). Retail buyers need to bring a fruit container with them or pay a deposit for the basket if they want to take it away with them. Depending on the specific grade, the wholesale price at the central wholesale market varies according to the price set by the original market, including supply and demand in the market as well as market conditions for fruit on that day. The marketing channel of fresh longan from farmers to consumers is shown in figure 5.13.

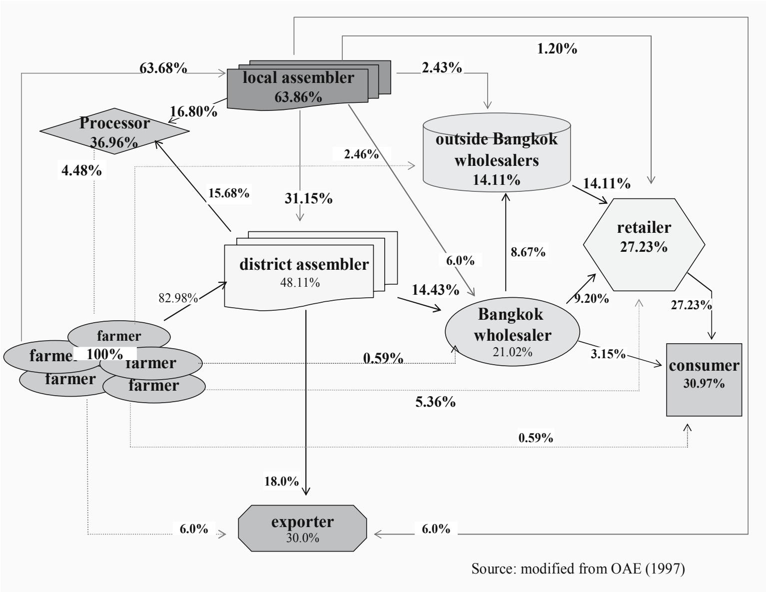

Figure 5.13: Marketing channel of fresh longan.

5.5.3 Daily Price Fluctuations at the Assembly and Central Wholesale Markets and the Marketing Margin

Given a particular market, the market force of supply and demand determines market price. A differential market price at different market levels reflects a marketing margin which is a combination of marketing cost and entrepreneur profit. In order to observe price fluctuation at the district assembly market and at the central wholesale market, the average daily recorded price of 4 large assemblers at the market of origin in Chiang Mai and that of 4 wholesalers at the final market in Bangkok was used as a case study. The recorded period was from 16th July to 31st August 2002 (see table 1 in the appendix). The jumbo grade of the E-dore variety was chosen for this study because it is a common variety found in the market. Furthermore, the length of output supply for this variety is longer than others. In addition, the jumbo grade is rather a unique fruit size per kg compared to others.

Figure 5.14 demonstrates daily price fluctuation between the two markets. The peak supply of the E-dore variety is around the fourth week of July, reflecting a small marketing margin at this time. However, the price gap between the two markets is wider when the supply falls at the end of the season. By taking the average price of each price set, the price at the market of origin is 33.54 Baht per kg, and that in the final market is 37.75 Baht per kg. Judging from the difference between the two average prices, the average marketing margin is around 4.21 Baht per kg. The margin represents around 11.2% of the price at the final market. ISVILANONDA et al. (2002) found that the marketing cost of fresh longan between the original and final markets is around 2.5 Baht per kg. Of this amount, the cost of transportation is around 70.5%. Given this marketing cost, the average profit obtained by wholesalers at the final market is 1.71 Baht per kg.

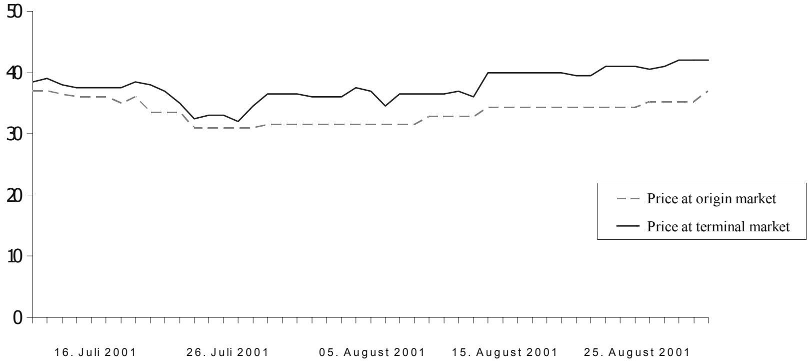

Figure 5.14: Wholesale fresh longan price fluctuation between the assembly market in Chiang Mai and the central market in Bangkok.

5.5.4 A Test of the Two Markets' Integration

An analysis of spatial market integration as an agricultural commodity was initially introduced by RAVALLION (1986) and later improved by ALEXANDER and WYETH (1994). They provide a mechanism to test a basic model for a long-term relationship between prices at different markets. That is, for a long-term relationship between two prices P and R (equation 5.3), long-term integration requires that in equation 1 the β equals 1 and α is a constant that can take any value. A test result would then reflect a constant marketing margin at the two different markets.

$$P = \alpha + \beta R \tag{5.3}$$

where P represents the price at central market and R represents the price at regional market and α and β are coefficients. However, it is not necessary that P be a dependent variable in the model, but it can be an independent variable if the regional price is strong enough to dominate the Bangkok price. From a static form of equation (5.3), we can further extend the model to cover a dynamic analysis of time series price, as in equations (5.4) and (5.5).

$$P_t = a_1P_{t-1} + .. + a_jP_{t-n} + b_0R_t + b_1R_{t-1} + .. + bjR_{t-j} + a_0 + e_1 \tag{5.4}$$

$$R_t = c_1R_{t-1} + .. + c_nR_{t-n} + d_oP_t + d_1P_{t-1} + .. + d_nP_{t-n} + c_0 + e_2 \tag{5.5}$$

ALEXANDER and WYETH (1994) suggested that equations (5.4) and (5.5) can be rewritten using the error correction mechanism of the reduced form equation as equations (5.6) and (5.7).

$$\Delta P_t = \theta_{11}\Delta P_{t-1} + .. + \theta_{1n}\Delta P_{t-n} + \theta_{21}\Delta R_{t-1} + .. + \theta_{2n}\Delta R_{t-n} + \beta_1 P_{t-1} + \beta_2 R_{t-1} + \varepsilon_{1t} \tag{5.6}$$

$$\Delta R_t = \theta_{31}\Delta P_{t-1} + .. + \theta_{3n}\Delta P_{t-n} + \theta_{41}\Delta R_{t-1} + .. + \theta_{4n}\Delta R_{t-n} + \beta_3 P_{t-1} + \beta_4 R_{t-1} + \varepsilon_{2t} \tag{5.7}$$

That is, a test for long-term co-integration is a test of the hypothesis as to whether (5.8) equals zero or whether (5.9) equals zero. Rejecting the null hypothesis as shown in equation (5.8) implies causality from R to P. Similarly, rejecting the null hypothesis of equation (7) indicates causality from P to R, where P is a central market price and R is a regional wholesale price. In the model θ and β are the coefficients.

$$\theta_{21} = \ldots = \theta_{2n} = \beta_2 = 0 \quad (5.8)$$

$$\theta_{31} = \ldots = \theta_{3n} = \beta_3 = 0 \quad (5.9)$$

However, before estimating equations (5.6) and (5.7), each individual price set is required to check an order of integration for a stationary price series by using the ADF-test. The result of an ADF-test for the order of integration of each price set is provided in table 1. The test shows that both Chiang Mai and Bangkok price sets have integration of order two. This information is further used in specifying the degree of variable lag in equations (5.6) and (5.7) for estimation.

Table 5.7: Result of Augmented Dickey Fuller (ADF) test for order of integration of each price set.

Items(1)	I(1)vI(0)(2)	I(2)vI(1)(3)	I(3)vI(2)(4)
Price at assembly market in Chiang Mai	-1.20^{NS}	-3.22^{**}	-4.16^{***}
Price at central market in Bangkok	-2.26^{NS}	-2.17^{NS}	-3.71^{***}
Critical value of ADF-statistic	-2.58	-2.88	-3.48
Level of significance	10%	5%	1%

Note: I(1)vI(0) represents a test for the hypothesis that $H_0 : \Delta y_t \sim I(1)$ and $H_1 : \Delta y_t \sim I(0)$
I(2)vI(1) represents a test hypothesis that $H_0 : \Delta y_t \sim I(2)$ and $H_1 : \Delta y_t \sim I(1)$
I(3)vI(2) represents a test hypothesis that $H_0 : \Delta y_t \sim I(3)$ and $H_1 : \Delta y_t \sim I(2)$
Where y stands for price. ^{NS} indicates no statistical significant;
** indicates significant level at 5% and *** indicates significant level at 1%.

A causality test is summarized in table 5.7. The result indicates that the price relationship between the Chiang Mai market and the Bangkok market is a one-way response, judging from the statistical significance of the F-causality test as summarized in column (1) in table 5.7 and its statistical insignificance in column (2) of the same table. That is, the assembly market in Chiang Mai has a stronger power than the wholesaler in Bangkok to dominate wholesale prices. That is, the assembly market in Chiang Mai could considerably be a reference market for fresh longan.

Table 5.8: Causality and exogeniety test result for the co-integration of the two price sets

Items	To (dependent market)	
From (independent market)	Bangkok (1)	Chiang Mai (2)
Bangkok		X^{NS}
Chiang Mai	√**	

Note: X indicates no influence on price; √ indicates influence on price
^{NS} means no statistical significance; * * means significant level at 1%
Source: Summarized from statistical analysis as shown in tables 5.7 and 5.8 of the appendix.

5.5.5 Conclusion

Longan is a horticultural fruit crop which is mostly grown in the north. The production of longan is not only for domestic consumption but also for export. About one-third of fresh longan is supplied for domestic consumption. Among the middlemen in the marketing flow, district assemblers in production areas play a dominant role as distributors not only to wholesale markets in Bangkok, but also to exporters and processors. Between the assembly market in Chiang Mai and the central wholesale market in Bangkok, a close relationship was found between these two price sets. There exists a co-integration between the two markets. Nonetheless, the assembly market in Chiang Mai is a reference market for fresh longan. The study suggests that a policy for improving the longan market structure at the assembly level would enhance prices at farm level as the assembly market in the north exhibits a strong longan demand not only for fresh consumption and processing, but also for exports whereas the central market in Bangkok has only the demand for fresh consumption.

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Appendix table 1: Wholesale prices of E-dore variety (Jumbo grade) at the assembly market in Chiang Mai and at central market in Bangkok.

Date	Average Bangkok price	Average Chiang Mai price	Date	Average Bangkok price	Average Chiang Mai price
16 Jul. 01	38.5	37.0	09 Aug.01	34.50	31.50
17 Jul. 01	39.0	37.0	10 Aug.01	36.50	31.50
18 Jul. 01	38.0	36.5	11 Aug.01	36.50	31.50
19 Jul. 01	37.5	36.0	12 Aug.01	36.50	32.75
20 Jul. 01	37.5	36.0	13 Aug.01	36.50	32.75
21 Jul. 01	37.5	36.0	14 Aug.01	37.00	32.75
22 Jul. 01	37.5	35.0	15 Aug.01	36.00	32.75
23 Jul. 01	38.5	36.0	16 Aug.01	40.00	34.25
24 Jul. 01	38.0	33.5	17 Aug.01	40.00	34.25
25 Jul. 01	37.0	33.5	18 Aug.01	40.00	34.25
26 Jul. 01	35.0	33.5	19 Aug.01	40.00	34.25
27 Jul. 01	32.5	31.0	20 Aug.01	40.00	34.25
28 Jul. 01	33.0	31.0	21 Aug.01	40.00	34.25
29 Jul. 01	33.0	31.0	22 Aug.01	39.50	34.25
30 Jul. 01	32.0	31.0	23 Aug.01	39.50	34.25
31 Jul. 01	34.5	31.0	24 Aug.01	41.00	34.25
01 Aug.01	36.5	31.5	25 Aug.01	41.00	34.25
02 Aug.01	36.5	31.5	26 Aug.01	41.00	34.25
03 Aug.01	36.5	31.5	27 Aug.01	40.50	35.25
04 Aug.01	36.0	31.5	28 Aug.01	41.00	35.25
05 Aug.01	36.0	31.5	29 Aug.01	42.00	35.25
06 Aug.01	36.0	31.5	30 Aug.01	42.00	35.25
07 Aug.01	37.5	31.5	31 Aug.01	42.00	37.00
08 Aug.01	37.0	31.5	Average	37.75	33.54

Source: Own daily records kept from 14th July to 31st August, 2001.

Appendix table 2: Estimation results and statistical values (with the wholesale price at Chiang Mai as a dependent variable).

Items	Price at assembly market in Chiang Mai
Constant	3.51(90.94)
ΔR_{t-1}	0.04(0.29)
ΔR_{t-2}	0.09(0.66)
ΔP_{t-1}	-0.01(-0.09)
ΔP_{t-2}	-0.06(-0.47)
R_{t-1}	-1.01(-15.10)
P_{t-1}	-0.01(-0.18)
Adjusted R^2	0.99
F-ratio	1,350.15***
F causality	0.09^{NS}

Source: own estimation.
Note: In this table, P is the wholesale price at the central market in Bangkok and R is the price at the assembly market in Chiang Mai.

Appendix table 3: Estimated results and statistical values (with the wholesale price at the central fruit market in Bangkok as a dependent variable).

Items	Price at central wholesale market in Bangkok
constant	3.57(66.19)
ΔP_{t-1}	-0.11(-0.60)
ΔP_{t-2}	-0.42(-2.31)
ΔR_{t-1}	0.12(0.63)
ΔR_{t-2}	0.44(2.37)
P_{t-1}	-0.17(-1.94)
R_{t-1}	-0.86(-9.16)
Adjusted R^2	0.99
F-ratio	713.80***
F causality	28.56***

Source: own estimation.
Note: In this table, P is the wholesale price at the central market and R is the wholesale price at the assembly market in Chiang Mai.

5.6 Interregional Trade Flows and Market Stability

Angela Hau and Matthias von Oppen

5.6.1 Introduction

Stable markets and reliable marketing channels are essential preconditions for farmers, particularly in remote rural areas, to ensure sustainable farm incomes and livelihoods.

5.6.1.1 Trade and Sustainability

The importance of trade and particularly that of agricultural commodities for the development process in developing countries has long been recognized. In recent years, researchers and policy makers have been discussing the sustainability of increasing global trade (ALEXANDRATOS, 1995). This discussion can be divided into two main categories; one revolves around the sustainability of economic development and the other concerns the impact of continuous trade liberalization on the environment (DIXON, 2004). This paper will concentrate on the sustainability of economic development, taking the mango market in Thailand as an example. Here, the effects of price changes - caused for example by climate shocks such as El Niño - on welfare generation are analyzed (NATIONAL DROUGHT MITIGATION CENTER, 2003 and FAO, 2004). As Pascal Lamy stated in his speech at the Rio +10 conference in 2001; "The pattern of economic development should be maintained in the short and medium term and sustained for future generations". Farmers in Thailand need secure incomes from agriculture to pursue agricultural sustainability.

5.6.1.2 Objectives and Hypothesis

In well-functioning market systems, prices at the different market levels are directly related to each other (TAMIMI, 1999). Thus, the first objective of this paper is to analyze the efficiency of the mango market in Thailand. To this end, it is hypothesized that the mango market is efficient and that there is a relationship between export (FOB[3]) and domestic prices in Thailand. Despite technological advances in horticulture, the mango market is characterized by seasonal supply and fluctuations in supply from year to year. Thus, the mango market is price volatile both during the season and over the years. Therefore, the second objective of this paper is to analyze how price changes affect the world mango market with respect to trade flows and welfare generation. Price changes correlate with shifts in production caused for example by climate changes, such as the effects of El Niño in 1997/98, which led to a reduction in production and a price increase in Southeast Asia. It is hypothesized that such an upward shift in the supply curve will lead to a total loss in net welfare, particularly in Thailand and other Asian countries. In summary, this paper aims to determine the impact of market instabilities on Thai farmers and on the welfare Thailand generates from the mango trade.

5.6.2 The Efficiency of the Thai Mango Market

5.6.2.1 Correlation of Mango Markets in Northern Thailand

The Thai market for fruit is totally free and privatized. In general, there are a few wholesale markets accompanied by other wholesale centers in the different regions of Thailand, and many retail markets. In northern Thailand, Muang Mai Market in Chiang Mai city is the largest and most important wholesale market of the region. Daily mango prices, based on the year 2001/02, were collected from this market as well as from two retail markets, namely Sompet and Ton Payom within Chiang Mai City, and from a retail market in the neighboring province Lamphun. Mangoes are priced according to variety and grade. The prices of the Nam Dok Mai variety and the highest grade were used for all analysis

3 In this study, the export prices are based on the FOB (free on board) Bangkok price.

presented in this paper. Correlation coefficients were calculated according to Pearson (GUJARATI, 1995):

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left[n\sum x^2 - \left(\sum x\right)^2\right]\left[n\sum y^2 - \left(\sum y\right)^2\right]}} \tag{5.10}$$

As can be seen in table 5.9, the correlation coefficients range from 0.866 to 0.524. All coefficients are significant at the 0.01 level.

Table 5.9: Correlation between markets in northern Thailand based on daily prices in 2001/2002.

	Muang Mai Wholesale	Sompet Retail	Ton Payom Retail	Lamphun Retail
Muang Mai Wholesale	1.000	0.866**	0.663**	0.809**
Sompet Retail		1.000	0.602**	0.637**
Ton Payom Retail			1.000	0.638**
Lamphun Retail				1.000

** Correlation is significant at the 0.01 level (2-tailed).

Source: Own Calculation, 2004.

The most commonly used guidelines for the interpretation of correlation coefficients are that of COHEN (1983) and GUILFORD (1973) (table 5.10). According to Cohen, the markets in Chiang Mai have a strong to very high correlation with each other and according to Guilford a moderate to high correlation.

Table 5.10: Interpretation of correlation coefficients according to Cohen and Guilford.

Degree of Correlation	Cohen	Guilford
Very low correlation Almost negligible relationship	≤ 0.20	≤ 0.20
Low correlation Definite but small relationship	0.20 – 0.40	0.20 – 0.40
Moderate correlation Substantial relationship	0.40 – 0.60	0.40 – 0.70
High correlation Marked relationship	0.60 – 0.80	0.70 – 0.90
Very high correlation Very dependable relationship	≥ 0.80 or more	0.90 –1.00

Source: based on COHEN, 1983 and GUILFORD, 1973).

Furthermore, the high correlation of between the retail markets andto Muang Mai Market identifies Muang Mai Market as the lead market. As Muang Mai is the lead market, the question arises if as to whether the prices of the retail market prices are lagged. However, the results in Table 5.11 show no evidence of a lag between wholesale and retail prices, as the coefficients diminish with increasing lags. Thus, retail markets react on the same day to price changes at the wholesale market Muang Mai. This result is realisticin line with reality, as retailers reported that they buy products from Muang Mai market on a daily basis.

Table 5.11: Analysis of time lags of retail market prices.

Time lags	Sompet	Ton Payom	Lamphun
Daily base data	0.866**	0.663**	0.809**
1 day lag	0.823**	0.524**	0.779**
2 day lag	0.834**	0.548**	0.788**
3 day lag	0.798**	0.502**	0.767**
4 day lag	0.762**	0.523**	0.740**
5 day lag	0.755**	0.503**	0.708**
6 day lag	0.709**	0.523**	0.693**
7 day lag	0.721**	0.572**	0.692**

** Correlation is significant at the 0.01 level (2-tailed).

Source: Own calculation, 2004.

5.6.2.2 Correlation between Markets in Northern Thailand and Bangkok

As a next step, the correlation was tested between the four markets in Chiang Mai and the wholesale market Talaad Thai in Bangkok. Daily prices from this market on every third to fourth day per week in the year 2002 are used. Apart from the normal categorization of mangoes by variety and grade, prices for three different levels of fruit ripeness - old, ripe and young - are included in the data set.

Table 5.12: Correlation between Talaad Thai Market in Bangkok and markets in northern Thailand.

	Talaad Thai old	Talaad Thai ripe	Talaad Thai young
Sompet	0.200	0.634**	0.630**
Ton Payom	0.255	0.497*	0.678**
Lamphun	0.476	0.812**	0.927**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Source: Own calculation, 2004

In table 5.12, the Chiang Mai markets clearly correlate most strongly with the "young mangoes" at Talaad Thai market in Bangkok. This result is realistic, as yellow mango varieties are traded slightly unripe, particularly at the wholesale level, due to harvesting practices and the fact that unripe mangoes are less perishable in transport than ripe mangoes. This data set was also tested for a lag between the prices in Bangkok and Chiang Mai, but no lag was detected, implying an immediate price reaction between Bangkok and Chiang Mai.

