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**The Agrarian Transformation in Northeast Thailand:
An Interdisciplinary Study of Agricultural System
Change**

โดย

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Executive Summary

Prof. Dr. A. Terry Rambo
Project Principal Investigator

1. Introduction

This project was designed to support basic research on the rapidly changing agricultural system of Northeast Thailand (commonly called “Isan”). This research was badly need because, for the past 35 years, this vast region has been undergoing a massive agrarian transformation that involves major changes in multiple different aspects of agriculture and rural society, including technology, economic and social relations, and cultural values. Northeast Thailand today is a vastly different place than it was when the transformation began, but the nature and extent of changes has not yet been fully documented. Key aspects of change include widespread adoption by rainfed rice farmers of the improved glutinous RD6 rice variety, use of machines for land preparation, and the use of diesel pumps to provide supplementary irrigation using water from farm ponds. The resulting higher and more stable yields of glutinous rice have largely solved the problem of food security allowing farmers to plant a larger share of their land to non-glutinous KDML105 which provides a new source of cash income. Aided by remittances sent back to their families by migrant workers as well as cash earned by engaging in off-farm employment in new factories and service jobs in rapidly expanding local urban centers, Isan farmers have been rapidly adopting modern agricultural technology, including new varieties, chemical fertilizers and farm machinery. Multiple cropping and growing of high value crops to supply urban markets are becoming widespread, further helping to boost farm incomes. A new pattern of adaptation is emerging as a central feature of this agrarian transformation in which the livelihood portfolio of rural households is increasingly based on agricultural intensification and specialized production of cash crops (e.g., rubber, high value niche crops, and livestock), greatly increased dependence on off-farm employment as the main source of income, and growing dependence on extra-local social networks and government assistance to provide a social safety net. The rural social system has also been undergoing rapid change, with declining rates of poverty, increasing levels of economic differentiation, improving levels of education, and ever deepening integration with extra-local social and economic systems. The on-going transformation is deeply affecting every dimension of rural existence, including demography (shift to long-term out-migration, declining fertility, population aging), social organization (increased economic stratification, weakening of village solidarity, expansion of extra-local social networks, new types of family structures), culture (erosion of indigenous knowledge base, adoption of cosmopolitan cultural patterns), health and nutrition (increased prevalence of drug addiction and alcoholism, increased incidence of obesity and diabetes), education (raising of age of mandatory schooling, increased valuation of education as a route to upward mobility), and employment (scarcity of agricultural labor, off-farm employment as the main source of income).

This project has generated significant new knowledge about the agrarian transformation. Participating researchers have published 10 papers in national and international journals and one chapter in a book published by an international publisher. An additional 6 papers have been accepted by international journals, 5 manuscripts are under review and 5 manuscripts are in advanced drafts and will be submitted soon to journals. The manuscripts of 2 books are in advanced drafts.. The project helped to support the thesis research of 7 doctoral and 2 masters students. Of the doctoral students, 3 have already received their degrees, and 2 have successfully defended their theses but will not receive their degrees until after their papers are accepted for publication by journals; The thesis defenses of 3 of the doctoral students were rated as “excellent” and one as “good. Two doctoral students have not yet completed their studies. The two masters students have both been awarded their degrees.

To make its findings more widely known the project co-organized two academic meetings on the agrarian transformation in Isan in collaboration with the Center for Southeast Asian Studies of Kyoto University as well as a TRF Basic Seminar. The Principle Investigator also made an oral presentation of project findings at the TRF Basic Research Conference in Cha Am in 2016.

The project organized three writing workshops in which experienced researchers helped young lecturers and graduate students to prepare manuscripts for submission to academic journals.

2. Acknowledgements

The success of this project in meeting its objectives has depended on the contributions of many individuals. I would like to especially thank my colleague in the Program on System Approaches in Agriculture, Dr. Arunee Prokhambut, and the project research assistant Ms. Yuko Shirai, for all the help they have given me in managing this complex project. Prof. Dr. Fukui Hayao, Assoc. Prof. Dr. Suchint Simaraks, Assoc. Prof. Dr. Suwit Laohasiriwong and Assoc. Prof. Dr. Chai Podahista have devoted much effort to assisting the young lecturers and graduate students in doing their sub-projects under this project. Prof. Dr. Aran Patanothai was a constant source of useful advice. Ms. Sujaree Son-ngay, the TRF Program Officer for this project, has been invariably helpful in advising me about TRF’s administrative requirements.

3. Objectives of the project

This project had three main objectives: 1) to do high quality empirical research to improve our knowledge and understanding of the agrarian transformation in Northeast Thailand, 2) to improve the capacity of young lecturers to do agricultural systems research, and 3) to support thesis research by graduate students in the KKU Program on System Approaches in Agriculture who participated in this project.

3.1. Research to improve our knowledge and understanding of the agrarian transformation in Northeast Thailand.

The agrarian transformation has occurred so recently, and has progressed at such a rapid rate, that our understanding of its impacts on the agricultural system of the

Northeast has seriously lagged behind reality on the ground. Consequently, much of the information used to teach university students about Isan agriculture and society was badly obsolete. This project was designed to collect new empirical information needed to bring perceptions of the situation in the rural Northeast into closer alignment with the reality on the farms and in the villages. This information was to be disseminated in journal publications and materials to be used in the teaching curriculum for university level programs on agricultural systems.

8.2. Building the capacity of young lecturers to do agricultural systems research.

Improving the research capability of young lecturers is an urgent requirement if the field of agricultural systems is to continue to develop in Thai universities. Six young lecturers (3 from Khon Kaen University and 1 each from Nakhon Phanom University and Sakon Nakhon and Udorn Thani Rajabhat universities) were to carry-out individual sub-studies under the close guidance of the principal investigator and project senior researchers (Table 2).

8.3. Support of thesis research relevant to this project by graduate students in the KKU Program on System Approaches in Agriculture.

Providing support for thesis research is needed to increase the output of qualified young scholars in agricultural systems. To help meet this need, 7 graduate students enrolled in the KKU Program on System Approaches in Agriculture (including 3 who already hold appointments as lecturers in KKU and other regional universities) were to do their thesis research as part of this project under close supervision of project senior researchers

4. Results and Discussion

Project research has documented multiple changes in the agrarian system of Northeast Thailand. Because the Principal Investigator has already presented a summary of the main findings of this project in a paper entitled “The agrarian transformation in Northeast Thailand: A review of recent research” (accepted for publication in *Southeast Asian Studies*), it is not necessary to present a detailed discussion of them here. Instead, a summary of main achievements is provided.

As originally planned the project was to study 6 themes including, 1) agricultural mechanization, 2) agricultural intensification, 3) role of biodiversity in rural livelihoods, 4) The continuing role of indigenous knowledge and technology in agricultural development, 5) Urbanization and agriculture, and 6) Aging and agriculture. Due to changes in thesis topics by some participating graduate student researchers and the withdrawal from the project of two researchers it was not possible to complete all planned sub-projects under themes 1, 3, 5, and 6, although significant new knowledge on all these themes was still generated by the project. Table 1 summarizes themes, sub-projects, researchers and outcomes.

Table 1. Summary of project research themes, sub-projects, researchers and outcomes

Theme	Individual sub-studies	Researchers	Outcome
1. <i>Agricultural mechanization</i>	None	Mr. Chalee Gedgaew (Lecturer in Udon Thani Rajabhat University and KKU Ph.D. student) Dr. Suchint Simaraks	The researcher changed his thesis topic to Theme 2
2. <i>Agricultural intensification</i>	Multiple cropping in rainfed rice cropping systems	Dr. Arunee Promkhambut (KKU lecturer) Dr. A. Terry Rambo	1 paper accepted by an international journal
	Value intensification in Northeastern mountain agriculture	Dr. Sukanlaya Choenkwan (KKU doctoral student and now KKU lecturer) Dr. A. Terry Rambo Dr. Hayao Fukui Dr. Arunee Promkhambut	Doctoral degree awarded 2 papers published in international journals, 1 paper published in a national journal, 2 papers under review by international journals
	Changes in land use and agricultural systems on the river banks along the Mekong River	Dr. Sorat Praweenwongwuth (Lecturer in Nakhon Phanom University) Dr. Attachai Jintrawet Dr. A. Terry Rambo	1 paper accepted by an international journal
	Contract Farming of Hybrid Tomato Seed in Rain-fed area of Khon Kaen Province	Mr. Chalee Gedgaew (Lecturer in Udon Thani Rajabhat University and KKU Ph.D. student) Dr. Suchint Simaraks	Doctoral thesis successfully defended but degree will not be awarded until after acceptance of 2 papers by journals. 1 paper accepted by an international journal, 1 paper