5.6.2.3 Correlation between Farm-Gate, Domestic Market and FOB Prices

As farm-gate prices and FOB prices are only available on a monthly basis, a separate analysis was run to test the relationship between farm-gate, retail, wholesale and FOB prices. The retail markets Sompet and Ton Payom and the wholesale market Talaad Thai show a significant, marked relationship to FOB prices. The retail market Lamphun and the wholesale market Muang Mai show a moderate correlation to FOB prices without significance. However, there is no direct relationship between farm-gate prices and FOB prices. All retail and wholesale markets in Thailand have a substantial relationship (Table 5.13) to farm-gate prices, albeit not significant. Even though the coefficients lack significance, the high coefficients can be interpreted as a strong indication of correlation between farm-gate prices and retail and wholesale markets. The lack in significance can be explained by possible lags between farm-gate, retail, wholesale and FOB prices, which could not be tested here due to the limitations of the data. Nevertheless, the results indicate that prices at various market levels correlate with each other and that there is a correlation between FOB prices and domestic Thai prices.

Table 5.13: Correlation between mango prices in Thailand and FOB prices:

	Farm-gate Price	Lamphun Retail	Sompet Retail	Ton Payom Retail	Muang Mai Wholesale	Talaad Thai Young	FOB Price
Farm-gate Price	1.000	0.886	0.751	0.789	0.797	0.822	-0.018
Lamphun Retail		1.000	0.790	0.875	0.913**	0.978**	0.512
Sompet Retail			1.000	0.987*	0.771*	0.795	0.809*
Ton Payom Retail				1.000	0.969**	0.945	0.970**
Muang Mai Wholesale					1.000	0.936*	0.518
Talaad Thai Young						1.000	0.893*
FOB Price							1.000

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

5.6.3 Simulation of the Effect of Price Fluctuations on Interregional Trade

A correlation between the different market hierarchies was determined in section 2, indicating that the Thai mango market is efficient. In this section, the effects of price fluctuations on welfare are examined.

5.6.3.1 Price Volatility

Although nowadays mangoes can be produced all year round, the main production season is from around the end of February to the end of July, during which the supply shifts regionally due to different climatic zones. Figure 5.15 shows average prices for the highest grade of Nam Dok Mai mangoes in Thailand. At the beginning of the season, mango market prices are high, decrease during the peak of production and pick up again at the end of the season. However, towards the end of the season, mango prices are curbed by the market entry of other fruits between April and June.

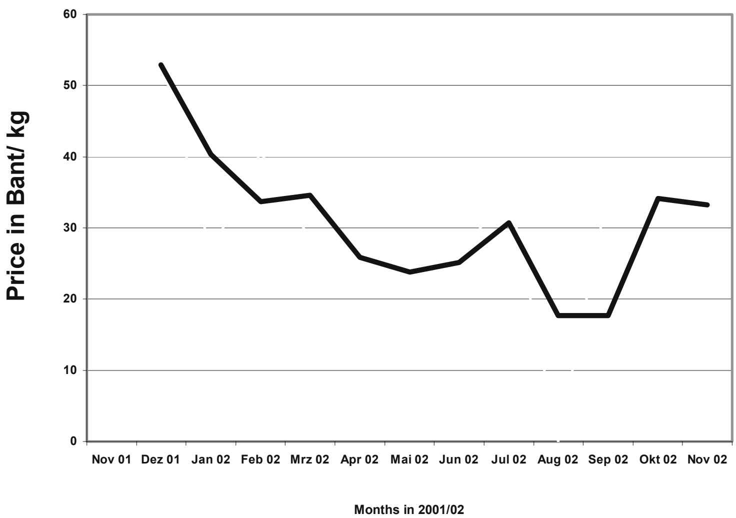

Figure 5.15: Overview of average Thai mango prices in 2001/2002
Source: Own calculation, 2004.

The course of this curve in figure 1 is similar from year to year, but the mango season can shift over time by as much as six weeks. In addition, the price increased sharply in the year 1998 as shown in figure 5.16. Farmers are exposed to these seasonal and annual price fluctuations and have little opportunity to react due to the short shelf life of mangoes and the fact that they are perennial crops.

In 1997/98, Thailand and most other parts of Southeast Asia experienced a drought caused by El Niño which led to a 20% decrease in mango production, resulting in an upward shift of the supply function. As can be seen in figure 5.16, price movements are driven by production. In other words, if the production increases, the price decreases and vice versa. Here, the effects of a 20% decrease in production on producer supply and the net welfare of Thailand are analyzed using an interregional trade model.

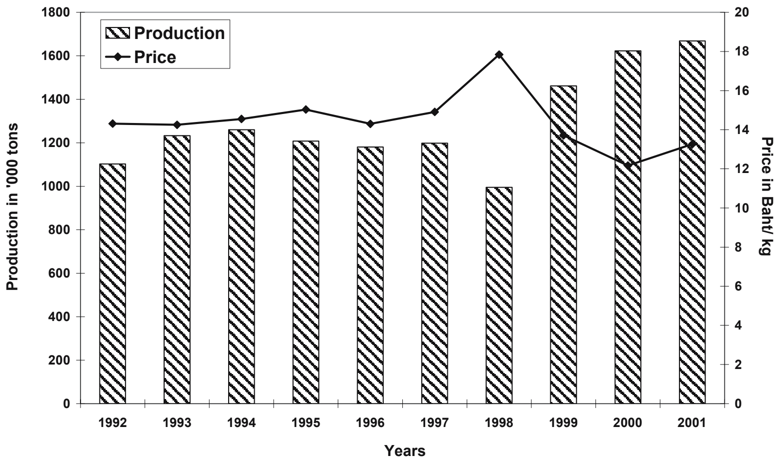

Figure 5.16: Thai mango production and average annual prices source: Office of Agricultural Economics, Ministry of Agriculture, Bangkok, Thailand, 2002.

5.6.3.2 Specification of the Interregional Trade Model

A non-linear, spatial equilibrium model is used to measure the impact of trade and marketing variables on welfare distribution (VON OPPEN and SCOTT, 1976). According to SAMUELSON (1952), the net welfare function of this model is defined as the integral of the function of demand $D_j(x_j)dy_j$ minus the integral of the function of supply $S_i(x_i)dx_i$, minus transportation costs $T_{ij}X_{ij}$; i representing the regions of supply and j the regions of demand.

$$\text{NW(y,x,X)} = \int_0^y D_j(x_j)dy_j - \int_0^x S_i(x_i)dx_i - T_{ij}X_{ij} \quad (5.11)$$

In this model, infinitely small quantities of demand are associated with infinite prices, therefore a lower boundary of demand at 0.05 percent of reference quantity must be set in order to run the model. The interregional trade model for mango consists of eight regions, namely North America, Latin America, Europe, Africa, Arabia (including Israel), as well as three Asian regions. The last distinguish between mango-producing countries in Asia (India, Pakistan, the Philippines, China, Sri Lanka, Indonesia, Vietnam, Malaysia, Laos, Cambodia, Bangladesh and Australia), non-mango producing countries in Asia (Japan, Hong Kong, Macao, Singapore and the Republic of Korea), and Thailand. The elasticities used are based on estimations made by ISLAM (1990) in table 5.14.

Table 5.14: Price elasticities of supply and demand.

Regions	Supply	Demand
Africa	0.58	-0.71
Arabia	0.48	-1.04
Mango- Producing Asia	0.58	-0.71
Thailand	0.58	-0.71
Non-Mango Producing Asia	0.48	-1.04
North America	0.48	-1.04
Latin America	0.58	-0.71
Europe	0.48	-1.04

Source: based on Islam, 1990.

To simplify the model, the demand, supply and production of each region are assumed to be concentrated in one point. All quantities of supply and demand in the reference model are based on statistics from the Food and Agriculture Organization of the United Nations for the year 2001 (FAO STATISTICS, 2002). Supply is defined as the aggregated sum of mango production and imports of all countries belonging to one region. The production capacity is defined as unlimited. Demand is equal to the aggregated sum of mango production and imports of all the countries from one region, minus aggregated export.

Mango transportation costs have been obtained from several major shipping companies such as Maersk Sealand (2002), Hapag Lloyd (2002), Evergreen Marine Cooperation (2002) and Orient Overseas Container Line Limited (2002). The transportation costs used in this model are shipping costs by sea for fresh mangoes and range from 280 to 600 Dollars per ton, depending on destinations.

The effect El Niño had on production in 1997/98 is derived from FAO data for the Asian region. On average, production decreased by 20% for mango-producing Asia and Thailand. For the scenario, the supply is recalculated for these two regions.

5.6.3.3 Effects of El Niño on Interregional Trade

The results show that the base run corresponds well to reality, with a few variations. In comparison, the base run calculates the quantity of mangoes traded at 6.5 million tons higher than the actual amount of the total mango trade.

Table 5.15: Reference data - volumes of supply, demand and shipments in '000 tons by region.

Regions	Volume of		Volume of Shipments by Region							
	Supply	Demand	AF	AR	AM	TH	AN	NA	LA	EU
AF	2234	2203	2203							
AR	132	121		72	60					
AM	16317	16189			16189	0.2				
TH	1350	1340				1340				
AN	56	56			46	10				
NA	222	222						3	219	
LA	3227	2901							2901	
EU	172	172	31	11	23				107	

Source: Own calculation, 2004.

Table 5.16: Base run - volumes of supply, demand and shipments in ‘000 tons by region.

Regions	Volume of		Volume of Shipments by Region							
	Supply	Demand	AF	AR	AM	TH	AN	NA	LA	EU
AF	2696	2696	2696							
AR	92	315		92	200	23				
AM	21105	20823			20823					
TH	1746	1723				172				
AN	41	123			82		41			
NA	177	458						177	281	
LA	4202	3813							3813	
EU	139	247							108	139

Source: Own Calculation, 2004.

Table 5.17: Scenario - volumes of supply, demand and shipments in ‘000 tons by Region.

Regions	Volume of		Volume of Shipments by Region							
	Supply	Dema	AF	AR	AM	TH	AN	NA	LA	EU
AF	2696	2696	2696							
AR	96	287		96	171	19				
AM	18666	18425			18425					
TH	1543	1524				152				
AN	43	113			70		42			
NA	177	458						177	280	
LA	4201	3813							381	
EU	139	247							107	139

Source: Own Calculation, 2004.

In reality, Europe (EU) is supplied with mangoes from Latin America (LA), Arabia (AR), Africa (AF), and mango-producing Asia (AM), but in the base run Europe is solely supplied by Latin America and supplies itself (Tables 5.16 and 5.17). Non-producing Asia (NA) actually relies solely on imports from neighboring Asian countries and in the model it also supplies itself with mangoes. These differences may be due to the fact that additional factors which are not depicted in the model - such as the time of market entry, business relations and seasonality - have an influence on trade flows.

With a reduction of 20% in mango production for Thailand (TH) and mango-producing Asia, the amount of mangoes traded also decreases overall by 10%. This reduction, however, does not change the direction of mango trade nor trade patterns or quantities in Africa, the Americas and Europe. For the Asian regions and Arabia, demand decreases by 11% and 9% respectively (Table 5.18).

In additional analysis not presented in detail here, it was determined that Africa enters trade with exports to Arabia when Asia's production decreases by at least 23%. Furthermore, if the Asian regions suffer production losses of 39% or more, they no longer export mangoes and non-mango producing Asia is supplied by Latin America.

Table 5.18: Comparison of reference prices and equilibrium prices in US$/ ton.

Regions	Reference Prices		Equilibrium Prices	
	Supply	Demand	Base Run	Scenario
AF	280	515	387	387
AR	1275	1512	602	659
AM	194	431	302	359
TH	194	431	302	359
AN	1263	1500	652	709
NA	930	1172	584	584
LA	180	417	284	284
EU	1115	1352	654	654

Actual prices of demand and supply are in some cases higher and in other cases lower than the equilibrium prices of the base run. For importing regions, model prices are lower while the prices of exporting regions are higher than in reality. The reason may be that factors other than just transportation costs are actually affecting prices more than the model can show (Table 10). The reduction in production leads to price increases for the Asian and Arabic regions by an average of 9%.

Table 5.19: Comparison of welfare between base run and the scenario in million US $ by region.

Regions	Base Model			Scenario		
	Consumer Surplus	Producer Surplus	Regional Welfare	Consumer Surplus	Producer Surplus	Regional Welfare
AF	5882	661	6543	5882	661	6543
AR	510	37	547	493	43	536
AM	36607	4038	40645	35540	4244	39784
TH	3029	334	3363	2941	351	3292
AN	209	18	227	202	21	223
NA	666	70	736	666	70	736
LA	6378	755	7133	6378	755	7133
EU	406	62	468	406	62	468
Σ	53687	5975	59662	52871	6261	58715

Source: Own calculation, 2004.

In the base run, 59.7 billion dollars of total net welfare is generated from mango trade with producers gaining 6 billion dollars in surplus and consumers ca. 53.7 billion dollars (table 5.19). Exporting countries, mainly developing countries, gain a total 57 billion dollars of welfare and importing countries 2 billion dollars. The results of the scenario show that a 20% reduction of Asian mango produce reduces total net welfare and the welfare of the Asian regions and Arabia. In all of these four regions, producer surplus increases and consumer surplus decreases.

5.6.4 Summary and Conclusion

This paper is divided into two parts. The first part focuses on the efficiency of the Thai mango market. The results of the correlation analysis show that the Chiang Mai and Bangkok retail and wholesale markets have a marked to very dependable relationship with each other at the 0.01 level of significance. The correlation coefficients between farm-gate prices and all Thai markets is high, though not significant. Talaad Thai market and the two Chiang Mai retail markets correlate significantly with FOB prices. A direct correlation between FOB price and farm-gate is not given, maybe due to time lags that could not be tested due to the high level of aggregation of some of the data sets. However, a step by step approach indicates a relationship between FOB prices and domestic prices in Thailand. Furthermore, the asserted correlations between markets imply that the mango market is efficient. In the second part of the paper, the results show that a 20% fall in supply from Asia leads to a 9% increase in prices for Thailand, mango-producing Asia and Arabia. Overall, global mango trade reduces by 10% but does not affect the direction of trade flows. In the Asian regions, producer surplus continues to increase while production decreases, as the increase in price more than counterbalances the loss of product quantity. However, this result should be interpreted carefully, as losses in production can be confined to a smaller region. In this case, a reduction in production may not influence the world prices and thus the producer surplus of the affected region would decline. Overall, Thailand and Asia as a whole encounter welfare losses due to losses in consumer surplus, and thus the hypothesis can be accepted. This analysis has shown on the one hand how climate shocks caused by global warming can jeopardize market stability for a region and on the other hand how market instabilities can result in net welfare losses.

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5.7 Synthesis

Suwanna Praneetvatakul and Franz Heidhues

Chapter 5 addresses economic constraints, influencing factors and future potential of rural households in their use of natural resources in mountainous regions of northern Thailand and northern Vietnam. Given the large differences in natural resource endowment and ecological environments along the gradient from valley bottoms via the foothills and middle uplands up to the high altitude mountainous regions, it is not surprising that economic conditions, rural livelihoods and food security vary greatly. Concomitantly the pressure on natural resources differs and with it the tendency of overuse and resource degradation and of households` practices in sustainable resource management.

The contributions of this chapter also show that economic conditions and natural resource management can be influenced by economic policies and development measures. Overcoming isolation and linking people to markets is shown to be of key importance (DOPPLER AND DO ANH TAI). This underlines the need for infrastructure investments in roads and communication systems. Equally important, particularly for sustainable resource management, is access to productivity raising innovations, knowledge and education for households in rural areas (PRANEETVATAKUL and ZEDDIES/SCHÖNLEBER). Thus, investments in agricultural research, extension and education systems are important for sustainable resource use. Apart from creating market and communication linkages for rural areas, markets need to be sufficiently interconnected (SOMPORN) both nationally and regionally and thus enhance market stability (VON OPPEN/HAU).

The analyses presented in this Chapter also point out the close link of economic conditions to the institutional framework, discussed in Chapter 6. Thus, investments in building institutions and strengthening their services for remote rural areas are called for. This involves programs for strengthening innovation development, for creating a well functioning rural finance market and for promoting tenure security and fair access to resources.

6.0 Institutional Framework for Sustainable Land Use

6.1 Introduction

Andreas Neef and Benchaphun Ekasingh

6.1.1 Definitions and Concepts of Institutions and Institutional Pluralism

Institutional economists have defined institutions as "the rules of the game in a society, or more formally, the humanly devised constraints that shape human action" (NORTH 1990: 3) or as "socially constructed, routine-reproduced, program or rule systems" (JEPPERSON, 1991: 149). Institutions influence the economic and social behavior of individuals, communities and organizations, and determine the potential for cooperation in resource management. Their function is to expand human choices, enhance the predictability of human behavior (PEJOVICH, 1995) and establish the basic rules of social transactions. Well-defined institutions contribute to sustainable development by providing more efficient ways of organizing economic activity (OSTROM et al., 1989) and "reduce transaction costs by ameliorating information and enforcement problems" (BURKI and PERRY, 1998: 143).

Institutions can be both formal and informal. Formal institutions encompass written laws, rules and procedures whereas informal institutions are embodied in customary regulations, cultural norms, social practices and patterns of collective behavior. Institutional and legal pluralism describes a situation where formal and informal regulations, norms and laws coexist, overlap or interact (cf. MERRY, 1988). In most parts of the developing world, institutional pluralism is particularly evident. State laws, traditional customs, religious and cultural norms, project procedures and donor regulations are often intertwined in a complex institutional interplay (VON BENDA-BECKMANN, 1991), with important implications for development and conservation issues. Some authors have emphasized the negative implications of this institutional and legal pluralism. BANDAROGA (2000: 4), for example, states "in many developing societies, informal rules have the tendency to override formal rules, making the enforcement of formal rules very difficult and thereby affecting performance." Other authors, while acknowledging that institutional and legal pluralism can impose constraints on the activities of various actors, claim that the coexistence of institutions can also open up new opportunities, particularly in the field of natural resource management (VON BENDA-BECKMANN, 1991; MEINZEN-DICK and PRADHAN, 2002; GANJANAPAN, 2003).

6.1.2 Institutional Constraints Faced by Highland People in Southeast Asia

Highland people in Thailand, Vietnam and other Southeast Asian countries are mostly composed of different ethnic minority groups that have been consistently marginalized by both the dominant population in the lowlands and national governments. Major institutional constraints for ethnic minority people include (1) lack of permanent and secure land use rights, (2) limited access to formal credit and other financial services, (3) an agricultural research system that does not recognize local people's priorities and practices, and (4) top-down government policies that limit the scope for action of highlanders and continue to control a large share of the natural resource base. These constraints reinforce each other and add up to a vicious circle of institutional failures visualized in Figure 6.1.

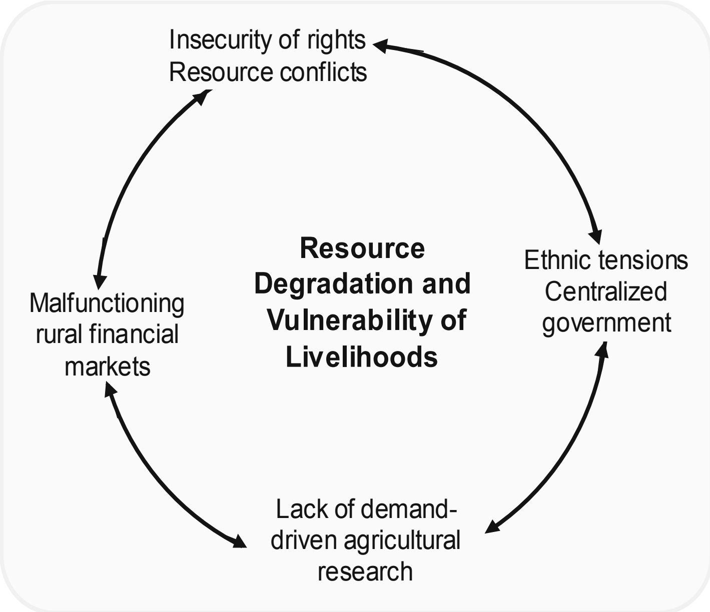

Figure 6.1: Vicious circle of institutional failures in mountainous regions of Southeast Asia.