			submitted to national journals. 1 paper is under review by a national journal
3. <i>Rural livelihoods (Modified from original theme of “role of biodiversity in rural livelihoods”</i>	Rural Household Livelihoods in the Context of the Agrarian Transformation in Northeast Thailand	Ms. Yuko Shirai (Ph.D. student) Dr. A. Terry Rambo Dr. Fukui Hayao Dr. Suchint Simaraks	Doctoral thesis successfully defended but degree will not be awarded until after acceptance of 2 papers by journals. 1 paper published, 1 paper accepted and 2 papers under review by international journals
	Roadside stall as alternative to agriculture in Northeast Thailand	Mr. Warramon Maicharean (Ph.D. student) Dr. Suchint Simaraks Dr. A. Terry Rambo	1 paper in advanced draft, field research continuing for paper 2
3. <i>The continuing role of indigenous knowledge and technology in agricultural development</i>	Spatial variations in the density of trees in paddy fields in different parts of the Northeast Region	Mr. Moriaki Watanabe Dr. A. Terry Rambo Dr. Patma Vityakon Dr. Hayao Fukui	Doctoral degree awarded 1 paper published in an international journal, 1 paper accepted by an international journal
	Structure and functions of homegardens of different ethnic groups in Northeast Thailand	Ms. Pijika Timsuksai (Lecturer in Sakon Nakhon Rajabhat University) Dr. A. Terry Rambo Dr. Hayao Fukui	Doctoral degree awarded 2 papers published in international journals, 1 paper published in a national journal
	Soil classification systems of different	Mrs. Sujitra Yodha (Ph.D. student)	1 paper in advanced draft, field research

	ethnic groups in Northeast Thailand and farmer knowledge about soil management	Dr. A. Terry Rambo	continuing for paper 2
	The productive efficiency of Vietnamese Homgarden: A comparative study of Ha Tinh and Nakhon Phanom, Northeast Thailand	Mr. Nguyen Dang Hoc (Lecturer in Hanoi University, Vietnam) Dr. A. Terry Rambo Dr. Pijika Timsuksai	Masters degree awarded, 1 paper published in a national journal, 1 paper in advanced draft
	The continued use of earthen weirs (<i>tham nop</i>) for irrigation by villagers	Ms. Prapatsorn Wongsalee Dr. Hayao Fukui Dr. A. Terry Rambo Dr. Arunee Promkhambut	Masters degree awarded
	Integrating indigenous and scientific knowledge to develop more sustainable agriculture	Dr. Nisit Kamla Dr. Suchint Simaraks	Researcher withdrew from the project
4 <i>Urbanization and agriculture</i>	Impacts of urban expansion on periurban agricultural systems	Ms. Patcharaporn Phumchantuk (Lecturer in KKU and RGJ Ph.D. student) Dr. Aran Patanothai Dr. A. Terry Rambo	Researcher withdrew from the project. This topic has been partly covered by the research of Dr. Sorat Praweenwongwuth under theme 2.
5. <i>Aging and agriculture</i>	The role of elderly people in agricultural production	No suitable researcher could be recruited to study this topic.	This topic has been partly covered by the research of Yuko Shirai under theme 4.

5. Conclusions

This project has generated considerable new information about changes in the agrarian system of Northeast. These changes are manifold, inter-linked, and, to a significant, but as yet undetermined degree, self-amplifying. Every dimension of the