Property rights regimes have a significant impact and play a central role in the use and management of natural resources. Highland people in mainland Southeast Asia share similar historical experiences as regards access to natural resources. They have seen their resources put under centralized control by government agencies, according to the policy that all land not designated by law as private property is owned by the state (e.g, NEEF et al., 2003). Vietnam is the only country in mainland Southeast Asia to have recently started to reverse this policy,[1] which has largely failed in conserving natural resources, particularly forests. As governments have not been able to enforce the existing legal framework for protecting forests, communal systems of resource management have often been ignored, downgraded and

1 Whether granting private land use certificates to forest land is a viable approach to forest protection and reforestation in Vietnam remains a contested issue, however.

undermined (VANDERGEEST, 1996; GANJANAPAN, 2000). To date, the rights of local communities in highland areas to manage their own resources have not been endorsed by law. In many cases, lowland people have taken advantage of the tenure insecurity of local communities and encroached onto hillsides in order to establish large-scale plantations or engage in logging activities. In Vietnam, resettlement of lowland populations into the northern and central highlands has been an official policy for several decades, one designed to ease the population pressure in the densely populated delta regions. In sum, these migratory movements have added to the already existing ethnic tensions in mountainous areas.

Access to rural credit and other financial services is considered to be an important prerequisite for adopting new technologies and sustainable agricultural practices (KERKVLIET, 1995). Formal credit institutions in highland areas rarely meet the demands of the poorest households. In Vietnam, some ethnic groups, such as the Hmong, are extremely disadvantaged in their access to formal credit. As compared to the Thai minority in the valleys, their transaction costs are higher because they live in remote areas, often do not speak the official language and do not have the necessary collateral (e.g., SCHENK et al., 1999; BUCHENRIEDER and THEESFELD, 2000). In Thailand, a large number of minority people are excluded from access to formal credit, simply because they do not have citizenship rights (e.g., ERHARDT, 2002).

Government policies towards ethnic minorities represent a considerable, externally imposed driving force shaping the agricultural and socio-economic environment of many highland people. Government institutions continue to perceive most of these minorities' traditional agricultural practices as a threat to the natural resource base (cf. CHIENGTONG, 2003). Negative stereotypes of ethnic minority people in highland areas have proven extremely persistent among the majority, lowland-based population (e.g. the Kinh in Vietnam and the native Thai in Thailand).

The failure of the national research systems in Thailand and Vietnam to develop suitable agricultural technologies for highland areas is largely due to research approaches that fail to take into account the heterogeneity of agro-ecological conditions, the diversity of farming systems, local priorities and farmers' own knowledge and experimental skills. As a consequence, many of the technical innovations proposed as alternatives to slash and burn agriculture and measures for soil and water conservation in sloping areas have not been adopted by highland farmers (EL-SWAIFY, EVANS et al., 1999). Only in cases where these technologies have provided substantial, direct economic benefits have they been integrated into the heterogeneous farming systems of the highlands.

6.1.3 How to Create Institutions in Support of Sustainability?

In the following sections, the authors set out to explore the impact of the complex institutional setting in mountainous areas of Thailand and Vietnam on resource management, and identify policy measures that make both formal and informal institutions more supportive of sustainability. The challenge is to turn the vicious circle of institutional failures depicted in Figure 1 into a virtuous circle of viable institutions (Figure 6.2), one that makes individual farmers and rural communities in the highlands more resilient against external shocks and enhances their adaptability to economic and social dynamics.

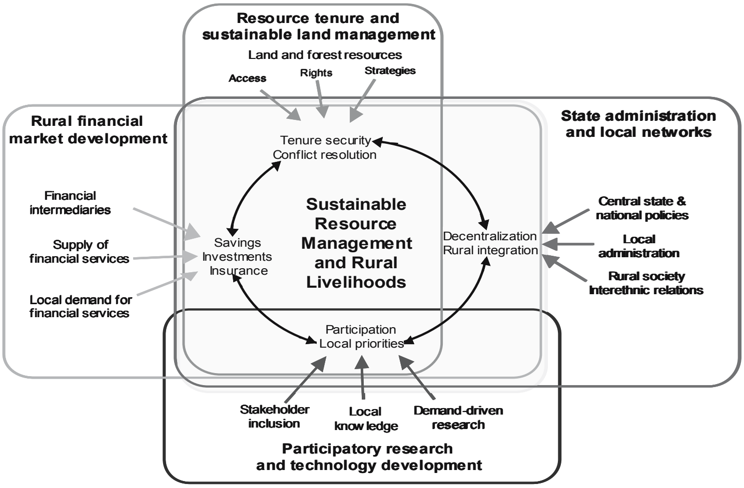

Figure 6.2: Virtuous circle of functioning institutions in support of sustainability.

The elements of this virtuous circle also provide the outline for the contributions to this chapter. Drawing on studies from Vietnam and Thailand, sub-chapter 6.2 entitled "Resource Tenure and Sustainable Land Management" is concerned with access to natural resources, the rights of ethnic minorities in using and managing land and the impact of different policies on resource management. The authors identify individual farmer and local community strategies to enhance tenure security and resolve resource conflicts. Sub-chapter 6.3, "Rural Financial Market Development," describes the financial intermediaries in the uplands of northern Vietnam as well as the financial services that they offer, and analyzes whether these services are compatible with the demand of rural households of different ethnic origin. Suggestions are made as to how to increase the responsiveness of rural financial services to the particular needs of the poor and socially marginalized. In sub-chapter 6.4, "Participatory Research and Technology Development", the authors discuss approaches to eliciting farmers' priorities and local concepts of sustainability. They present an example of how farmers can be involved in the development of soil conservation technologies and analyze the current institutional context for participatory approaches to research and development in Thailand and Vietnam. Sub-chapter 6.5, entitled "State Administration and Local Networks," deals with the complex interface between state agencies and local communities in rural development, drawing on a study in Pang Ma Pha district in north-western Thailand. The authors analyze the internal workings of an ethnic minority network and its development after the departure of international donors and also during a transition period from a highly centralized society to a more autonomous rural administration.

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6.2 Resource Tenure and Sustainable Land Management – Case Studies from Northern Vietnam and Northern Thailand

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6.2.1 Why does Resource Tenure Matter?

Property rights regimes can have a significant impact on the use of natural resources, especially land, forests, pastures and water. The literature identifies many environmental problems such as soil degradation and forest depletion as a result of incomplete, inconsistent or poorly enforced property rights (BROMLEY and CERNEA, 1989; FEDER and FEENY, 1991; KIRK, 1999). GORDON (1954) and HARDIN (1968) claimed that under common property regimes, natural resources would be prone to overexploitation because the costs of negative externalities like pollution of water or overgrazing of pastures are borne by the community as a whole, whereas the potential benefits accrue to the individual. The general interpretation of these theorems in many Southeast Asian countries was that collective ownership was the culprit for forest destruction, land degradation and water pollution and that private property or control by state authority was crucial to sustain natural resources (CHALAMWONG and FEDER, 1985; NARKWIBOONWONG et al., 1994). However, a growing amount of empirical evidence suggests that sustaining environmental resources does not primarily depend on whether the property rights regimes are based on states, communities or individuals, but rather on a well-specified property rights regime that is congruent with its ecological and social context (OSTROM, 1990 and 2001; BROMLEY, 1991). Drawing on the case of Northeast Thailand, FEDER et al. (1988) showed that land titling significantly enhanced both access to credit and investment in land by individual farmers. In northern Vietnam, there has not been much research on the effects of land allocation on adoption of soil conservation measures and long-term

investments in land. Most studies focus on the allocation process itself (e.g., NGUYEN THUONG LUU et al., 1994; SIKOR and DAO MINH TRUONG, 1999).
After a brief overview of tenure policies in mountainous regions of Thailand and Vietnam (section 2), two case studies are presented in this sub-chapter that analyze the complex interrelation between tenure security, long-term investment and resource management. The first case study from Northwest Vietnam is based on quantitative and qualitative data collected from a sample of 265 households in six villages in Yen Chau district, Son La province between November 2001 and March 2002. These cover three ethnic minority groups, namely Black Thai, Kho'mu and Hmong (section 3). The second case study presents a combination of a qualitative analysis of local people's strategies to enhance tenure security and an econometric analysis of the causality between tenure security and long-term investment. This is based on a survey of 80 farming households in two Hmong communities in Mae Sa watershed, Chiang Mai province carried out from April 2001 to April 2002 (section 4). Results are discussed from a comparative perspective in section 5.

6.2.2 Tenure Policies in Mountainous Regions of Thailand and Vietnam in Comparative Perspective

The evolution of land and forestry policies targeted at mountainous areas of Thailand and Vietnam, and the current controversy surrounding them, suggest completely diverging approaches. Until the late 1980s, forestry policies in Thailand were mainly concerned with managing concessions for timber extraction. Poor management of the concessions and concessionaires, and serious institutional weaknesses and constraints, combined with rural population growth and expansion of the agricultural frontier, have resulted in seriously degraded forests, malfunctioning watersheds and a significant loss of biodiversity. In 1989, following a flood in southern Thailand that claimed the lives of more than a hundred people, deforestation became a nation-wide issue and a national logging ban was issued (e.g., NEEF and SCHWARZMEIER, 2001).

Fuelled by the global environmental movement and local concerns about dwindling forest resources and biodiversity, the area classified as national parks, wildlife sanctuaries and watershed conservation zones has been expanded to more than 15 percent of the country's territory in 2003 (WORLD RESOURCES INSTITUTE, 2003), completely disregarding the fact that a major proportion of the newly declared protected areas are inhabited by forest-dependent people. The boundaries of those areas were defined by the state, without any consultation with the local people. The majority of Thailand's ethnic minorities now live in national parks, wildlife sanctuaries and forest reserves. Existing forestry laws follow a strict state paradigm and a 'forest without people' principle for conserving forests and their biodiversity (VANDERGEEST, 1996; GANJANAPAN, 1997; JOHNSON and FORSYTH, 2002; NEEF et al., 2003). However, policies towards the population living in protected forest areas have been far from consistent. Whereas forestry agencies have engaged in reforestation activities without people's participation and called for resettlement of villages away from critical watersheds, various government agencies and project initiatives have improved infrastructure, provided agricultural inputs and introduced new cash crops in these same areas.

In contrast to the persistent state paradigm in northern Thailand, land and forestry policies initiated under the reform program of the Vietnamese government are aiming towards a large-scale devolution of the use, management and governance of land and forests in northern Vietnam. Having experienced a sharp decline in per capita food production in the late 1970s (AKRAM-LOHDI, 2001; PINGALI and VO TONG XUAN, 1992), the Vietnamese government responded to growing food insecurity with a series of agricultural reforms. The first step was Directive 100 issued in 1981, which shifted responsibility for production from agricultural cooperatives to farming households. Land allocated to co-operatives could be sub-contracted to individual households (e.g., NGUYEN VAN TIEM, 1992; KERKVLIET, 1995). Another major step in the agrarian reform was Resolution 10 in 1988, which restored the farming household as the main unit of agricultural production and instigated a large-scale decollectivization in most parts of the country. The new Land Law in 1993 and its revision in 1998 brought about the allocation of so-called red book certificates (RBCs), that claimed to guarantee rights to exchange, transfer, inherit, mortgage and lease long-term land use rights (e.g., DAO THE TUAN, 1995; RAMBO et al., 1995; NEEF et al., 2000). The following section examines the impact of the agrarian reform on the construction of rice terraces in Yen Chau in the period from 1988 to 2001.

6.2.3 Land Allocation and Long-Term Investment in Northwest Vietnam: The Construction of Rice Terraces in Yen Chau District, Son La Province

The Black Thai of Yen Chau consider the cultivation of rice – their main staple food – as an essential part of their farming system. Wet rice production is preferred to upland rice production, as it requires less labor and land per output unit. Traditionally, paddy land was controlled by the lineages within the villages, which allocated paddy fields to their member households for a limited period according to their needs. The maintenance of the terraces and the irrigation system, and the extension of the perimeter to meet the needs of a growing population, were undertaken jointly (SIKOR and DAO MINH TRUNG, 2000; WIRTH et al. 2003). Following the independence of North Vietnam in 1954, cooperatives were established in the villages in Yen Chau. While this state intervention failed to replace traditional institutions at village level, it had a major impact on investments. Each cooperative received a production goal for agricultural products and thus investments were closely linked to these goals. In those years, investment in new rice terraces was limited to irrigation projects on two of Yen Chau's main rivers - Suoi Vat and Suoi Sap - funded by the central government of Vietnam.

After decollectivization in 1988, 36 households from the total sample of 265 households in the villages had built new rice terraces by 2001. Not surprisingly, the results vary greatly between the different villages, depending on the village location and the availability of suitable land. In two villages, no such investment took place. In the high-altitude Hmong village of Bo Kieng there is not enough water available for paddy cultivation and in Sai, a Thai village in the main valley, all suitable land was already covered with terraces before 1988. In Dong, the other main valley village, only two households (4.3%) built new paddy fields. In the remote villages, the share of households that invested in terraces varies from 21% to 56%. The total area of new paddy fields is 4.1 ha.

Corresponding to the changes in institutional framework (cf. section 6.4.2), the years from 1988 to 2001 can be divided into three phases. In the first phase (1988 to 1993), the production quota system was gradually removed and prices were liberalized. From 1994 to 1998 (second phase), a first land allocation process based on the Land Law of 1993 was carried out in the villages along the national road no. 6. The third phase (1999-2001) saw a re-launch of the land allocation process covering the whole district, as the outcome of the first allocation of Red Book Certificates (RBCs) proved incompatible with national guidelines and failed to eliminate the co-existence of formal and traditional tenure systems (SIKOR and DAO MINH TRUNG, 2000; WIRTH et al., 2004).

Figure 6.3 shows that most of the new rice terraces were built in the first two periods. In addition, the average size of investment also declined in the final period to 740 m^2 from over 1200 m^2 previously. Furthermore, rice terraces have only been built in the two remotest villages since 1999. In these villages, the process is still ongoing.

The construction of new rice terraces reflects the dichotomy of formal and traditional land tenure regimes. Tenure security can be provided by either system. Table 6.1 shows that almost half of the investing households obtained tenure security only through the traditional system. However, 12 households were able to increase tenure security on their new rice terraces through the formal system. Before the implementation of the 1993 Land Law, these households would not have been able to secure their claims in the traditional system. Nevertheless, the rather high share of households that have made long-term investments without enjoying a high degree of tenure security suggests that farmers' confidence in the traditional tenure system is high.

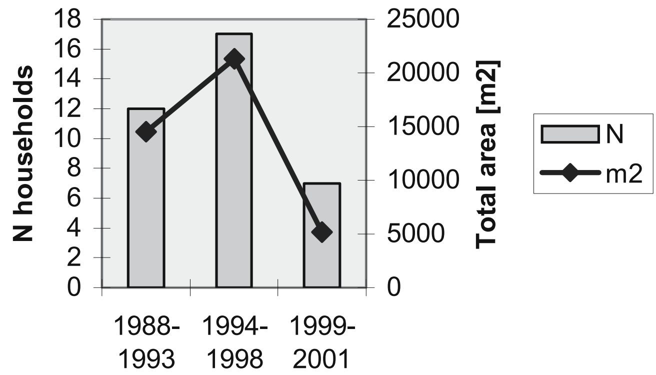

Figure 6.3: Area of newly-constructed rice terraces and number of households involved by periods.

Table 6.1: Tenure security on the newly-built rice terraces provided by government and traditional institutions.

			Traditional tenure security		Total
			No	Yes	
Formal tenure security	No	N	6	17	23
		% of total	16.7%	47.2%	63.9%
	Yes	N	12	1	13
		% of total	33.3%	2.8%	36.1%
Total		N	18	18	36
		% of total	50.0%	50.0%	100.0%

Households that built new rice terraces have some common characteristics; they are more likely to be members of the cooperative and to have an official position within the village. They tend to have a bigger area for maize cultivation and a smaller area of paddy land than households that did not invest in new rice terraces. After the investment, the paddy area is still smaller on average, but the difference is no longer significant. As a consequence, a more equitable distribution of paddy land in the villages can be observed, which is reflected in the changes in the Gini coefficient (Table 6.2).

Table 6.2: Gini coefficients of paddy land distribution in 1988 and 2001.

Location	Village	Ethnic group	Gini coefficient		Change 1988-2001	
			1988	2001	abs	%
main valley	Dong	Black Thai	0.2177	0.2129	-0.0048	-2.2
	Sai	Black Thai	0.2316	0.2316	0.0	0.0
slope	Than	Kho'mu	0.3881	0.3316	-0.0549	-14.1
remote	Tat Heo	Black Thai	0.4423	0.2260	-0.2126	-48.9
	Na Pa	Black Thai	0.6528	0.5782	-0.0746	-11.4

The process of terrace-building is still ongoing in the remote villages and thus the situation in these villages can be expected to continue to improve in the ways outlined above.

This example from the north-western mountains of Vietnam underscores the importance of tenure security – whether derived from customary institutions or from state-driven land allocation – for providing incentives for long-term investment. The following case study from northern Thailand, in contrast, presents a situation where the government's forest conservation policies have undermined local institutions and decreased tenure security, provoking different responses from local actors.

6.2.4 Tenure Security and Long-Term Investment in Northern Thailand: The Case of Mae Sa Watershed, Chiang Mai Province

The two Hmong communities Mae Sa Mai and Pha Nok Kok are located within the area of the Suthep-Pui National Park (table 6.3), and the majority of the farm households do not have officially recognized land titles. The creation of the national park in 1981 and its further expansion in 1996 have significantly reduced tenure security in the two villages, rendering all agricultural activities illegal by national law.

Table 6.3: Characteristics of the villages studied

Name of village	Mae Sa Mai	Pha Nok Kok
Ethnic group	Hmong	Hmong
Number of households	210	64
Altitude [m asl]	1000	1100
Main production	Litchi, vegetables	Vegetables, litchi, flowers
Location	Suthep-Pui National Park (since 1981)	Suthep-Pui National Park (since 1996)
Sample size	40	40

Faced with continuous threats of eviction and land claims by government agencies, villagers in the two communities have adopted a range of strategies to enhance tenure security. In Mae Sa Mai, the old tradition of worshipping the village spirit believed to reside in the tallest tree overlooking the village was revived in the mid-1980s, on the initiative of the then village headman of Mae Sa Mai. In contrast to the traditional practice of only protecting the immediate environs of the so-called *ntoo xeeb* tree, the shaman and the village headman declared an area of about 18 ha to be ritual forest. The area was further expanded in the 1990s at the expense of agricultural land, with the collective agreement of all villagers. Today, the protected community forest covers an area of ca. 800 ha and serves as a public demonstration of the community's willingness to conserve the forests in the head watersheds. The establishment of a conservation group, which was initiated by a group of young villagers in 1994, can be seen in a similar light. In cooperation with a university-based international NGO, this group has engaged in several reforestation campaigns since its inception. Villagers in Mae Sa Mai take decisions after communal consultations as to which fields should be set aside for restoring the forest. Several representatives from both Hmong villages have also joined an action-research project, initiated by a local NGO and supported by the Thai Research Fund, with the objective of clarifying water use rights in the watershed. Cooperation with government agencies is another strategy to secure the resource claims of the community. In 1991, the villagers of Mae Sa Mai reached an agreement with the National Park authorities to construct fire barriers and to monitor and extinguish forest fires, in order to protect the forest conservation area. In 1996, the villagers of Pha Nok Kok also started to engage in fire protection activities.

For many years, the activities of the Royal Project (RP) have indirectly supported the claims of the villagers of Mae Sa Mai for sustaining their livelihoods in this particular sub-catchment. Continuous cooperation with the RP improves the security of their land rights and makes them less vulnerable to eviction than, for instance, their neighbors in Pha Nok Kok, which is not linked to a Royal Project station.

Apart from strategies developed by the community and by its sub-groups, individual villagers have their own strategies to cope with insecure tenure. In Mae Sa Mai and Pha Nok Kok, planting of fruit trees, particularly litchi, has increased tenure security in sloping areas. The National Park authorities acknowledge these practices as being at least more sustainable than growing vegetables and other annual, erosion-prone crops. However, the history of the two villages suggests that planting fruit trees does not provide full tenure security. Some cases are reported in which trees were cut down by park rangers or by angry lowlanders, who claim that the Hmong use too much water for their orchards. Nevertheless, this strategy proved successful for most of the villagers, some of whom even leave their unproductive fruit trees in the orchard to avoid land claims by the RFD. However, fruit trees cannot be grown just anywhere, as they depend on water supply during the dry season. In cases where only annual crops can be grown, permanent cultivation of the fields is a viable strategy against land claims, since fallow periods lead to immediate eviction from the land (cf. TURKELBOOM et al., 1996; KNÜPFER, 1999).