agricultural system has been affected, including technological, demographic, economic, social, and cultural aspects. The Northeast of 2560 BE is an almost totally different world than that of 2530. Changes in agricultural technology have had profound impacts: Mechanization (e.g., adoption of tractors, small irrigation pumps, and combine harvesters) has greatly reduced the need for manual labor, speeded up essential cultivation tasks and, to a great extent, ended the tyranny exercised by irregular rainfall on the success or failure of the rice harvest. Mechanized plowing, adoption of improved photo-period sensitive rice varieties, and the shift from transplanting to broadcast seeding have reduced the amount of time that farmers must spend in their paddy fields, allowing them to earn more income from off-farm employment. Increased use of chemical fertilizers has allowed farmers to overcome the inherent low fertility of the region's sandy soils. These technical changes have been accompanied by greatly increased intensification, diversification and specialization in agriculture which has helped to boost farm incomes and retain more young people in their villages, rather than migrating to Bangkok as so many in their parent's generation were forced to do to earn their livelihoods. Perhaps the most profound changes have occurred in the social and cultural dimensions of the agrarian system. A consumption-oriented economy, in which people strive to earn cash in order to buy consumer goods, has largely replaced the traditional subsistence-oriented one. The pursuit of higher cash income has led many young adults to leave their villages and migrate to Bangkok and even abroad. This has resulted in changes in the structures of rural households, especially the decline in the number of nuclear type households and the emergence of skipped generation households where children are raised by grandparents rather than their parents, who are away working elsewhere, is profoundly affecting the socialization of the new generation. In any case, young villagers are growing up in a vastly different information environment from that of their parents and grandparents. The spread of modern telecommunications (TV, mobile phones, the internet) has led to a vast increase in the flow of information about the outside world into the formerly isolated villages, which is stimulating deep changes in local value systems. Rather than striving to accumulate land as an endowment for their children, households now focus on investing in their education, seeing academic achievement as the best route to upward mobility. Young Isan farm kids, whose parents were poor barely literate rice farmers, are even earning doctorates in regional universities.

The agrarian transformation is still very much a work in progress and it would be foolhardy to try to predict its ultimate outcomes. But it is already evident that we all need to revise our old conceptions about the nature of the agrarian system of Isan.

6. Outcomes of the project

6.1 Papers (summary of the papers that have been published, submitted and under review, and that will be submitted in the future)

Participating researchers to date have published 10 papers and one book chapters in national and international journals and has had an additional 6 papers accepted but not yet published by international journals. (Table 2). Copies of all published papers are included in an appendix. An additional 5 papers are currently under review by international journals (Table 3) while 5 papers are in advanced drafts and will soon be submitted to journals in the future (Table 4).

The Principal Investigator's paper "A Burning Issue: Rethinking the Transition from Hunter-Gatherer to Industrial Sociometabolic Regimes" in the *Journal of Industrial Ecology* (JIE) was nominated for one of the JIE's best paper prizes for 2015.

Table 2. Papers and book chapters that have been published or accepted for publications

No.	Name of Journal/Book Chapter	Impact Factor	Title of the Paper	Name of the First Author
1	Environmental Management	1.647	Can't see the forest for the rice: Factors influencing special variations in the density of trees in paddy fields in Northeast Thailand	Watanabe, Moriaki, Patma Vityakon, and A. Terry Rambo
2	Journal of Industrial Ecology	2.276	A burning issue: Rethinking the transition from hunter-gatherer to industrial sociometabolic regimes	A. Terry Rambo
3	Mountain Research and Development	1.1	Agriculture in the mountains of Northeast Thailand	Sukanlaya Choenkwan, Jefferson Metz Fox, and A.Terry Rambo
4	Mountain Research and Development		Does agro-tourism benefit mountain farmers?	Sukanlaya Choenkwan, Arunee Promkhambut, Hayao Fukui, and A.Terry Rambo
5	Khon Kaen Agriculture Journal	TCI: 0.176	Agricultural land use in the mountains of Northeast Thailand	Sukanlaya Choenkwan, Arunee Promkhambut, Hayao Fukui, and

				A.Terry Rambo
6	Ethnobotany Research & Applications	-	Urban demand for wild foods in Northeast Thailand	Yuko Shirai and A.Terry Rambo
7	Southeast Asian Studies (Kyoto)	SCOPUS but no impact factor	Homegardens of the Cao Lan, a Tai-Speaking Ethnic Minority in Vietnam's Northern Mountains	Pijika Timsuksai, Nguyen Dinh Tien, and A.Terry Rambo
8	Khon Kaen Agriculture Journal	TCI: 0.176	A comparative study of the ecological structures of homegardens of different ethnic groups in Northeast Thailand	Pijika Timsuksai, and A.Terry Rambo
9	PLOS ONE	3.534	The influence of culture on agroecosystem structure	Pijika Timsuksai and A.Terry Rambo
10	Khon Kaen Agriculture Journal	TCI: 0.176	Cost – benefit analysis of vegetable production in the Thai-Vietnamese homgardens in Northeast Thailand	Nguyen Dang Hoc, Pijika Timsuksai, and A.Terry Rambo
11	A Special Issue of <i>Southeast Asian Studies, the Journal of Kyoto University</i>	SCOPUS but no impact factor	The agrarian transformation in Northeast Thailand	A. Terry Rambo
12			Multiple Cropping in Rain-Fed Rice Cropping Systems	Arunee Promkhambut and A.Terry Rambo
13			Factors and Conditions Hybrid Tomato Seed Long Term Production Under Contract Farming in Northeast Thailand	Chalee Gedgaew, Suchint Simaraks and A.Terry Rambo
14			Factors Influencing Variations in the Density, Extent of Canopy Cover and Origin of Trees in Paddy Fields in a Rainfed Rice-farming Village in Northeast Thailand	Watanabe, Moriaki, Patma Vityakon, and A. Terry Rambo
15			Rural Household Livelihoods in the Context of the Agrarian	Yuko Shirai and A.Terry Rambo

			Transformation in Northeast Thailand	
16			Recent changes in agricultural land use in the riverine area of Nakhon Phanom Province, Northeast Thailand	Sorat Praweewongwuth , Tewin Kaewmuangmoon , Sukanlaya Choenkwan and A.Terry Rambo
17	Book chapter 52: Shifting cultivation and environmental change	-	Afterword: Swidden agriculture in retrospect	A. Terry Rambo

Table 3. Papers that have been submitted to journals and are currently under review

No .	Name of Journal	Impact Factor	Title of the Paper	Name of the First Author
1	Journal of Rural Studies	2.206	The influence of local non-farm employment on rural households	Yuko Shirai, Jefferson Metz Fox, Stephen J. Leisz, Hayao Fukui, and A.Terry Rambo
2	Applied Geography	2.5	Does Rural Industrialization Reduce Out-Migration? Commuting Distance, Levels of Local Non-Farm Employment And Out-Migration in Rural Villages in Northeast Thailand	Yuko Shirai, Stephen J. Leisz, Jefferson Metz Fox, and A.Terry Rambo
3	Landscape and Urban Planning	3.654	Using the niche concept to explain the spatial distribution of agricultural systems in the mountains of Northeast Thailand	Sukanlaya Choenkwan and A. Terry Rambo
4	Journal of Mountain Science	1.02	Agricultural systems in the mountains of Northeast Thailand	Sukanlaya Choenkwan and A. Terry Rambo

5	Khon Kaen Agriculture Journal	TCI: 0.176	Hybrid tomato seed production under contract farming in Northeast Thailand: Growers' complex practices and the economic worthiness	Chalee Gedgaew, Suchint Simaraks, and A.Terry Rambo
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Table 4. Draft papers that will be submitted to journals after completion

No.	Name of Journal	Impact Factor	Title of the Paper	Name of Author (s)
1	Asia Pacific Journal of Tourism Research	1.023	Is local social organization a constraint on development of community-based tourism? Case study in a homestay village, Wang Nam Khiao district, Nakhon Ratchasima province, Thailand	Sukanlaya Choenkwan and A. Terry Rambo
2	Journal of the Agriculture, Food, and Human Values Society	2.222	Factors influencing long term tomato seed production under contract farming in a rain-fed area in Northeast Thailand	Chalee Gedgaew, Suchint Simaraks, and A.Terry Rambo
3	Singapore Journal of Tropical Geography	1.085	Spatial distribution of roadside stalls selling agricultural products in Northeast Thailand	Waramon Maijaroen, Suchint Simaraks, and A.Terry Rambo
4	Geoderma	2.855	An Assessment of Inter-informant Agreement about Soil Names and Classification among Thai-Lao Farmers in a Rain-fed Rice-growing Village in Northeast Thailand	Sujitra Yodda and A. Terry Rambo
5	Journal of the Human Environment	2.6	Factory Workers and Farmers: The Influence of the Availability of Local Non-Farm Employment on	Yuko Shirai, Stephen J. Leisz, Jefferson Metz Fox, and A.Terry Rambo

			Agricultural Activities in Rural Villages in Northeast	
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6.2 Books

Two book manuscripts are in advanced stages of editing but are not yet ready to submit to publishers (Table 4).