To test the linkage between tenure security, access to credit, input use, long-term investments and productivity, a conceptual framework based on PLACE and HAZELL (1993) has been further expanded by adding a multi-dimensional view of tenure security. Following NEEF (1999), we consider (1) type of rights, (2) duration of rights and (3) occurrence and potential for conflict as the major dimensions of tenure security (for details see box 1 in annex). The relationship is expressed in the form of the following structural model, based on plot or parcel-level observations (i) for each household.

$$L_i = f(X^h, X^v, S_i^t, S_i^d, S_i^c, X_i^p, C) \qquad (6.1)$$

$$I_i = f(X^h, X^v, S_i^t, S_i^d, S_i^c, X_i^p, C, L_i) \qquad (6.2)$$

$$Y_i = f(X^h, X^v, X_i^p, L_i, I_i) \qquad (6.3)$$

$$C = f(X^h, S^c, S^t, S^d, r, F) \qquad (6.4)$$

where
C = amount of credit obtained by the farming household in the past year
X^h = variables characteristic of the household (e.g. number of household members, non-farm income, wealth, occupation of all household members, and head of household characteristics such as age, education and farming experience)
X^v = village dummy or dummy for location (upstream or downstream)
S_i^t = type of rights such as
(1) use rights - right to grow annual crops, right to grow perennial crops or make permanent improvements
(2) transfer rights, differentiated into (a) complete transfer right (fields that can be sold without restrictions, (b) preferential transfer right (fields that cannot be sold but can be given or bequeathed to members of the same family or lineage), and (c) limited transfer right (fields that cannot be permanently transferred)
S_i^d = duration of rights
S_i^c = potential for conflict
L_i = long-term investment in land improvement of the i^{th} field
X_i^p = plot-specific characteristics (e.g. soil fertility, mode of acquisition, topography, distance from house, size and crops grown)
I_i = the past season's use of inputs on the i^{th} parcel
Y_i = yields of the i^{th} parcel in the past season
r = interest rate (%)
F = source of funding (formal or informal)

In the following, we will focus on the relationship between tenure security and long-term investments without presenting the effects of tenure security on access to credit, input use and productivity.[2] In the farming household survey, different types of long-term investment in land were considered, such as installation of irrigation equipment, planting of perennial crops, making terraces

2 Effects of tenure security on access to credit are discussed in NEEF ET AL. (2004). The impact of tenure security on input use and productivity is difficult to assess as cropping systems in the study villages were extremely diversified.

or ditches, growing cover crops, applying organic fertilizer and leaving the land fallow. Results from all study villages show that an increase in the level of tenure security has a positive effect on long-term investments in land (L_i). In Mae Sa Mai, both the dimensions 'duration of rights' (S^d) and 'conflict potential' (S^c) had a significant impact on investment (Eq. 6.5), whereas in Pha Nok Kok, only 'conflict potential' significantly influenced long-term investments in land, such as planting of perennial crops, installation of irrigation equipment and terracing (Eq. 6.6).

Mae Sa Mai

$$L_i = \underset{(2.232012)^{**}}{0.704801} + \underset{(2.429722)^{**}}{0.164282}\ S^d + \underset{(3.006395)^{**}}{0.377271}\ S^c \qquad (6.5)$$

$n = 150 \qquad R^2 = 0.349288 \qquad \bar{R}^2 = 0.331338 \qquad D.W. = 1.990178$

Pha Nok Kok

$$L_i = \underset{(3.694555)^{**}}{1.311486} + \underset{(4.914961)^{***}}{0.548518}\ S^c \qquad (6.6)$$

$n = 122 \qquad R^2 = 0.621178 \qquad \bar{R}^2 = 0.611547 \qquad D.W. = 1.920425$

At first sight, these findings would support conventional wisdom about the mono-directional relationship between tenure security and long-term investment. However, as our data obtained from qualitative interviews (see section 6.4.4.1) had indicated that farmers make a wide range of long-term investments under relatively insecure tenure conditions – as a strategy to secure land use rights contested by national law and local government agencies – we decided to estimate tenure security as the dependent variable with Ordinary Least Square (OLS). In the following equation we used an aggregate value for tenure security.

Mae Sa Mai

$$S = \underset{(11.00142)^{***}}{8.087949} + \underset{(8.620391)^{***}}{2.233936} L_i \tag{6.7}$$

$n = 150$ $R^2 = 0.286306$ $\bar{R}^2 = 0.271641$ $D.W. = 1.984279$

Pha Nok Kok

$$S = \underset{(13.24332)^{***}}{11.39207} + \underset{(3.687393)^{**}}{0.698280} L_i + \underset{(2.830946)^{**}}{0.107052} Year\_set \tag{6.8}$$

$n = 124$ $R^2 = 0.34876$ $\bar{R}^2 = 0.26965$ $D.W. = 1.878230$

Results from the OLS analysis underscored the hypothesis – formulated on the basis of the qualitative survey – that long-term investment significantly enhances tenure security, with confidence levels of 95% in the case of Mae Sa Mai (Eq. 6.7) and 99% in the case of Pha Nok Kok (Eq. 6.8), albeit with relatively low R^2 values. These findings suggest that – in the absence of adequate protection of customary property rights by the government's legal system – long-term investments, such as planting of trees or construction of terraces, may provide a source of evidence for defending land claims both against government intervention (e.g. eviction by the forest department) and against fellow farmers. In Pha Nok Kok, tenure security was also positively influenced by the duration of the settlement rights (*Year_set*), i.e. tenure rights of well-established farmers were significantly more secure than the rights of relative newcomers.

Discussion of Results in a Comparative Perspective

Evidence from both studies suggests that the interactions between local tenure security, government interventions in tenure regimes, long-term investment and natural resource management in mountainous regions of Southeast Asia are extremely complex. The study from Yen Chau district shows that tenure security can be provided by both customary institutions and official land registration processes. In this particular case, the implementation of the land law has allowed households, which had been granted only limited tenure security by the customary system, to secure their investments in the long term. Although the households who benefited from the allocation of red book certificates and invested in new paddy fields are not among the poorest, resource endowment of the households became more equitable, particularly in the villages located on slopes and in remote villages. The expansion of rice terraces does not only contribute to improving food security, but also reduces erosion in sloping land. This is especially important as other approaches like hedgerows and micro-terraces – promoted by both national extension services and international development programs – have failed so far as they have not been accepted by the local population (LORD, 2001).

In the particular socio-economic context of protected areas in northern Thailand, where there is no legitimate evidence of ethnic minority people's land use rights, long-term investments can play a significant role in enhancing tenure security. Results of the study in Mae Sa Watershed suggest that the dichotomy between state-governed forest land and customary property regimes in protected areas has led to a variety of strategies on the part of local communities to secure their land use rights, ranging from the revival of traditions and cooperation with NGOs and development projects to a wide spectrum of long-term investments. In a local arena characterized by political pressure and ignorance of local people's own tenure arrangements, ethnic minority people have proven their capacity to learn the rules of the game, to develop new forms of "human agency" (Long, 2001: 4) and to make use of positive external effects of investments and technology adoption on tenure security (cf. KNOX et al., 2002). Hence, the 'room for maneuver' in asserting land and forest rights in the Thai highlands depends on a complex interplay of government interests, intervention by development projects, NGOs and other actors serving as outside allies, and the ability of local communities to influence the local administrative system in their favor. In this 'institutional arena,' individual and collective strategies are creatively combined to secure both rights to individual agricultural land and rights to common-pool resources.

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6.3 Sustainable and Less Sustainable Developments in the Rural Financial Market of Northern Vietnam

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6.3.1 Introduction and Conceptual Framework

It has been pointed out repeatedly that broad access to appropriate and lasting financial services is important for poverty reduction, as this contributes to higher income and better food security (ADB, 2000; HEIDHUES, 1998; ZELLER et al., 1997). Enhanced access to financial services can support sustainable land use through increased agricultural productivity. This is achieved by giving farmers the opportunity to use external production inputs. Higher agricultural productivity can potentially contribute to natural resource protection; with higher yields on existing fields, farmers may be less prone to move into vulnerable, marginal areas.[3] Besides, access to appropriate financial services also improves the ability of poor farmers to better manage external shocks. This again reduces the probability of farmers beginning to exploit marginal areas in times of crises and, therefore, supports resource protection.

The establishment of sustainable financial institutions is a key issue in broadening outreach and increasing the impact of financial institutions, as sustainability today will mean more leverage and

3 It should be pointed out here that, without proper extension work, access to financial services and particularly credit may, under certain circumstances, lead to the opposite of the intended effect, namely intensify the pressure on natural resources. LUIBRAND (2002) found for example that small-scale farmers using high yield maize varieties in the uplands of northern Vietnam did not immediately notice the detrimental effects of their cultivation methods on sloping land, since the higher yields compensated to some degree for the soil losses in the short run.

impact tomorrow. Sustainability is therefore only the means of achieving greater outreach (CONNING, 1999; WRIGHT, 2000; RHYNE, 1998). Consequently, the objective of this sub-chapter is to analyze and discuss the sustainability (or lack thereof) of the rural financial sector in northern Vietnam. In this contribution, the focus is more on the demand side, as former research mainly focused on the supply side. Knowledge of the financial market environment and its institutions is also central to the analysis. Therefore, data collection and analysis consists of three levels (the macro, meso and micro levels), with a special focus on the farm-household, i.e. the micro level. Figure 1 illustrates the various levels, actors, and research methods applied in this research project. The upper part of Figure 6.4 depicts the rural financial market with its different actors, and the lower part presents the different levels and the corresponding data collection methods. The figure clearly shows the intersections between and within the different levels. These intersections highlight again the importance of a combined analysis of the above-mentioned three levels. This sub-chapter is structured as follows: In Section 2, important financial market macro issues and their implications for the rural financial sector in Vietnam are discussed. Section 3 describes information asymmetries in the client selection process of the former main rural credits supplier in Vietnam (meso level), namely the Vietnam Bank for the Poor (VBP) and the Vietnam Bank for Agriculture and Rural Development (VBARD). The micro level is analyzed in Section 4, where outreach of the rural lenders and demand-oriented financial products are discussed.

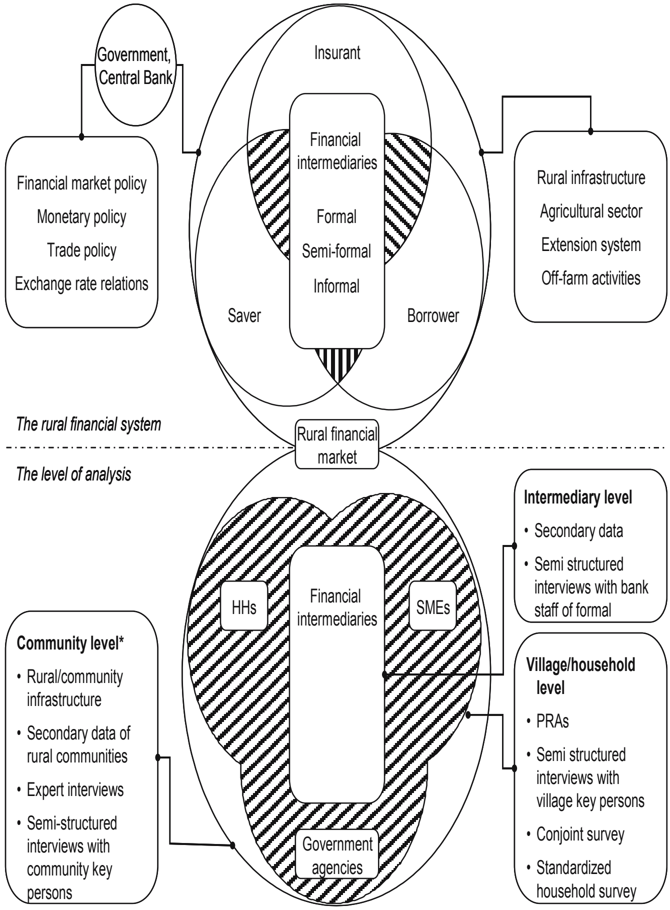

Figure 6.4: The rural financial market and the levels of analysis
Source: Own draft.
Note:*The community level is defined as all institutions, policies, and infrastructure above village level. PRA = Participatory rural appraisal, HH = Household, SME = Small and medium enterprise

While most publications in this sub-project deal with the household level (i.e. DUFHUES and BUCHENRIEDER, 2002; DUFHUES and BUCHENRIEDER, 2003; DUFHUES and BUCHENRIEDER, 2005; DUFHUES et al., 2003; DUFHUES et al., 2003a; DUFHUES et al., 2003b; DUFHUES et al., 2004; GEPPERT and DUFHUES, 2003; HÄUSER et al., 2004) and some with the intermediary level (i.e. DUFHUES et al. 2001; DUFHUES et al., 2002a; DUFHUES et al., 2002b; DUFHUES et al., 2004a; DUFHUES et al., 2004b), just one covers the entire financial system (DUFHUES, 2003). GEPPERT et al. (2002) discuss part of the agricultural system influencing the rural financial sector. The following sections cover the most important results from these publications.[4]

6.3.2 Selected Financial Sector Sustainability Issues

This section aims to review important processes in the transformation of the financial system in Vietnam. Special attention is given to the transformation of the rural financial market. The methodology underlying this section is based on a review of Vietnamese financial market policies and secondary data combined with anecdotal evidence. An overview of the main formal financial institutes in rural Vietnam is given in Box 6.1.

Box 6.1: The formal financial players in the rural financial market since 'doi moi'

1987 - 1990	Changing of the former mono-bank system into a two-tier banking system consisting of the State Bank of Vietnam as central bank (tier 1), and an operating system (tier 2). The Vietnam Bank for Agriculture and Rural Development (VBARD) was established as part of tier 2.
1993	Creation of the People Credit Funds (PCFs) to fill the gap left by the collapse of the rural credit cooperatives in the early 1990s.
1995	Foundation of the Vietnam Bank for the Poor (VBP) as the poor people's lending outlet of the VBARD, consisting only of a head office in Hanoi. Below this level the facilities of the VBARD were used.
1999	Establishment of the Vietnam Postal Savings Company (VPSC) under the authority of Vietnam Post and Telecom.
2003	The Vietnam Bank for Social Policies (VBSP) succeeded the VBP, which now had its own branches independent of the VBARD. The VBSP took over all operations from the VBP and the PCFs.

4 As space is limited, we will not engage in any methodological description. For further readings on the methodology, please refer to the above-mentioned publications.

After a slow-down of the overall financial system reforms in Vietnam in recent years, banking sector reform is back on schedule (WORLD BANK, 2001). The government has adopted a comprehensive banking reform package, focusing on the restructuring of banks and on improvements in their regulatory and supervisory framework. The past decade witnessed a rapid deepening in the level of monetization of the Vietnamese economy. The growth of the non-banking financial sector, and especially of the insurance business, has also been remarkable, although the size of the sector remains small in absolute terms (WORLD BANK, 2002). A formal agricultural insurance market hardly exists and rural farming households have to rely mainly on informal mutual aid schemes to reduce their livelihood risks (VANDEVEER, 2000).

Despite the liberalization of interest rates, the government continues to supply huge parts of the population, mainly in rural areas, with subsidized credits. While the liberalization of interest rates offers the potential for financial intermediaries to supply cost-covering services, it is unlikely that financially viable services will be offered in the rural financial market, as long as rural lenders have to compete with highly subsidized loans, e.g. of state-owned banks such as the Vietnam Bank for Social Policy (VBSP, formerly known as VBP).[5]

The government of Vietnam recently recognized that the rural population, including women and the poor, is able to save. The Vietnam Postal Saving Company (VPSC) was founded in 1999 to develop the potential of the rural deposit market. Although the VPSC potentially reaches out to the commune and village level, the 710 postal savings service outlets are far from having a significant outreach to the rural population and particularly to the rural poor. As the WORLD BANK (2002: 46) states; “In a country where 80% of the population lives in rural areas, even the 2000 branches of the VBARD cannot reach wide, nor deep enough to the population at large.”[6] Nevertheless, the perceptions and policies of

5 The VBP was replaced by the VBSP in 2003, which has taken over all its operations.

6 While the existing branch network is sufficient to provide a broad credit outreach (see sections below), it is not yet dense enough to attract rural savings.

VBARD and VBSP have not changed as far as the implementation of a savings scheme to reach the rural population is concerned. A paradigm change is required before this can happen. The rural financial intermediaries in Vietnam need to recognize the ability and the demand of the rural population to save.

The huge amounts of non-performing bank loans taken out most state-owned enterprises are not new and are well-known. However, there are strong indications that this problem is spreading to the private sector and particularly to rural households. At present, it appears that lenders will not grant another loan within the next decade to households with non-performing loans. Thus, household access to potential new lenders in the market is blocked and, at the same time, the market is denied new lenders. Both add to the already high entry barriers to the rural financial market and keep competition at a very low level.

In the rural financial market, centrally fixed production targets - e.g. reaching 90% of the poor households with credit, regardless of whether there is a demand for it - are still active. To reach this target group, the Government created the VBP and VBARD, with the VBSP recently taking over these objectives from the aforementioned two banks. Earlier evidence from agricultural development banks in other countries suggests that VBARD, now freed from policy lending, is likely to dismiss its peasant clientele and concentrate on the more lucrative rural business with bigger and wealthier farmers (ADAMS and PISCHKE, 1992; HEIDHUES and SCHRIEDER, 1999). As the VBSP will continue lending highly subsidized credits, it will obviously become a drain on public resources. The question is how long can the Vietnamese Government finance the policy-lending of the VBSP and who will serve the rural poor if the VBSP has to stop its operations due to lack of funding?

6.3.3 Shortcomings of Information Channeling - The VBP/VBARD Conglomerate[7]

This section describes VBP/VBARD's information channels to rural households, revealing important information asymmetries and other system shortcomings. It is mainly based on qualitative data gained from semi-structured interviews with bank staff and participatory rural appraisals (PRAs) conducted with rural households.

The VBP was established in 1995 and existed until 2003, when the VBSP took over all operations. It had a head office in Hanoi but no branch network of its own. All operations were carried out by VBARD staff. The analysis has shown that VBP/VBARD's financial information flows were inefficient, despite an extensive formalization of the channels. The screening, monitoring, enforcing and information procedures have been mainly outsourced to local officials, who are often overloaded with work and not qualified for these tasks. The use of local authorities in these procedures is, in principle, a good strategy for reducing information asymmetries and thus lender transaction costs. Nevertheless, the involvement of these crucial information gatekeepers at different administrative levels may impede, divert, and attenuate the dissemination of information. These gatekeepers normally belong to the same or related social and political networks. In this context, VAESSEN (2001) states that a formal rural lender's key informants in a certain region should not all belong to the same network. In this way, the lender can avoid falling into the trap of lending solely to a certain network of people, while households outside this network are excluded. One means of expanding to new networks in Vietnam could be to employ credit officers from different ethnic minorities. So far, 95% of the credit officers in Ba Be district (one of the research areas) belong to the Tay minority. The remaining 5% are Kinh (Vietnamese). Other ethnic minorities dwelling in this region like the Dao, Hmong, Nung, etc. are not represented within the staff

7 The VBSP is setting up its own financial infrastructure, thus effectively eliminating the VBP/VBARD conglomerate .

structure. A greater ethnic diversity of employees could not only diversify information networks but also give hints as to the design of incentive schemes for information gatekeepers, in order to improve the information flow to marginalized groups. Another way of making the information available more transparent to potential borrowers could be to establish local information centers (although this might, in the beginning, increase the transaction costs for the lender). A good location for such an information center could be the communal post office where the lender, normally the VBARD or VBSP, could arrange an information corner. This could be combined with the introduction of a regular information day (e.g. market days), which all commune members should be made aware of and where the credit officer is locally available for questions and discussion. This would allow the farmers to seek information and advice directly from a professional and do their business at the market. Officially, credit officers are already asked to follow such fixed visiting schedules, but they rarely follow it in practice.[8]

Passive information flow to households could also be improved by using the mass media, particularly the radio. Today, 95% of the country's population and 98% of the nation's territory has access to Radio Voice of Vietnam. In the past, most radio programs were broadcasted in Vietnamese, which excluded many of the ethnic minorities from information. But more recently, the Radio Voice of Vietnam has bolstered its broadcasting network to include ethnic minority languages.

By way of summary, improving the top-down and bottom-up information flow in the credit market for the rural poor could not only significantly reduce the operation costs of the formal rural lender concerned, but also increase market access of the poor target group with profitable investments.

8 For instance, market days are held every fifth day in the area. But bank officers follow the standard working week from Monday to Friday. Thus, market days often coincide with the officers' weekend.

6.3.4 Client-Lender Intersections within the Financial Market – The Services

While sections 2 and 3 were based mainly on qualitative data, this section relies on quantitative micro-data for its analysis. In total, 260 households were interviewed in Ba Be and Yen Chau districts between March 2001 and March 2002.

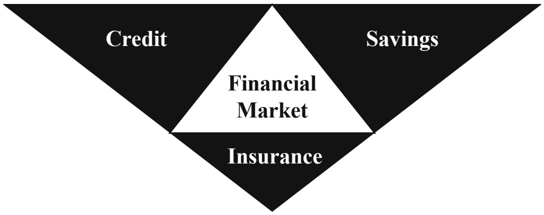

Figure 6.5: Rural finance product triangle.

From the clients' perspective, rural finance products may, to some degree, substitute each other (figure 6.5). Open access savings products and emergency loans can act as a form of insurance, while insurance products can also be used for the accumulation of capital. In the case of credits, the money is collected after disbursement of the lump sum, beforehand in the case of savings, and continuously in the case of insurances. While saving was recognized as the forgotten half of finance in the 1980s, insurance was termed its forgotten third in the 1990s (ZELLER ET AL., 1997). Clearly, the main financial services in rural Vietnam include credit, sometimes savings, and to some extent insurance, mainly livestock insurance.

Credit: This research provided some valuable insights into how to improve the financial services of rural lenders to the population by adapting existing credit services. The empirical evidence suggests that individual loans are strongly preferred as compared to the dominant group loans.[9] It could also go hand in hand with the increasing introduction of physical collateral instead of a pseudo group liability, which is not working. Farmers demonstrated that

9 Group loans are negatively associated with a long period from the day of expressing demand until the disbursement.

they are able and willing to use their land use rights (Red Books) as collateral for individual loans.[10] However, without an effective land market, it will probably be risky for the lenders to rely solely on land use rights as collateral, although this is no riskier than relying on a pseudo group liability.

VBP (now VBSP) and VBARD already have an enormous combined outreach. 56% of the interviewees in the survey had an effective credit demand and about 28% did not have a demand for credit during the survey period, but had potential access to credit. Thus, only 16% of the population is effectively access-constrained (Figure 6.6). However, it is worth to mention that within this group of access constrained households a higher then average share of credit unworthy households can be found. Trying to broaden the outreach with general instruments to this group of people, e.g. by further cutting interest rates, would probably increase the use of loans for unprofitable investments and further increase the non-performing loan volume (see Section 2). Therefore, a consolidation policy of the credit market would be the most reasonable reaction, e.g. raising interest rates and thus improving the cost coverage of the rural lenders and lowering effective demand. Nevertheless, preliminary results from DUFHUES and BUCHENRIEDER (2005) indicate that socially marginalized households are most often access constrained. Very specific instruments must be applied to reach those households but without lowering credit risk standards to avoid a rise of non-performing loans (see section 3 for examples).

10 The group members are not held liable for each other. If one group member defaults, it is enough to expel the defaulter from the group in order to obtain a new credit. Therefore, joint liability does not exist and the concept of peer pressure does not work.

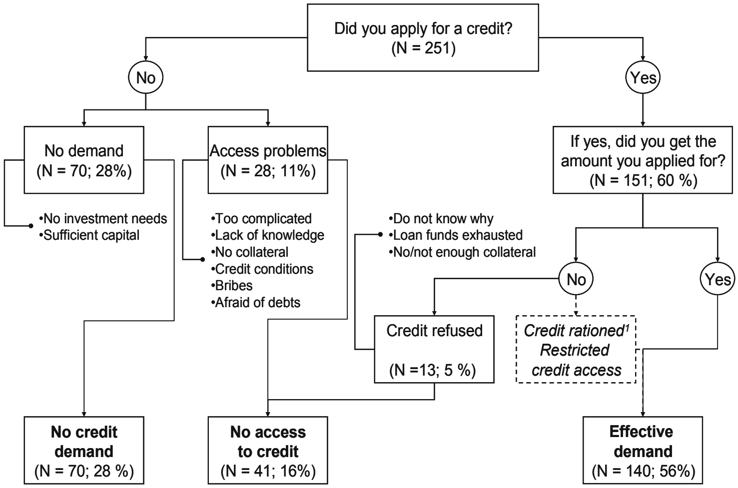

Figure 6.6: Decision tree of effective credit demand in the formal sector.

Source: DUFHUES and BUCHENRIEDER, 2005, adapted from BARHAM, BOUCHER and CARTER, 1996; HEIDHUES and SCHRIEDER, 1998.

Note: [1] Credit rationed households do have access to the formal financial system and are therefore not separated in the analysis. Besides, in one research area (Ba Be) not a single household was rationed. Nine households have been excluded from the sample because of missing values. This decision tree includes the formal and semi-formal financial institutes VBARD, VBP and the State Treasury.

Savings: The results of this research support the hypothesis that rural households in developing countries, even the poor and poorest, demand micro-savings services. However, this empirical result still contrasts with the views of many decision-makers within the Vietnamese Government and the two state-owned banks for rural development. They still consider credit as the only financial measure to promote rural livelihoods and strongly believe that the rural poor are unable to save. Analysis of the empirical data has shown that poor households are able and willing to save. Over 80% of the 260 interviewed households demand a formal savings scheme and would save on average 25 US$ per year. The supply of savings services offers both the possibility of strengthening financially sustainable structures within the existing institutes and increasing the outreach of the formal financial sector.

When offering savings services to the rural population, especially to the poor, close physical proximity to customers is seen as a key factor of success, particularly for women. Women are responsible for many tasks in the household and on the farm. It is much more difficult and costly for them to reallocate time towards other activities than it is for men. The World Bank and DFID (1999) state that any kind of policy intervention must consider the women's tight time schedules. This proximity could be achieved by creating decentralized profit centers. Credit officers would collect and pay out savings as well as performing all credit activities. Thus, the deposit collection could be done within the village. Local savings collection by the credit officer would also very positively influence the credit business. The credit officer has access to a much broader range of information to assess the clients' creditworthiness. These profit centers also guarantee good internal monitoring of most operational costs involved in financial intermediation. The Bank Rakyat Indonesia offers a good example. Besides, savings instruments need to be promoted much more than credit. Therefore, a marketing and advertisement strategy is essential to absorb the substantial amount of rural savings. Nevertheless, the strongest decision parameter is still the interest rate.[11] Farmers want to get paid for a temporary renunciation of consumption due to their high time preference rate. The main challenge will be to implement a safe, attractive and cost-covering deposit collection system at village level. Simple savings products can coexist with more complex market-segment-oriented saving products. Therefore, a range of products should be implemented and promoted with time. The implementation of the VPSC represents a right step in this direction.

Livestock insurance: Scholarly evidence (e.g. MUSTAFFA-BABJEE et al., 1987; WORLD BANK and DFID, 1999) as well as our own data show that farmers suffer losses among their animals,

[11] DUFHUES ET AL. (2003a) showed that households place special emphasis on a high interest rate for savings products. Corresponding to economic theory (i.e. time preference rate), this tendency is more marked in indigent households.

hinting at the need for a risk management mechanism. The stated demand for livestock insurance among farmers is high, covering 77% of all farmers in this sample. Yet the supply of insurance schemes in the market is low and relates mainly to small-scale schemes or very limited regions. One problem plaguing all suppliers of livestock insurance in Vietnam is the limited availability and low reliability of data concerning livestock mortality. Thus, insurers must calculate their premiums based mainly on assumptions. This leaves the insurer at great risk of setting the premiums too low and thus endangering its financial sustainability. As long as no public information on the real mortality rates of farm animals is available, it is almost impossible to price livestock insurance correctly. Nevertheless, it is reasonable to assume that demand for the schemes would decrease drastically if premiums reflecting the real mortality were charged.

6.3.5 Conclusions

The liberalization of interest rates is an important step towards full transformation of the financial system in Vietnam and offers the potential for financial intermediaries to supply cost-covering services. However, as long as the Government continues to supply subsidized credits to major parts of the population, it is unlikely that any viable services (private or state-owned) can be offered in the rural financial market.

A promising development is the attempt to integrate savings services for the rural population into the financial system. This attempt resulted in the creation of the VPSC and might indicate a paradigm change, namely recognition of the rural population's demand for deposit instruments. Finally, this paradigm change might bring the tradition of considering credits as the only financial tool for development to an end. Nevertheless, the VBARD, despite its immense network, has never reached deep enough into the country to attract rural savings. Furthermore, the VBSP does not show any intention to offer savings instruments to its customers. Therefore, discontinuing the Vietnamese soft loan policy will most likely take much more time.

Despite all the progress achieved in the transformation of the financial system, its sustainability is still threatened by a pile of non-performing loans accumulated by state-owned enterprises over the years. In addition, the problem of non-performing loans is spreading to the private sector and particularly to rural households. The situation will possibly be aggravated by the fact that the VBSP will supply subsidized loans for higher education. Without the creation of appropriate jobs, however, newly graduated young debtors will face difficulties in paying back the loan, as has just been the case in China (THE ECONOMIST, 2004). Apart from macro-economic threats to the financial system, this behavior of moral hazard is hindering the establishment of any viable rural financial intermediation.

A more sustainable way to promote outreach would be to improve the rural population's knowledge of credit application procedures, as access by ethnic minorities is often hampered simply by a lack of information. An ethnic diversification of bank employees could broaden the information networks available. Local information centers, in combination with the introduction of regular information days (preferably market days), when bank staff are locally available for questions and discussion, would further improve the availability of information. Designing employees' contracts to include incentives to pass on information to different social networks, would round off a transparent credit policy.

Nevertheless, state-owned rural lenders have enormous outreach. At this stage, implementing a consolidation policy and establishing financially sustainable structures would deserve to take priority over boosting credit outreach further by introducing new structures. An important element for inducing innovation in the microfinance industry is to nurture conditions for greater competition between different suppliers. As long as no effective competition exists, there is little incentive for the existing institutes to improve their products.

Although there is a demand for insuring credit-financed livestock investments (particularly by poorer households who invest in cattle or buffaloes) and there are many advantages in offering (compulsory) livestock insurance to rural lending institutes in Vietnam (protecting poor clients from risk, reducing lenders' loan defaults and earning additional income related to the loan portfolio), only sound and financially sustainable lenders should offer micro-insurance services. The main rural lender in northern Vietnam (VBSP, formerly VBP) is not financially sustainable and, therefore, is not suitable for offering insurance products. The VBARD might become financially sustainable in the near future and could expand its products to also offer livestock insurance. Nevertheless, it is highly recommended to involve a professional insurer in this process through 'partnering'. ALDERMAN and PAXSON (1992) state that the absence of insurance possibilities limits the households' ability to reduce consumption fluctuations, yet this does not necessarily imply that the most effective intervention would be to set up insurance programs. Providing better access to savings and loans may be a preferable method for helping clients to manage risk. While formal credit coverage is immense, there is a vast, unsatisfied demand among the rural population for accessible savings products.

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6.4 Participatory Research for Sustainable Development in Vietnam and Thailand: From a Static to an Evolving Concept

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6.4.1 Participatory Research and Sustainable Land Management: What is the Link?

According to its proponents, participatory agricultural research is related to sustainable land management in various ways. First, it is argued that sustainable agricultural technologies can only be developed and turned into innovations and farmers' practices if land users' priorities are adequately addressed by the research agenda (section 2). Second, sustainability is not a static condition, but rather a negotiated and contested concept in which various tradeoffs exist, and different – and often dissenting – perspectives of numerous stakeholders have to be taken into account (section 3). Third, involving farmers in technology development and making use of their knowledge and comparative advantages in experimenting is regarded as a prerequisite for generating innovations that contribute to sustainable land use (section 4). Finally, the institutional and socio-political setting plays an important role in creating a favorable environment for sustainable land management (section 5).

6.4.2 Lessons from Applying Participatory Methods in Setting Research Priorities

A research program that aims to address local stakeholders' needs requires that their views and priorities be integrated into the conceptualization phase. Few studies have dealt with eliciting stakeholders' priorities for agricultural research (e.g., PINGALI et al., 2001). In the preparation phase of The Uplands Program, the ranking method was used to give male and female farmers in selected villages the opportunity to set their own social and economic priorities for the following five-year period. This was done by presenting them with various pictures showing a whole range of agricultural and non-agricultural subjects. They were given a specified number of maize seeds and were asked to distribute them on the pictures. The more seeds they placed on a picture, the higher the topic's priority for them. The procedure started with general topics such as health, education, agriculture and forestry (first filter), followed by a second and third filter, which focused the discussion on more specific agricultural topics. More detailed information could then be gathered by open questions on specific topics such as crop diseases, animal nutrition problems or market access. Not surprisingly, the results unveiled a high variation in priorities depending on the socio-economic status, ethnic origin, age and gender of the respondents (NEEF and HEIDHUES, 2005). Several methodological and conceptual concerns with regard to farmers' priority- setting, such as difficulties in distinguishing between research and development projects and a tendency to give 'politically correct' answers, were also considered (cf. NEUBERT, 2000).

Designing a research program around an inquiry into farmers' priorities requires that their wishes be balanced with funding agencies' constraints and researchers' interests. It is also important to take other local stakeholders' priorities into account, since some upland farmers' priorities (e.g. increasing land under irrigation) are in sharp conflict with the interests of farmers in lowland areas. Farming in erosion-prone regions can have considerable external effects on downstream dwellers (e.g. by flooding, sedimentation or agrochemical pollution) and even on the international community (global warming through deforestation and slash and burn practices). A simple 'farmer-first approach' would not take these externalities into account (NEEF and HEIDHUES, 2005). Notwithstanding local stakeholders' conflicting priorities, scientists from all three partner countries remained the most powerful stakeholders and decision-makers, with DFG (German Science Foundation) reviewers of The Uplands Program having the last word in the evaluation process. Hence, the final version of the research proposal was a compromise between the specializations, research interests and capacities of German, Vietnamese and Thai scientists, farmers' priorities and other factors, such as the internal politics of all participating research institutions. Nevertheless, at least seven of the The Uplands Program´s research proposal were significantly influenced by, or even based on, the results of the participatory surveys designed to identify local stakeholders' priorities (*ibid*).

The DFG-reviewers suggested that local stakeholders' priorities should also be integrated into the preparation of the second phase of The Uplands Program. Compared to the relatively open methods chosen for farmers' priority-setting in the first phase, a more formal approach was adopted in Thailand to identify and confirm research topics for the second phase. In a questionnaire, scientists from partner institutions and representatives of government institutions in Thailand were asked to classify a total of over 70 research topics according to their relative priority in the respective research area. During a village meeting in the main study village of Mae Sa watershed, posters and short presentations were used to introduce research projects to an audience of 200 farmers. As a follow-up to this event, the village headman, his committee and 20 randomly selected villagers were asked to rank the projects presented according to their importance and to propose topics that they would like The Uplands Program to address in the second phase. The different stakeholder groups' major research priorities are summarized in table 6.4.

Results from the different priority-setting exercises in Thailand have largely confirmed the objectives and topics pursued by The Uplands Program. In addition, they showed how complex the research process becomes once different stakeholders engage in processes to negotiate pathways towards sustainable land use and sustainable rural development. Whereas farmers highlighted the importance of sustaining yields and incomes, mentioning topics such as plant protection, irrigation and plant nutrition as their favorites, representatives of local organizations put particular emphasis on research topics related to improving environmental quality. It can be concluded that priority-setting in agricultural research is always played out between a myriad of actors and goals; donors' demands, government policies, consumers' perspectives, researchers' preferences and farmers' priorities. The true challenge is to find the right balance between them (cf. NEEF and HEIDHUES, 2005).

Table 6.4: The six most important research priorities of different stakeholders in Mae Sa watershed in northern Thailand (2002).

Representatives of Thai local organisations n=13	Scientists from partner universities n=12	Village heads and village committee of Mae Sa Mai n=5	Villagers of Mae Sa Mai n=20
Soil fertility analyses	Increase in fruit tree productivity	Pest management in litchi cultivation	Pest management in litchi cultivation
Development of Environmental Information Systems	Fruit processing	Improvement of irrigation systems	Cover plants in litchi cultivation
Organic agriculture	Water-saving irrigation systems	Fruit processing	Optimisation of plant nutrition for litchi
Pesticide residues in water	Pesticide residues in water	Marketing of fruit	Fruit processing
Measuring soil erosion	Marketing of vegetables	Development of bio-insecticides	Water availability in soil
Resource rights	Marketing of fruit	Optimisation of plant nutrition for litchi	Reducing pesticide use in litchi

Priority-setting for the second research phase in Vietnam was embedded in a study of ethnic minorities' concepts of sustainability, which is presented in the following section.

6.4.3 Who Takes the Long-Term View? Local Perspectives of Sustainability

To date, experience of integrating rural people's perspectives and arguments into the definition of sustainability and in finding suitable indicators for its assessment remains scant. This is particularly true for mainland Southeast Asia, where misperceptions and generalizations of ethnic minorities' local knowledge and the sustainability of their agricultural practices have proven to be extremely persistent. Much of the literature on the traditional and current agricultural practices of ethnic minorities in mountainous regions of Vietnam and Thailand either generally classify these practices as 'non-sustainable' or categorize ethnic groups into 'conservers' and 'non-conservers' (NEEF, 2001; CHIENGTHONG, 2003). These judgments are often based on false assumptions, simplifications, misconceptions or prejudices. Those scholars who base their classifications on scientific analysis mostly adopt partial approaches to sustainability by using technical and biophysical parameters, such as erosion rate in tons per hectare or the crop-fallow ratio (for a noteworthy exception, see RAMBO and JAMIESON, 2003). The starting point of our study on "Ethnic Minorities' Perspectives of Sustainability" is that rural people's interpretations and concepts of sustainability are rarely considered in the scientific and development discourse. As a contribution to filling this gap, we explore outsiders' concepts and local people's perceptions of sustainability, compare the two and reveal areas of intersecting views as well as contradictions. This is in line with recent calls for a more "interactive (social) science" (RÖLING, 1996, 2001) or "dialogic research" (MOHAN, 2001) as a basis for bridging differences in worldview between so-called experts and local people in a dialogue on sustainability. Methodologically, we borrow ideas from approaches recently developed and adopted by British research teams in Uganda (HOWLETT et al., 2000) and Malawi (CROMWELL et al., 2001). A major difference in our approach is that we emphasize group discussions rather than individual interviews. As an analytical concept, we use the sustainable rural livelihoods framework developed by CARNEY (1998). It assumes that rural people depend on five different assets (natural, human, financial, physical and social capital) to sustain their livelihoods. The methodological challenge of the study is that the concept of sustainability as defined by scientists and development practitioners is generally not shared by rural people. It is therefore necessary to approach the subject with concepts that are more familiar to them. Farmers in selected villages of Yen Chau district, Son La province, Vietnam, were asked during group meetings to indicate factors determining the success and failure of local farming practices. Groups were stratified by age, social status and gender. All the factors mentioned by group members were visualized on cards to facilitate discussion. As a next step, respondents ranked success factors according to their relative importance. They were then asked to discuss the strategies they use to improve their livelihoods and to identify major constraints in this process (NEEF et al., 2003).

The aim underlying this procedure was to design data collection activities in the form of group discussions with arguments visualized on cards, so that local people's (and scientists') perspectives or knowledge systems could be elicited and interaction could begin. Although the communication process was hampered by various constraints, such as language barriers, unclear role distribution, different agendas among participating scientists and differing knowledge of the local contexts (FRIEDERICHSEN and NEEF, 2002), a considerable wealth of information could be obtained from the group discussions. Both male and female farmers showed awareness of decreasing soil fertility in their upland fields as a major threat to successful farming in the future. As participants feel they lack the means to counter erosion, they compensate for declining soil fertility by using high-yielding hybrid maize and by investing in animal husbandry. While animal husbandry is considered highly profitable, farmers are afraid of the risks of animal diseases, especially in pig and poultry production. Participants in the group meetings mentioned limited availability of feed resources as a major constraint for increasing the numbers of cattle and buffalo. Aggregating the factors mentioned in the ranking exercises to five forms of capital (assets) suggests that ethnic minority farmers put great emphasis on human (knowledge, skills, health, labor force), natural (soil quality, access to water) and financial capital (money to buy fertilizer or animals), whereas physical and social capital was of minor importance in the discussions (table 6.5). However, additional secondary data (e.g. time series) and longer-term observation are necessary to interpret the information gained through group discussions. This leads to the hypothesis that a major strategy of farmers to increase cash income is currently to expand the upland area under maize, regardless of the decrease in soil fertility. Improving the fodder base for big ruminants and intensifying livestock production, on the other hand, are promoted by local authorities and investigated by researchers, both with a more long-term orientation. Whereas several fodder species have been identified as attractive in terms of nutritional value and as being adapted to local agro-ecological conditions, adoption of these new technical solutions, beyond demonstration and experimental plots, is still low.

We conclude that, as a scientific concept, sustainability remains a tool of analysis mostly used by outsiders, experts and scientists. The sustainable rural livelihoods framework can, however, help researchers and practitioners structure the discussion of sustainability in a way which gives voice to rural people's own interpretations of livelihood, environmental and socio-economic trends and sustainability. This is a starting point for contrasting and negotiating scientists', local people's and policy makers' perceptions and interpretations of sustainability. An agreement on common indicators, accepted by all local stakeholders for analysing sustainable land management and sustainable rural livelihoods, would be a further step towards a more people-centered concept of sustainability as a basis for social learning and policy-making (NEEF et al., 2003).

Table 6.5: Factors for successful farming attributed to the five assets of the Sustainable Rural Livelihoods Framework.

Groups	1st rank	2nd rank	3rd rank	4th rank	5th rank
Bo Kieng village (H'mong, male respondents)[1)]	N	H	H	H	-
Ban Bat village (Black Thai, male respondents)	F	N	H	H	N
Ban Kha village (Black Thai, women's group)	N	F	H	H	H
Ban Kha village (Black Thai, young farmers)[1)]	S	H	H	H	S
Ban Kha village (Black Thai, 4 elders)	H	H	F	F	F
Na Pa village (Black Thai, 4 heads of newly-established households)	H	H	S	F	F

1) No ranking was carried out in these meetings. Factors are listed in order of their being mentioned during the discussions and grouped according to the following categories: N = natural capital, F = financial capital, H = human capital, S = social capital, P = physical capital.

In the following section, we present a case study from northern Thailand, which shows that local people can be involved not only in setting priorities and negotiating concepts of sustainability, but also in the process of technology development.

6.4.4 When Farmers Take Over: A Case Study of Developing Soil Conservation Technologies in Northern Thailand

In the hillsides of northern Thailand, cover legumes adapted to low-fertility soils are seen as a promising option for soil conservation and weed control, soil improvement and, at the same time, as potential forage plants in smallholder hillside orchards. Sub-project C1 "Cover Plants for the Sustainable Improvement of Fruit Production Systems in Hillsides of northern Thailand" analyzed the potential of 14 wild-species legumes to be used as multi-purpose cover crops in fruit orchards. A species x environment interaction study was established at three sites of contrasting altitudes in the area of Chiang Mai city, Chiang Mai province, northern Thailand.

One cover crop, *Arachis pintoi* cv. Amarillo, was of particular interest to farmers in Mae Sa Mai, where one of the controlled experiments was carried out. In a joint effort by sub-projects C1 and A1, farmer-controlled experiments with *Arachis pintoi* were initiated to follow up on the on-station and on-farm experiments under controlled conditions. Farmers had been introduced to the new cover crop during a presentation in the village and a field day organized on the on-farm experimental plot in Mae Sa Mai. Six farmers finally decided to test the cover legume in their own orchards. Researchers gave a short introduction to the techniques of vegetative propagation and distributed plastic bags with stolons from the Mae Hia and Chiang Khian experimental sites according to farmers' individual demands. The experiments were entirely farmer-managed and jointly monitored by farmers and researchers. Farmers decided on the location and size of the experimental plots and were responsible for planting and maintenance (weeding, fertilizing). Farmers were very cautious in determining the size of the experimental plots. None of them designated an area of more than one percent of the total field size for the experiment. Planting densities of 50 x 50 cm were recommended by the researcher, but most farmers varied the planting densities according to their own judgement. The researchers distributed field books to the farmers for regular recording of labor and other inputs. As some of the farmers were illiterate, a research assistant helped in keeping the field book. The researchers monitored the *Arachis* cover density in the experimental plots at monthly intervals over a five-month establishment phase. Farmers were highly creative in experimenting with *Arachis* in their hillside orchards. Some created their own experimental designs, such as varying weed management prior to stolon planting and comparing the effects of different light intensities.

Data on vegetative propagation could be recorded on six experimental plots. While one member of the initial group of six experimental farmers abandoned the experiment after a few weeks due to lack of time for maintaining the plot, another farmer subdivided his plot into one part that was treated with herbicides prior to planting *Arachis pintoi* and one part that was hand-weeded before planting. Data on cover densities suggest a high variation in ground cover during the establishment phase of *Arachis pintoi* and a significantly lower than average performance of the crop in farmers' fields as compared to controlled trials (table 6.6). Farmers reported various problems in the first months, such as adverse effects caused by periods of drought, insect pests and weed competition, the latter particularly after using fertilizer. Labor input turned out to be a decisive factor in establishing *Arachis*. Farmers who frequently weeded their plot achieved the highest cover densities of *Arachis*. In the case of two farmers, weeding time interfered with other economic activities, such as growing vegetables and working off-farm (NEEF et al., 2004).

Table 6.6: Cover densities of *Arachis pintoi* in farmers' fields in Mae Sa Mai as compared to controlled on-station and on-farm experiments.

	Type of experiment	Fertiliser level	Cover density (month, %) 1	2	3	4	5
Lowor no participation	On-station trial (controlled, 3 repl.*)	low	2.8	23.1	57.5	86.7	95.0
	On-station trial (controlled, 3 repl.)	high	3.0	30.9	65.8	85.0	93.3
	On-station trial (controlled, 3 repl.)	low	4.5	47.8	96.7	98.3	100
	On-station trial (controlled, 3 repl.)	high	5.0	56.5	97.5	99.2	100
	On-farm trial (controlled, 3 repl.)	low	2.8	13.5	55.0	91.7	96.7
	On-farm trial (controlled, 3 repl.)	high	3.0	16.5	49.2	94.2	95.8
	Type of experiment	**Labor input**	**Cover density (month, %) 1**	**2**	**3**	**4**	**5**
High degree of participation	On-farm trial (farmer-managed)	high	12.0	61.6	70.8	80	60
	On-farm trial (farmer-managed)	high	12.0	50.4	68	90	70
	On-farm trial (farmer-managed)	Low	6	9.4	13.2	13.2	10
	On-farm trial (farmer-managed)	Low	5.2	30.4	19.2	18	16
	On-farm trial (farmer-managed)	Low	10	34.8	30.8	30	25
	On-farm trial (farmer-managed)	Low	20	43.5	70.4	20**	25.3

*repl. = replications; ** effect of herbicide spraying

Source: Data from sub-project C1 (SCHULTZE-KRAFT et al.), cited in The Uplands Program (SFB 564), 2003, p. 241; NEEF, SCHULTZE-KRAFT et al., 2004.

The major conclusion from the farmer-managed experiments is that farmers have to invest a considerable amount of time into establishing a crop whose direct benefits accrue mostly in the long term. As cover crops like *Arachis pintoi* can provide substantial indirect benefits for downstream users in terms of reducing erosion and preventing landslides, temporary subsidies to support the establishment phase of the crops may be justified. On the methodological side, the experimental capacities of farmers in the *Arachis* trials confirm other authors' findings suggesting that farmers' experimentation has a much more formal character than often expected by scientists, and that combining researcher-controlled experiments and farmer-managed trials can provide valuable synergetic effects (cf. VAN VELDHUIZEN et al., 1997; SUMBERG et al., 2003).

6.4.5 Institutional and Socio-Political Context of Participatory Research Approaches in Vietnam and Thailand

Participatory approaches in agricultural research are still regarded as a kind of experimental field that may create some success stories. If participatory research can prove its usefulness in at least some defined areas, the logical consequence is to mainstream these successful approaches. The chances of implementing participatory research approaches – beyond the experimental field of a collaborative research program financed by a foreign donor – have to be estimated within the wider institutional and socio-political context, including current experience of participatory approaches.

Participatory approaches in agricultural research projects in northern Vietnam. In Vietnam, participatory approaches emerged at the beginning of the 1990s through the influence of bilateral projects and international donor agencies. The political climate for the adoption of these approaches started to become favorable under the policy of '*doi moi*' (renovation), initiated by the Vietnamese government in 1986. Today, most international rural development projects in Vietnam carry the 'participatory label'. National programs such as the 'Poorest Commune Program' have also formally adopted local participation and decentralization as key strategies for hunger eradication, poverty alleviation and overall rural development. This is in line with the spirit and letter of the 'Grassroots Democratization Decree' (decree 29) launched in 1998, which calls for greater transparency and political participation (cf. FRITZEN, 2000; NEEF et al., 2002). While several studies point to the difficulties of implementing decree 29, such as a lack of devolution of power from provincial and district to the commune level, civil servants' top-down attitudes and a lack of incentives for more transparent procedures (PROHL et al., 2001; WORLD BANK, 2002), its main principles of information, consultation, discussion, joint decision-making and monitoring by local people represent an important step towards wider public participation. The decree also creates a more favorable environment for participatory agricultural research.

To date, a significant proportion of research activities in national agricultural research institutions are carried out under on-farm conditions, though purely farmer-managed experiments are rare exceptions. Incentives from international donors and the political program for participation are still entangled with a notion of science shaped by positivist and reductionist concepts on the one hand and a political environment where centralized planning prevails on the other. Findings from a workshop organized by Vietnamese and German members of the participatory research sub-project showed that many research projects in mountainous regions of northern Vietnam have been implemented without coordination and with a narrow focus ignoring the complex and heterogeneous environments in those areas. To avoid the shortcomings of these approaches, the Vietnam Agricultural Science Institute (VASI) has collaborated with various foreign and domestic partners to develop research networks with the participation of different organizations at all levels. One of the lessons learned from the network approach is that continued field presence and regular contacts between farmers, researchers and extension workers create an environment of mutual learning and information exchange. A prerequisite for success is that all partners in the network are considered equal and agree upon clear management mechanisms and shared responsibilities (DOANH, 2002).

Experience of on-farm research at the National Institute of Animal Husbandry (NIAH) suggests that farmers can be talented researchers and are able to identify research priorities, make plans, monitor, compare, analyze and draw conclusions from the results of the experiments. It is therefore considered crucial that farmers be actively involved in all phases of the problem-solving cycle and in decision-making processes. Various case studies from NIAH's work show that participatory, on-farm research is more effective, though more costly, than on-station research. Some professionals, however, criticize the lack of scientific accuracy in on-farm animal research. There is also a tendency for local elites - the rich and the literate in the villages - to dominate the process. Participatory research often fails to comply with higher-level planning targets, and senior officials in government organizations tend to be obstructive (NHO, TUNG and BINH, 2002). One of the major conclusions from national and international project experience in Vietnam is that involving extension workers, local authorities and other relevant stakeholders in the participatory innovation process is of paramount importance in putting technical and institutional innovations into practice and having them accepted in areas outside the project's boundary. The implementation of such multi-stakeholder approaches takes more time and requires increased commitment to nurture and re-negotiate relationships among stakeholders, but only through such integration into local structures (which persist beyond the project's duration) can the long-term sustainability of the project activities be achieved (NEEF, NGUYEN THE DANG and HEIDHUES, 2002).

Our research on lowland Kinh – upland minority relations suggests that working with particularly low-status and marginalized groups, such as the Hmong, poor villagers of any ethnic minority group and women would deserve more and special attention in participatory research (FRIEDERICHSEN, 2004). It is obvious that on-farm activities in the northern mountains tend to be focused on easily accessible locations in the valley bottoms for practical reasons. The implied preferential involvement of ethnic groups that are seen as rather close to the Kinh (e.g. the Tay-Thai language group or the Muong) is problematic, however, from an equity-perspective. It fails to address already existing differentials in wealth and access to outside knowledge. The predominant view among Vietnamese (and many foreign) researchers that scientific knowledge is superior to local knowledge and should be transferred to upland farmers to replace their 'backward' farming practices, impedes the creation of a more partner-like relationship between researchers and local people, where innovation would be a result of joint knowledge generation rather than a commodity transferred mono-directionally from scientists, via extension workers to farmers.

Participatory research and development in Thailand under the People's Constitution of 1997 and the 6th National Research Plan. Participatory approaches in watershed management gained popularity in northern Thailand from the late 1980s onwards, intertwined with the efforts of national agencies and international projects to develop alternative income opportunities for opium producers and to combat slash and burn agriculture, regarded as destructive of natural resources (e.g., PUGINIER, 2002). In the early 1990s, Thailand has launched a fairly ambitious experiment in decentralized governance, conferring greater responsibilities upon sub-district administrations (TAOs) and fiscal opportunities for local development planning. This process was reinforced by Thailand's new Constitution of 1997, which explicitly emphasizes the involvement of local people in decision-making processes that affect their livelihoods. This new paradigm challenges the top-down concept of government policies, the paternalistic attitudes of bureaucrats towards rural people, and the traditional mandate of line agencies under the Ministry of Agriculture and Cooperatives and the newly established Ministry of Natural Resources and Environment (DUPAR and BADENOCH, 2002; CHIENGTHONG, 2003; GILLOGLY, 2004). Putting the principles of the People's Constitution into practice and "ensuring democratic processes in all development activities, will require a radical departure from a very much centralized system of government. It also calls for a new system of thinking, not only on the part of public agencies but also on the part of the people themselves" (NABANGCHANG, 2005).

Attempts to include participatory research and development approaches in the Thai agricultural sector began in 1992 with a research project supported by the Canadian International Research and Development Center (IDRC) and involving the Department of Agriculture (DoA) and the Department of Agricultural Extension

(DoAE). Though the approach proved successful in enhancing Participatory Technology Development (PTD) and participatory extension approaches among government staff directly involved, it remained rather site-specific (confined to a few areas in the upper northern provinces) and commodity-oriented (towards wheat as a newly introduced crop) and was thus not able to bring about profound changes in the institutional culture of the two departments (DoAE, DoA and MCC, 1995; cf. CONNELL, 2005). Despite the link to high-level policy makers in the DoAE, it was obvious that institutional change favoring participatory technology development was more than could be handled at a project level. Another attempt was launched in 1999 by the Sustainable Agriculture Development Project (SADP), funded by the Danish Cooperation for Environment and Development (DANCED) over a period of two years. The responsible agency was the Department of Agriculture through the eight regional branches of its Research and Development Office. The main purpose of the project was to introduce sustainable agricultural practices to Thai farmers through PTD approaches, which involved much dialogue between government officials and farmer groups and new ways of working by the government agricultural researchers. Over the three years of its duration, with the support of Thai academics with long-standing expertise in participatory approaches, such as Phrek Gypmantasiri, Associated Director of the Multiple Cropping Center in Chiang Mai University, the project was able to create a pool of more people-oriented agricultural researchers. It also facilitated grass-root innovations and listened more to the needs of farmers. However, the linkage between researchers' scientific knowledge and farmers' knowledge was not clear. Rather than looking for ways to use farmers' knowledge to push forward the frontier of agricultural research, people tended to treat agricultural knowledge and development as equivalent to the discovery and extension of local knowledge. It also remained uncertain whether this project could induce the long-term institutional changes needed to make agricultural research more farmer-responsive. Notwithstanding these shortcomings, the success of the project lay in providing Thai agricultural researchers and extensionists with new approaches and insights into working with communities. In the Thai centralized bureaucracy, this achievement alone cannot be valued high enough.

The SADP project was succeeded by the Sustainable Agriculture for Environment Project (SAFE), funded by the Danish International Development Assistance (DANIDA) from 2003-2005. The project is operating at a nation-wide level and involves the two major departments of the Thai Ministry of Agriculture and Cooperatives (MoAC); the DoAE and the DoA. This project has switched the emphasis from participatory technology development towards biodiversity conservation and farmers' empowerment. Meanwhile, participatory approaches to agricultural R&D seem to be gaining more momentum in non-governmental organizations than in government line agencies under the MoAC. The Network of Sustainable Agriculture Foundation - a project assisted by the Thai Government through a network of NGOs emphasizing organic-based, community-oriented agriculture - has recently gained more multilateral support than any previous attempts by government agencies.

At the university level, the trend towards more participation in agricultural research and development is backed by the 6th National Research Program (2002-2006), which explicitly emphasizes closer cooperation between research institutions, users (farmers, industry), funding agencies and government bodies. Some funding agencies, such as the Thailand Research Fund, strongly emphasize community-driven, development-oriented research approaches with a focus on empowering local people. However, making the national agricultural research system in Thailand more receptive to local priorities and more participatory in its research processes remains a challenging task, given its tradition as a centralized, supply-driven system in which farmers have usually been passive recipients of the research output of universities and fragmented research institutes (ASIAN DEVELOPMENT BANK, 2001; NABANGCHANG, 2005).

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6.5 State Administration and Local Networks: The Case of Pang Ma Pha District, Northern Thailand

Rüdiger Korff, Hans-Dieter Bechstedt and Patcharin Nawichai

6.5.1 Sustainability from a Social Science Perspective

Certain basic aspects are often forgotten or ignored in the official discourse on sustainable development. By focusing on the technical and economic aspects, sustainability becomes a management problem that can be overcome by designing appropriate development policies. Based on an analysis of development policy in Lesotho, FERGUSON (1994) maintains:

"Development institutions generate their own form of discourse, and this discourse constructs a particular kind of object of knowledge, and creates a structure of knowledge around that object. Interventions are then organized on the basis of this structure of knowledge, which, while 'failing' on their own terms, nonetheless have regular effects, which include the expansion and entrenchment of bureaucratic state power, side by side with the projection of a representation of economic and social life which denies 'politics' and, to the extent that it is successful, suspends its effects." (FERGUSON, 1994: xv).

What are these easily forgotten basics? To start with, sustainability can only be achieved if the respective authorities are willing to embark on a course of sustainable development. But even if this is the case, development policies, projects and interventions, whether they aim at sustainability or not, depend on the structure of the state administration that designs and implements them, and on the reach of this administration in terms of administrative authority and supervisory capacity (GIDDENS, 1985). In a similar vein, the market economy can only allocate resources and play a role within its reach.

While state administration and a market economy refer to structural bases for sustainable development, personal consciousness is just as relevant. As long as the people perceive themselves to be mere objects of the state and market, these appear as external, uncontrollable forces, similar to natural calamities, ghosts or dangerous spirits that one has to placate through appropriate rituals.

In northern Thailand, some ethnic minority groups such as the Hmong and Lisu are portrayed as clever and efficient traders, rapidly responding to incentives. Indeed, many of the Hmong and Lisu communities have changed their crops from poppies to vegetables, fruit trees and other profitable agricultural cash crops over the last three decades. However, in both cases money (or formally silver) in their views is primarily defined as a means to gain status. For the Lisu especially, status - expressed in terms of silver and, increasingly over the past few years, in terms of consumer goods and cars - is most relevant, as this influences the choice of marriage partners, social standing within the village and even more so within the clan. In addition, the source of silver or money is rather irrelevant in measuring prosperity. Thus, whether the money comes from legal trade, drug trafficking or prostitution makes not much difference. The question, then, is whether we can define this system as a true "market economy", or whether it makes more sense to speak of market exchange embedded in a "moral economy". Morality is intertwined with a social unit, for which moral codes exist and which are institutionalized as forms of individual conscience. The most basic dimension of morality, and also for sustainability, is controlling violence.

The use of violence is commonly strictly regulated within the family, the clan and ethnic group, i.e. within communities or semi-communities. With the rise of the state and especially the nation-state, the social control of violence by communities is substituted by the monopolization of violence by the state as the basis for internal pacification (GIDDENS, 1985; ELIAS, 1989, 2001). This pacification through monopolization of legitimate violence exists, however, only where the state asserts control and is able to enforce it. Until the early 1960s and in more remote areas until the 1980s, the Thai state had little influence in many parts of the northern Thai highlands. In fact a foreign army, the Kuomintang, took over sovereignty functions in certain regions, while other areas, such as the Pang Ma Pha District in Mae Hong Son Province, were under the influence of neighbouring Shan warlords.

In conclusion, discussing sustainability from a social science perspective requires an analysis of the extent to which sustainability makes sense with regards to the region and the spaces studied. In fact, such an analysis is crucial to avoid, firstly, sustainability as being a mere official statement nobody is interested in implementing, secondly, sustainability as turning into a "cargo cult", i.e. a kind of ritual of governmental and non-governmental development organizations designed to receive support from donors, and thirdly, supporting a trend that facilitates under-development under the guise of sustainability by destroying the livelihoods of the local population through a process of development, dislocation and finally dispossession.

An analysis of sustainable development in Pang Ma Pha District thus requires, firstly, an analysis of the integration of this rather remote district into the Thai state administration and the market economy, and secondly, an analysis of local organisation patterns, and finally, the analysis of conscience.

6.5.2 Patterns of Local Integration in a Centralized Social System: Patronage and Sustainability

Thailand is commonly described as a highly centralized society. This is already evident from the predominant role of Bangkok, where not only more then 60% of the urban population of Thailand resides, and which has several times the inhabitants of the second largest city, Chiang Mai, but which is also where the political, socio-cultural and economic elites are centred. Development over the last fifty years has even increased centralisation, as the institutions on which a modern administration and economy depend tend to be in Bangkok. In terms of trade, for example, Thailand's official exports and imports go through Bangkok and are dominated by the large traders within the city. Even domestic trade often proceeds through Bangkok, and thus the markets in this city define prices in the provinces.

Centralization used to be intertwined with patronage. RIGGS (1966) speaks of a "bureaucratic polity" in which the heads of the bureaucracy are the dominant holders of political power. Those persons having political and economic power act as patrons, supporting the advancement of their respective clients by providing opportunities and support. In turn, the clients have to support the patron's interests, especially in the case of internal factional struggles. Patronage and clientelism are, following EISENSTADT and RONINGER (1984), specific forms of institutionalisation of inter-personal relations and especially of trust within social structures and their differentiation. It emerges particularly in those societies where the degree of internal cohesion and solidarity within society as a whole, as well as among the elites and other sub-groups, remains limited. In cases of a low degree of cohesion and thus integration, sub-groups, communities, etc. can maintain a high level of cultural, symbolic and organisational autonomy (EISENSTADT and RONINGER, 1984: 205).

The persistence of patronage obviously hinders sustainable development. It limits the integration of spaces into the administration as well as into markets, and limits pacification as a result. Violence is always lurking behind patronage, and force is applied if alternative forms of network institutionalization emerge. This is valid even for benevolent patrons, who try to appear as helping their poor clients.[12] If they do not have to use force against their clients, they apply force against other patrons. The warlords in the uplands of Burma are one example. But even if the level of violence is low, and while patronage maintains local autonomy, it consequently requires mediators between the local communities and their patrons on the one side, and the outside world of the state and market on the other side . As a result, there are no opportunities for "learning" how the market economy and administration work and, accordingly, no cognitive structures can evolve that allow for coping with them. The people thus remain objects of outside forces and have to turn to the patron for salvation. As a matter of fact, patrons follow their own agenda.

12 Patronage can easily evolve in development projects, which lack a truly participatory approach and are run in a top-down fashion, with the experts being perceived by the 'target groups'' as their patrons.

Finally, patronage is highly detrimental to the development of public sphere. While public life is integrative, and even integrates differences, patronage is atomizing. In conclusion, as long as patronage is predominant, sustainability remains a chimera.

6.5.3 The Integration of Pang Ma Pha District into State Administration and the Market Economy

Until the 1950s, the Thai Government managed most of the countryside with only a few district officers and policemen. During the 1960s, it started to promote export-oriented agribusiness, to build roads and push the administrative machinery into the countryside to oversee this expansion. *Phu yai baan* (village headmen) and *kamnan* (head of a group of villages or sub-district) were co-opted into the government pyramid as the lowest strata of rural administration. Formerly, these leaders had acted as the mouthpiece of the village community. *'Now they were transformed into the instrument through which outside forces penetrated the village.'* (PHONGPAICHIT and BAKER, 2002).

It was during that time that a district office was built in what is today Soppong's old town, but later removed to a new area just outside the town. Villagers recall that time as a period when large-scale timber extraction and poppy growing were the major agricultural activities in the district, with only a few wooden shop houses in Soppong around the old market, and most of the ethnic people moving around in the still densely forested mountains with no permanent settlements. It was also a time of lawlessness, with gunmen and warlords controlling law and order. The area was under the territorial influence of the notorious drug baron Khun Sa and his Shan army from neighbouring Burma, to whom the tribal people once a year – on the occasion of his birthday – went on a pilgrimage to show their respect and deference.

With the arrival of the Royal Forest Department, logging operations were officially banned and two "Wildlife Sanctuaries" established, with most of the other areas in the district falling under the category of "National Forest Reserve". In the past, forests in Pang Ma Pha were rich and largely undisturbed. Recently, due to the influx of new settlers and the increase in the indigenous population, the use of natural resources has intensified. Forests have degraded rapidly, wildlife - i.e. all bigger species - has disappeared, and water shortages have begun to adversely affect paddy production in the lower areas, especially during the dry season. Certain village groups, encouraged by outsiders, made a profit from cutting timber for commercial purposes. Others cleared forest land to convert it into agricultural land. As a result, many conflicts arose regarding forest encroachment, land and water use and village/community boundaries.

During the 1970s, the Thai state gradually established its territorial sovereignty by pushing Khun Sa back to Burma, suppressing the production and trade of opium and promoting (cash) crop substitution programs with the support of international organizations. This included the Thai-German Highland Development Program (TG-HDP), jointly executed by the German Agency for Technical Cooperation (GTZ) and the Office of Narcotic Control Board (ONCB) between 1981 and 1998 in the area of Pang Ma Pha, among other places. Thailand's broad development policies at that time were characterized by a close link between the efforts to secure national integration, drug control and a development approach that focused on modernization, aimed at integrating the national economy into the world economy (PHONGPAICHIT and BAKER). In short, there was little room in this context for traditional indigenous culture, as the penetration of capitalism and the market economy started to extend into even the remotest communities, as part of the emerging global economy and society (MCKINNON and VIENNE, 1989; MCCASKILL and KAMPE, 1997).

The definition of Pang Ma Pha as a district rather than a sub-district and its integration into wider trading networks led to shifts of the regional centres. However, the basic settlement pattern based on ethnicity remained. Looking at the historical process of founding new villages and inter-village relations, several patterns can be identified, based primarily on ethnicity.[13]

[13] Most of the villages not connected in the diagram are from the sub-district of Na Phu Phom, of which we still have only limited knowledge. The Lisu villages Kid 30 and Nam Po Sape more are

Apart from a single Lawa settlement, the oldest villages are of the Shan, a Dai-speaking minority people who, in cultural terms, are closely related to the northern Thai. The central site was Mae La Na, located in a fertile valley, thus allowing for intensive rice production that could feed a larger population and enabled rice exchanges with the surrounding hill tribes. The orientation was probably more towards the Shan state in Burma then towards Mae Hong Son or Chiang Mai in Thailand. Chiang Mai in particular was difficult to reach at those times. The Shan villages of Na Phu Pom in the western valley, Mae La Na in the centre and Tham Lod in the east were linked to each other and formed central places, through which the region was connected to other northern villages (Figure 6.7). Today, these three villages, together with Soppong, are the four sub-district centres of Pang Ma Pha District.

The Black Lahu entered from the north into the area of Pang Ma Pha and established their villages along the main mountain range towards the south. Similarly, the Red Lahu, who likewise in-migrated from Burma, moved to slightly more eastern locations and then moved further southwards. Commonly, the Lahu establish so-called "Pang Kham", which are fields located further away from the village, where some huts are built as shelter against the rain and sun, and some small animals (chicken and pigs) are raised. These shelters allow the farmers to stay there for a few days. Close to these "Pang Kham", new settlements (often referred to as satellite villages) were established if the village became too large or internal conflicts emerged. In such cases, some families left the older village and established a new one.

isolated, as they are not historically linked to other villages in Pang Ma Pha.

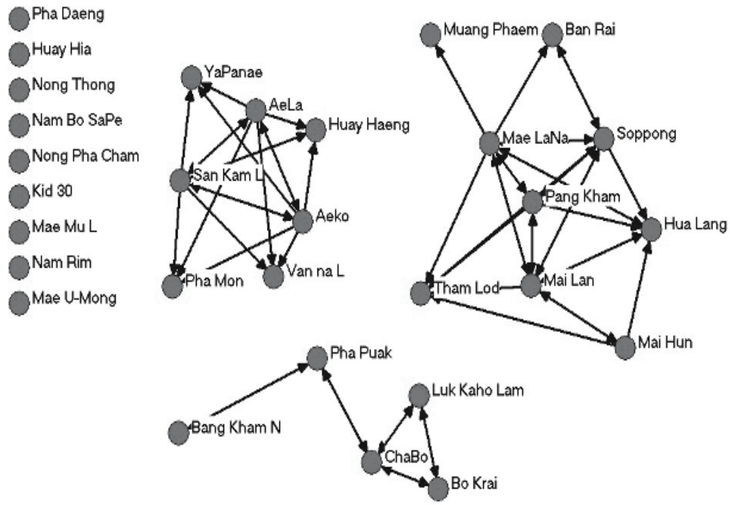

Figure 6.7: Inter-village relations in Pang Ma Pa District.

The Lahu and Shan, like other minorities, are specialized in adapting their livelihoods to different ecological niches and thus conflicts usually do not occur. The Lahu live higher up in the mountains and grow upland crops, while the Shan occupy the valleys. Cash crops, mainly opium until the 1990s, were traded through the Shan villages. The Lisu, who now live in the southern part of Pang Ma Pha, have moved into the district from the east, namely from Doi Saket and Chiang Dao Districts, Chiang Mai Province and, in some cases, from Pai District, Mae Hong Song Province, following the Pai river. An exception is the Lisu village of Nam Po Sape, whose residents came more recently from the north-west. Similar to the Lahu, the Lisu occupy the higher mountains. No Shan villages exist in their area of settlement. The origin of the District's only two Karen villages has still to be surveyed.

Today, ethnicity is still the main factor governing inter-village and intra-village relations. With few exceptions, the villages are homogenous in their ethnic composition. The pattern of settlement along mainly ethnic lines is still found in the district's current ethnic composition (Figure 6.8).

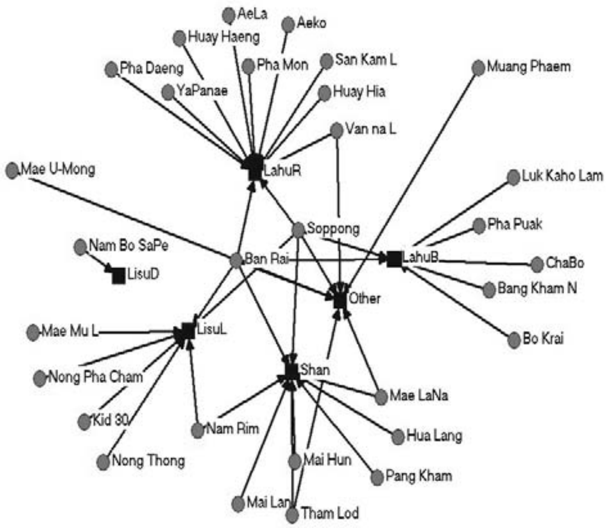

Figure 6.8: Pattern of settlement of ethnic groups.

While ethnicity displays features of segmentary differentiation, trading links rather suggest functional differentiation and thus constitute another form of integration. With the emergence of Soppong as an administrative centre, together with the building of the main road that provided closer district linkages to Chiang Mai and Mae Hong Son, Soppong became not only the district capital, but also the most central place in terms of trading relations. In particular, the building of the road triggered a rapid "urbanization" of Soppong and its rise as an administrative as well as a market centre. In this regard, a new centralization arose from a combination of infrastructural developments (roads, schools, hospital), state integration as an administrative seat and market integration. Consequently, Soppong has emerged as the major integrating location of the district. This becomes most obvious when comparing the fragmented structure of intra-district exchange outside Soppong with the trading structure centred in Soppong (Figures 6.9 and 6.10).

If we compare the respective networks based on cultural and ethnic relations with those based on trade, significant differences are evident. Soppong and Ban Rai as multi-ethnic villages are less integrated into the district in cultural terms, but are definitely trading centres. Both are rather new villages, even though in both cases they are based on old settlements. Soppong was once a small Shan settlement and Ban Rai settlement was regularly abandoned due to malaria in the valley.

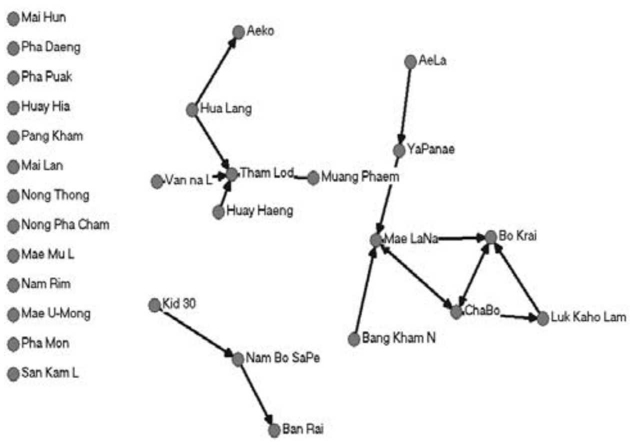

Figure 6.9: Trading relations outside the centre.

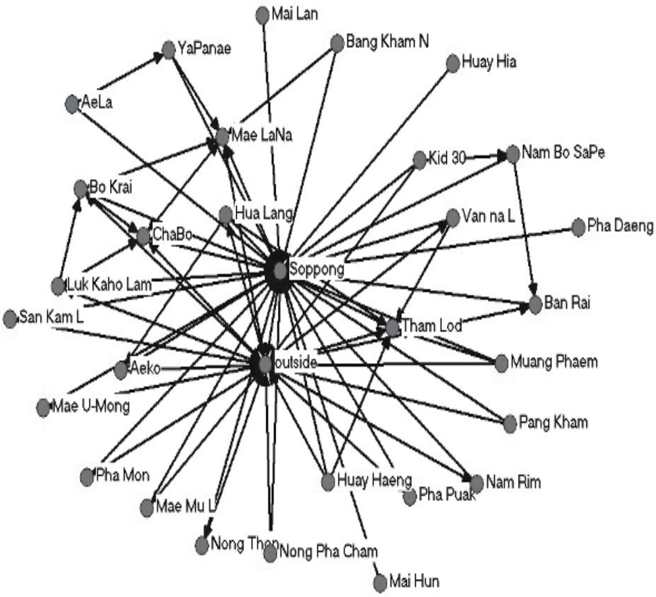

Figure 6.10: Trading relations through the centre.

Interpreting these data from the perspective of EISENSTADT AND RONNINGER (1984), the integration into the state and the market implies that centrality be redefined. The former central places declined and were substituted by new places, instead of a concomitant rise of the older settlements. The extent to which centrality in the district is linked to patronage can be seen from the history of one important local leader (Box 6.1).

Box 6.1. Lung Noi, the 'founder' of Soppong
Lung Noi and his family, all of them Thais originating from Pai District, is by far the most prominent and perhaps the richest person in Pang Ma Pha (PMP) district. His family owns the only gas station in the district town, the new market[14] and a

14 But he has no land title, as all of Soppong town is within the National Forest Reserve. However, land is sold and bought, although without

construction company, including a shop for construction tools and materials. He is greatly benefiting from government orders, as his son is the TAO Chairman of Soppong. It is said that in the past he was involved in the drug business, like most other well-off families in PMP. He is considered to be the founder of Soppong, as he moved the old market, already owned by him, to its present place around 30 years ago[15]. After that, many shops were set up by traders and merchants coming from Chiang Mai or other parts of Thailand. They settled around the new market under the patronage of Lung Noi's family. In the beginning, businesses in the district prospered due to the involvement of many traders in the opium and timber trade. However, with the logging ban, the successful suppression of opium production and trade in the 1970s and a more diversified market economy, traders, merchants, and lately also restaurant and guesthouse owners, became more independent and relied less on the extended network of Lung Noi's family, establishing their own networks instead. Resort owners, for example, attract their clients today through internet advertisements or through their network of tour operators.

land titles, and it is expected that in the future land ownership will be legalized.

15 Soppong market is a permanent consumer market offering products originating mainly from other parts of Thailand (even fruits, vegetables and meat mainly coming from Chiang Mai), but with clothes and electric appliances coming from as far as China. Once a week, on Tuesdays, a fresh market, where farmers from surrounding villages sell some of their surplus products, joins this permanent market. In general, agricultural products are bought by outside (urban-based) traders who come into the village to pick up the product, which is then sold in Chiang Mai or in other provinces.

Other key persons in the district are the former four elected sub-district Chiefs (*kamnan)* of Pang Ma Pha[16], Tam Lod, Na Poo Pom and Soppong. All of them are considered to be well off, either involved in the construction business (3 of them) or trade of agricultural products (1 of them), with a network of close relatives all over the district, and maintaining good contacts to local government officials and politicians. During the Government campaign against drug trafficking, three out of four were blacklisted by the police and went into hiding (Burma). To date, one has been killed by unidentified gunmen, another has been arrested, and the third is under house arrest. New *kamnan* were recently elected.

Another group of key figures are the government officials, with the officers of the Pang Ma Pha District Office at the apex. In Thailand today, both the district and provincial administrations are local state governments, i.e. hierarchical units administered, staffed and provided with a budget by the Ministry of the Interior (MOI). Districts are administered as sub-divisions of the province. Mirroring the organizational set-up of the provincial administration, the district oversees the work of local representatives from the various central line ministries and departments. As NELSON (1998) reminds us, there is neither a provincial nor a district administration in the real sense, as Thai administration is highly fragmented, consisting of officials separately delegated to work at these levels by their respective ministries or departments, such as the Ministry of Agriculture and Cooperatives or the Ministry of Education. Hence, relations between district-level officials *'are not intra, but inter-organizational relations'* (NELSONS 1998:32). Consequently, the functional ties remain limited and cooperation depends strongly on personal relationships among the officers.

Among the different ethnic groups and villages, the pattern of leadership differs. For the Lisu, leadership has never been strongly pronounced. The Lisu are basically akephal, hence the position as

16 Pang Ma Pha is the name of the district as well as of a sub-district. Unlike other places in Thailand, the centre of Pang Ma Pha District is Soppong town, while the centre of Pang Ma Pha sub-district is Mae La Na village.

village head does not necessarily imply a position of power within the village, although this seems to be changing. These changes partly result from access to the market as a source of prestige goods. The Lahu leadership is strongly based on charisma. In fact, if two charismatic leaders emerge within one village, this usually results in a split of the village, although among the Lahu, prestige goods are by far not as relevant as among the Lisu.

The Shan form a different category, as they had been integrated into a feudal form of political system (LEACH, 1954). However, as far as we could verify within Pang Ma Pha district, no aristocratic lineages ever played a role, probably because the valleys were too small and of little relevance compared for example to the Pai valley east of Pang Ma Pha. The Shan leadership depends strongly on charisma, combined with control over resources. In all these cases, charisma is, as always, not primarily dependent on personal characteristics, but on occupying central positions within the communities, which are a result of access to resources and prestige goods. Thus, even though patronage had not been instituted in a formal way, it was implicit to charismatic domination.

The basic problem with charisma is that cooperation is difficult, as two charismatic leaders tend to compete rather then cooperate. Furthermore, charisma is personal and thus based on personal relationships. With the integration into a wider context, the most crucial resource has increasingly become contacts and relationships with the local administrative officials, as well as personal relationships between communal/local leaders and officials, and also with local politicians and businessmen. These relationships are often combined and have been strengthened through the government-supported process of decentralization and the establishment of elected Sub-district *(tambon)* Councils.

The problem with the predominant role of charisma within local political systems is that it facilitates patronage, and patronage in turn makes the ‘quotidization’ of charisma difficult if not impossible. For Max Weber, the “*Veralltäglichung*” (quotidization) of charisma was crucial for the emergence of a modern bureaucracy. Charisma’s extra-everyday life is thereby transformed into administrative positions and made independent from the person. It is not the person that defines charisma, but rather the position that makes the person charismatic, which then allows for continuity.

6.5.4 Patronage or Self-Organization? The Rise of Ethnic Minority Networks in Pang Ma Pha District

In recent years, new forms of farmer networks have arisen, partly due to new political space and partly due to government bureaucracies that have largely failed to deliver adequate services. In northern Thailand, for example, ethnic communities came under increasing pressure due to new government legislation banning traditional forms of agricultural production in the name of conservation. Here, traditional forms of practices, information exchange and cooperation are revived and linked with new forms and opportunities. These new networks grew out of the need to fight for the protection of farmers' land, for conflict resolution over resource use among themselves or vis-à-vis other, often powerful and well-connected interest groups, for civil rights (e.g. citizenship), for protecting their community from drug trafficking and abuses, and for gaining access to relevant information, new technologies or development funds.

Networks are seen as a form of 'social capital', i.e. the capacity of individuals to command scarce resources by virtue of their membership in networks (PORTES, 1995), and are a basic pillar of sustainable development. To improve sustainability, then, means designing strategies to increase the efficiency and effectiveness of local institutions and self-organization. Thus it is not in itself evident whether the rise of these new networks in northern Thailand resulted from an increased process of self-organization or development intervention from outside. In other words, the question remains whether they contribute to 'social capital', enhance a 'public sphere' and thus contribute to a rising civil society or simply reproduce existing power relations by opening up new opportunities to the rural business and bureaucratic elite. The rise and decline of the multi-ethnic PMP Hill Tribe Network Organization reflects well the ambiguity of recent local people's networking in northern Thailand (Box 6.2).

Box 6.2: The evolution of ethnic minority networks in Pang Ma Pha District – sequence of events

1996: Villagers from three Lahu villages join forces to solve problems of competition related to the exploitation of non-timber forest products (bamboo sprouts, mushrooms, orchids, etc.) in their respective neighbourhoods.

The TG-HDP, joined by officials from the RFD, started to support what they called a 'People's Forum' for the group of forest collectors, and institutionalized regular meetings. A management plan for the collection of forest products was agreed upon in what the local people considered as their community forests.

1997: More villages join the 'People's Forum', as it is transformed into the Pang Ma Pha Hill Tribe Network Organization (hereafter 'PMP Network'). On the recommendation of the TG-HDP, the PMP Network adopts an administrative structure with a steering committee at its head, consisting of a chairman (headman of Ja Bo Village, Lahu), a vice-chairman (left vacant), a treasurer (Soppong, Thai) and a secretary (Mae Lana Village, Shan).[i] Both the treasurer and the secretary, supported by the TG-HDP, act as advisors to the network chairman.

1998: 20 villages, mostly from the Lahu ethnic group, have joined the PMP Network, and its scope broadened to include successful conflict resolutions over village boundaries, land use, encroachment on watershed areas and animal raising, among others. Its aims in broad terms are: (1) Strengthening cooperation and self-help capacity, (2) solving natural resource (land, water) conflicts, (3) increasing knowledge, skills and information exchange, (4) fighting drug abuses.

The TG-HDP has ended. However, AusAID has provided some limited funds for the following year. A Thai NGO (Project for the Recovery of Life and Culture), based in Mae Hong Son, supports the Network though an advisor.

1999: The PMP Networks received funding through the Social Investment Fund amounting to 1.9 million baht for the period from 1999 to 2002.

2000-2001: The PMP Network is at the peak of its development. 28 villages have now joined, including villages from different ethnic minority groups, such as Red and Black Lahu (still constituting the majority), Shan, Lisu, Karen and Lawa. Meetings are held monthly, composed of two elected representatives from each village, and hosted at every member village in rotation. With its broader scope, the PMP Network set up four different sections related to: (1) natural resources

and the environment, (2) culture and tradition, (3) drug prevention and control, and (4) education and accommodation (for students who want to further their studies in Soppong town). Later, a fifth section dealing with agriculture was added.
2002: Due to allegations against the PMP Network's chairman over the misuse of funds, the treasurer and the secretary both resign and withdraw from the PMP Network. They are replaced by close relatives of the chairman, bringing the PMP Network fully under his control.
With support from the ONCB (Office of the Narcotic Control Board), and on the initiative of the headman of Luk Khao Lam village, a new network, the so-called Black Lahu Network, is set up among the six Black Lahu villages in PMP District. Their main goals are to fight drug abuse and revive hill tribe culture. In order to prevent bureaucratization, they refuse to adopt an administrative structure. Decisions are made together by consensus, the committee has no chairman, and villages have equal rights.
2003: Due to lack of funds, activities conducted by the PMP Network are minimal. A Thai NGO continues to provide some limited support for network meetings, which are attended by fewer and fewer villages.
2004: The PMP Network chairman is elected as the new headman of Mae Lana sub-district (*kamnan*), while the former PMP Network treasurer becomes one of the two representatives of the Mae Lana Tambon Administrative Council.
A new network emerges, this time among the Red Lahu villages of PMP district, receiving support from ONCB, with a Christian missionary from Wanna Luang village as chairman.

Whilst conducting a number of ethnographic studies over recent years using an actor-oriented interpretative framework, it became obvious that enthusiasm for the contribution of local organizations and networks to civil society or at least to sustainable development seems premature. Networks have to be seen as a platform, where different people or groups of people interact according to their particular interests, and where objectives, procedures and activities are negotiated within the framework of internal, but also external factors and power relations. They do not automatically generate or enhance 'social capital' equally for all those involved, and, moreover, bonds of trust and support as the basis for 'social capital' can be, and often are, manipulated and misused. They are often embedded in traditional, patron-client power relations.

However, those traditional power relations have not gone uncontested. In recent years, tribal members from the younger generation in particular, having received a better education and on returning home from urban areas, challenge traditional leadership. With their support and some limited funds from ONCD, two other mono-ethnic networks, for the Red Lahu and the Black Lahu respectively, have been set up (cf. Box 2 above) at a more informal level.

6.5.5 Sustainability and Civilisation in Pang Ma Pha District

Looking at these processes in the district (integration into the administration and market economy, emergence of new local networks) from the point of view of sustainability gives rise to ambivalent results. Charismatic authority can imply sustainability, but it depends per definition on the person. An alternative would be a market regulating the allocation of resources in a sustainable way. Here the problem is firstly, that market exchange is at least partly embedded into patronage relations and secondly, that it allows dominance from afar because prices are strongly based on Bangkok and, increasingly, international markets, and thirdly, that the market tends to become polarized and produce winners and losers. Who becomes a winner and who loses is not least a result of clientelist structures. Winning in the competition results partly from resource overuse, and similarly, losers in the competition are often forced to base their sustenance on resource overuse. Thus, there is no guarantee that sustainable resource use can be achieved purely by self-regulating market mechanisms.

Another alternative is an administration that enforces sustainable resource use, for example through regulations and their strict implementation. However, the administration in the peripheral district of Pang Ma Pha itself is quite different from the ideal type of a modern bureaucracy as described by Max Weber. A policy supporting sustainability would be possible if the local head of the administration favours it, and for as long as he/she favours it. In other words, the policy is not a result of administrative rationalities, but individual preferences and competences.

If neither the market nor the administration can provide and guarantee sustainability, we have to look to the third means of integration, namely networks and civil society, or to the social regulation of action and its institutionalization. Unfortunately, as our data indicate, civil and social organisations in Pang Ma Pha are still based on ethnicity and communality. In this rather segmentary setting, the 'common good' is always defined in terms of ethnicity, village and family and, as long as charismatic leadership and patronage remain as strong as they are, in terms of the personal interests of its leaders. At best, sustainable communities and villages might emerge under the charismatic leadership of a patron. This appears, however, quite unrealistic, as the position of the leader often implies access to resources and resource overuse. Sustainability in terms of larger sustainable units can only emerge from a more functional differentiation and integration of higher social units, which requires a higher level of formalization of political and administrative power, economic relations and the public sphere.

Even though, as the diagrams of inter-village relations indicate, the degree of integration at the district level has increased over the last couple of years, administrative, trading and ethnic relations are not yet accompanied by social relations and political alliances. Hopefully, the elected sub-district *(tambon)* councils may lead to a higher degree of integration than exists at present. Finally, what is missing most is a form of consciousness among the people of belonging together, or being part of one unit that entails rights and obligations with regards to resource use, for example. The highly individualistic pattern of social integration and the importance of competition and status maintenance within the villages do not support the rise of such a consciousness.

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6.6 Synthesis, Conclusions and Implications for Institutional Development and Future Research

Benchaphun Ekasingh and Andreas Neef

6.6.1 Synthesis of Findings on the Institutional Framework

This chapter has revealed some of the institutional constraints hindering sustainable development in the mountainous regions of the two countries under study, Vietnam and Thailand. It provides many examples of how failure to achieve better institutional arrangements lead to shortfalls in sustainable development. The chapter goes into detail on particular aspects of institutions, namely land rights and tenure, rural financial markets, institutions for upland agricultural research and local administration.

The basic question is how to create institutions which support sustainability, despite many examples of these institutional failures. The answer is not simple and involves relationships of power and exchanges among local communities, local administrators, policy makers and scientists. In the comparative study on resource tenure and sustainable land management (section 6.2), it was found that while long term tenure security is an important underlying condition for the adoption of sustainable agricultural practices, farmers see tenure security neither as fixed nor as formal, but rather as an intricate interplay between formal and informal institutional mixes. They also see it as something that can be handled in part through various strategies - such as land investment, co-opting development practices, external partners and projects - in order to increase their long-term land tenure security. In this case, institutional and legal pluralism can open up new opportunities for upland farmers, as argued by von BENDA-BECKMANN (1991), MEINZEN-DICK and PRADHAN (2002) and GANJANAPAN (2003). Local communities' ability and willingness to adapt, strategize and influence the administrative system were evident in the case studies presented in Section 6.2. These local capacities need to be further explored by both researchers and local communities to ensure greater room for manoeuvre in achieving long-term land security for upland people in Southeast Asia.

In the case of rural financial markets in Vietnam, DUFHUES et al. demonstrate in section 6.3 that the sustainability of upland development is also dependent on the sustainability of the financial institutions which support it. Government subsidization of rural credit prevents effective competition and the viability of private financial institutions, which may be needed to fill gaps in credit needs created by the government. Non-performing loans are also a worrying factor affecting the sustainability of financial institutions in Vietnam. There is a need for savings and insurance services in the rural and agricultural sectors, which are still prevalent. Information asymmetries and a bias towards well-endowed, well-connected villagers have prevented adequate access to financial services among the poor and ethnic minorities. Improvements in institutional performance within the rural financial markets can lead to rapid progress in sustainable development. This requires institutional innovations and a recognition of the need for change among policy makers. It is an area where research can really help to highlight what needs to be done. Many improvements are a matter of incremental institutional changes which are easier to achieve than in other areas; e.g. land use security or centralization of bureaucracy or agricultural research.

In section 6.4, NEEF et al. highlight another side of the institutional complexity in promoting sustainability, namely dealing with participatory research and technology development. While technology development is crucial for sustainable development in the uplands of Southeast Asia, the process of successful introduction and adoption of such technology is far from perfect. Policy makers' or government officers' research agendas are very different from those of scientists and farmers' leaders or of farmers themselves. This situation does not come as a surprise, but is rather typical for marginal regions. An explanation of the differences should address the different hierarchies and horizons of concerns for each stakeholder. In making sure that research topics respond to the needs of those affected, researchers need to recognize the diversity of interests. The skill is to balance the different points of view in a manner which makes research work more useful and relevant for a broader range of stakeholders. Participatory technology development is an approach promoted by many, but to integrate this into an institutional framework with a long tradition of centralized administration like the Thai and Vietnamese bureaucracies is a major challenge. Despite new developments in participation and involvement of local people in Thai constitutional development and politics, the difficulties of realizing such an objective seem insurmountable. Moreover, research using the sustainable rural livelihoods framework shows that human capital development, as opposed to physical, natural or social capital, is more fundamental to the success and failure of local farming practices. The key question is: how do we bring about meaningful participation of local people beyond their mere physical presence in village meetings and group discussions? That is, how can they have a voice in decisions concerning research agendas that may ultimately affect their livelihoods? The translation of good principles into successful practices has proven to be more difficult when dealing with nation-wide institutions and rules, as opposed to working in a project-based area. In the meantime, the rhetoric of people's participation as a panacea to all ills is not helpful in bringing about institutional change. RAMBO (2004) warns us of many simplifications and myths concerning people's participatory work. One thing is clear from the findings presented in section 6.4; this is an important area of work, which is not only complex and difficult institutionally, but also requires more effort and long-term commitment from those involved.

In their study of Pang Ma Pha district in the north-western Thai province Mae Hong Son, Korff and Bechstedt suggest in section 6.5 that neither the market forces nor the local administration are working to support sustainability. Both fail in their own ways; the market fails to provide for sustainability and equity when market exchange is firmly embedded in local power relations and individuals are looking for individual gains at the expense of the community and society at large. Local administrative bodies, on the other hand, derive their policies less from an administrative rationale, but rather from the preferences and competences of individual leaders, or, at worst, from the arbitrary use of power. Local networks, as a potential third means of integration, fall short of providing for the 'common good' when people define the sense of the good in terms of ethnicity, kinship relations and patronage, as the history of the Pang Ma Pha Hilltribe Networks illustrates. As long as the personal interests of leaders regulate control of resources and social relations, sustainable rural development is hard to achieve. The missing link to conscience of the 'common good' certainly lies in the institutional innovations that can create commonly accepted 'rules of the game'. Whether the new, democratically elected sub-district administrative organizations can lead to a higher degree of social integration in a region characterized by great ethnic diversity and huge power differentials remains an open question.

6.6.2 Implications for Policy Formulation and Future Research

A number of policy implications emerge from this chapter regarding the institutional framework for sustainable land use in mountainous regions of Southeast Asia. Four aspects have received particular attention, namely resource tenure and sustainable land management, rural financial market development, participatory research and technology development and state administration and local networks. The general trend running through all these themes is that institutions need to be more responsive and adaptable to the needs of the poor and to minority people in particular. This requires that a certain degree of flexibility, the participation of stakeholders and dialogue between local actors and decision-makers be built into the institutions which govern rural development. Given the complexity and details of the issues involved, it is hard to prescribe a set of policy guidelines which will work for all communities or districts. The key words nevertheless are *security*, *participation*, *decentralization* and *access*. Thus, the vicious circle displayed in figure 6.1 can hopefully be turned into a virtuous circle as depicted in figure 6.2 (cf. section 6.1).

Research plays a crucial role in disclosing new facts, providing new trains of thought and proposing recommendations for action. Research on institutional innovations is necessary to offer insights into ways forward. Within this process, both the successes and failures of particular institutional arrangements must be studied. Lessons learned across countries are particularly valuable. The need for an interdisciplinary analysis of these issues is obvious. The problem of non-sustainable resource use cannot be approached from a disciplinary point of view. Neither can it be solved as a ready-made package of solutions. The interplay between the market economy and social networks and dynamics is of great interest, as it can project its intricate relationships onto land use, credit, savings, farming practices and social and economic activities. We need to understand the factors behind market failures, government failures and the failure of social institutions to overcome these failures. We also need to be ready to redefine and negotiate the yardsticks of sustainable resource management and sustainable rural development in a multi-stakeholder environment. Research in this area must proceed apace and cannot be carried out in isolation to policy development. Substantial evidence must be accumulated before it gains credibility and momentum for policy change. Research will balance emotions, ideologies and myths too often prevalent in policy development in mountainous regions of Southeast Asia. While this chapter has achieved some progress along this path, further research in different settings and according to different angles is an urgent necessity.

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7.0 Conclusion and Outlook

7 Conclusions and Outlook

Franz Heidhues

Carrying out research to foster sustainable land use and to contribute to improved rural livelihoods in mountainous regions of Southeast Asia is a highly complex and challenging undertaking. The mountainous regions are the world's richest source of biodiversity. They are vitally important for the climate world-wide; they are the reservoir of water and energy for billions of people and a rich source of cultural diversity. At the same time, these regions are highly fragile, ecologically and economically disadvantaged and extremely heterogeneous ethnically and culturally. They are placed under increasing pressure by rapidly growing demands on their natural resources and rising political rivalries. Given the importance of the uplands and the enormous pressure they are facing research addressing their sustainability is of utmost importance.

Research under The Uplands Program has shown that, given the complexity of issues involved, the information base for these areas in practically every respect is weak to inadequate. This applies to data on soils, water and three dimensional terrain features, to information on plant and animal genetic resources and production, processing and marketing conditions, to basic information on the socio-economic environment and institutional and socio-cultural systems and their functioning. A solid information base is a most important precondition for reliable research. National and local authorities together with researchers are called upon to devote higher attention to this issue.

Interdisciplinarity has proven to be a most useful approach to research on complex issues such as sustainable uplands development. Many innovations have been generated, adapted for practical application and offered to farmers, but were not accepted, often due to a neglect of the involvement of "other" disciplines, neglect of infrastructural needs and disregard for institutional support, social acceptability and economic profitability aspects. Strategy packages for land use integrating these different aspects are needed for fostering acceptance by farmers.

The Uplands Program places particular emphasis on participatory research, both to evaluate its usefulness in different disciplines and at different stages of the research process, and to assist researchers in applying suitable techniques and approaches. Participatory research has proven to be valuable in making research programs more farmer and problem relevant and in mobilizing local knowledge and integrating it in the research process. It has also been shown that participatory research is a complex process, requiring a well based methodology to avoid pitfalls that can distort and invalidate the process, such as elite bias, exclusion of the poor and false interpretation of local information. Integrating participatory approaches into an institutional framework that has a long tradition in centralized administration and hierarchically structured bureaucracies remains a major challenge. Similarly challenging will be to find a way to bring about meaningful participation of local people where their voice in decision making about their livelihood is being heard.

Research on sustainable land use requires the micro-level approach, often down to the plot level. To transfer those results to larger areas and use them for designing measures/policies at watershed or regional levels requires the development of suitable models; this remains an important challenge. Both, in natural sciences and in socio-economic research increasing emphasis needs to be placed on modeling and establishing the required data base.

Research and innovation generation in agricultural production and processing can play a vital role in reducing the pressure on mountainous regions. Research on fruit tree production systems has shown that the alternate bearing and seasonality of fruit trees can be reduced. Thus, fruit tree production can be stabilized and the harvest season extended into off-season periods. Innovations in fruit processing and conservation contribute to higher quality products and help to improve market potential. Livestock research in mountainous regions of North Vietnam has confirmed the vital contribution of livestock to sustainable land use and secure rural livelihoods. The rich genetic diversity of local races still found in mountainous regions is a big national asset that deserves to be maintained and conserved in the national interest.

Large differences in natural resource endowment, ecology and socio-economic conditions result in a great variety of economic conditions and rural livelihoods. As a result, the pressures exerted on natural resources and the degrees of resource degradation differ widely. Economic policies and development measures to promote sustainable resource use need to be adapted to the changing conditions. Of key importance are investments that help people to overcome isolation and to access education, innovations, information and input and output markets.

Institutional constraints hindering sustainable development in mountainous regions are widespread. Long-term land rights and tenure security are important conditions for investing in sustainable land use. In complex processes national regulations, institutional settings, socio-cultural traditions and local communities' capacities to adapt to the various constraints interact; together they determine whether long-term tenure security for upland farmers can be achieved. Sustainable rural finance institutions that uplands people and particularly ethnic minorities can access for credit, savings and insurance services can significantly contribute to sustainable land use. Policy changes at the national level and institutional innovations at the local level will go a long way towards these goals.

Sustainability in land use has been found to often receive little support from market forces and local administrative bodies. Markets fail to provide for sustainability and equity if they are dominated by local monopolies and powerful individuals. Local administrative bodies counteract sustainable rural development if their actions follow selfish preferences of individual leaders and if arbitrary rules predominate. Institutional innovations that lead to commonly accepted 'rules of the game' are needed for social integration in regions characterized by great ethnic diversity and huge power differentials.

The general principles guiding the concept for research in The Uplands Program have been found to remain valid for future research. The mountainous regions pose a particular and new challenge to agricultural science. As complex systems, where ecological, agricultural production, and technology, economic and socio-cultural processes interact and influence each other, they require an innovative integrated, interdisciplinary and participatory research approach as well as cooperation with policy and policy-implementing institutions. A four-dimensional research process is necessary: First, several disciplines covering the full spectrum of issues to be addressed need to be involved. Second, they must work in interdisciplinary approaches where the interactions between some disciplines are particularly close and interwoven. Third, local farmers and their intimate knowledge of the environment in which they live need to be brought into the research process; this has proven to be extremely enriching and valuable for the research work. Fourth, interactions with international research centers, such as the CGIAR centers, national research and policy implementation institutions, extension services and local authorities has proven to be successful and needs to be actively sought.

This research process, where different disciplines work together and interact in interdisciplinary approaches, where local stakeholders participate and local decision makers and institutions are part of the process of implementing sustainable land use and rural development, requires a high degree of flexibility and capacity to adapt. Still, the keywords will remain: sustainability, interdisciplinarity, participation, and equitable access for the poor.