Table 5. Book manuscripts

	Title	Name of Author
1	Earthen Weir (Tham Nop) Irrigation in Northeast Thailand	Hayao Fukui
2	The Human Ecological Perspective on Agricultural Systems	A.Terry Rambo

6.3 Graduate degrees earned by students participating in the project

The project helped to support the thesis research of 7 doctoral and 2 masters students. Of the doctoral students, 3 have already received their degrees, and 2 have successfully defended their theses but will not receive their degrees until after their papers are accepted for publication by a journals. Two doctoral students have not yet completed their theses. The two masters students have both been awarded their degrees.

6.4 Conferences and workshops

To make its findings more widely known the project co-organized two academic meetings in collaboration with the Center for Southeast Asian Studies of Kyoto University. It also organized a TRF Basic Seminar on the agrarian transformation in Northeast Thailand. The Principle Investigator also made an oral presentation of project findings at the TRF Basic Research Conference in Cha Am in January 2016.

6.5 Writing workshops

The project organized three writing workshops in which experienced researchers helped young lecturers and graduate students to prepare manuscripts for submission to academic journals.

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(Prof. Dr. A.Terry Rambo)

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**Financial Report has been attached in
an individual report.**

Sub-Project Reports
(A Total of 12 Sub-Project Reports)

1. Title of Sub-project: Multiple cropping in rainfed rice cropping systems

2. Names and Affiliations of Researchers

Arunee Promkhambut and Terry A. Rambo

Program on System Approaches in Agriculture, Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University, Khon Kaen, 40002, Thailand

3. Research Objectives

To identify localities, planted areas, types of crops and number of households growing crops after the harvest of rainfed rice in Khon Kaen province and to identify physical and social and economic factors associated with the occurrence of these cropping systems.

4. Research Methodology

Study areas

The study area was the whole of Khon Kaen province, Northeast of Thailand. It is located between latitude 15°40' to 17° 5' N and longitude 101°45' to 103°45' E. The province has an area of 10,886 km² with a population of 1,774,816 inhabitants in 2013. It is divided into 26 districts and 198 administrative sub-districts (*tambol*) (Khon Kaen Provincial Office 2013).

The topography of Khon Kaen province can be divided into 2 main types, lowlands and uplands (hills or mountains). Most parts, over 80 per cent, are flat to gently undulating land of 101-200 m MSL, and include the broad floodplain along the Chi River. This plain is dotted with inselbergs and inselberg ranges as high as 900m MSL (isolated and flat-topped mountains with nearly vertical cliffs) in the northern and western part of the province (Geo-Informatics Center for Development of Northeast Thailand 2009).

According to the Land Development Department, there are 33 soil series in the province. Generally, the upland soils have been formed from parent material composed of fine grained sandstone and shale. Soil groups distributed in the province are varied due to the topography. The Tropaquepts with fine textures are found in floodplain adjacent to the Chi river. Paleustults with sandy texture cover a large part of the northern and western part of the province. Paleaquults are mostly distributed in the depression of undulating land and nonflood plain (Viriya 2001). The climate of Khon Kaen province can be classified as Tropical Savannah according to the Koppen climate classification system. The average annual temperature is 27 °C and the mean maximum and minimum temperatures are 32.8 °C and 22.4 °C, respectively. The rainy season extends from May to October with almost no rainfall in the remaining months. Rainfall is unevenly distributed within the year and varies from year to year (*ibid.*). Average annual rainfall during 2000-2013 was 1,290 mm (Northeast Meteorological Center [Upper part] 2014).

The total cultivated area of Khon Kaen province is 699,047 ha (64.19 % of total area), of which only 98,349 ha (14%) is irrigated. In 2012, wet season rice was the major crop grown, accounting for 58.9% of the agricultural area. Sugarcane and cassava were the second and third most widely planted crops, covering 12.9% and 4.6% of the agricultural area, respectively (OAE 2014).

Data collection

Data on the locality, planted areas, types of crops and number of households

practicing multiple cropping after the rice harvest during 2012/2013 growing season in every sub-district (*tambol*) were collected by using formal questionnaires distributed to the agricultural extension officers in each *tambol* in 2013. The questionnaires were first pretested in 3 selected *tambols* in order to test their reliability and validity. After revising the questionnaires, they were distributed by mail or e-mail to the agricultural extension officers in every *tambol*. Follow-up telephone calls were made to ensure that the questionnaires were completed and returned to the researchers. Ultimately, 100% of the questionnaires were returned. Field observations were also made in selected *tambols* to verify the information provided by agricultural extension officers and follow-up interviews were done with 28 farmers. These farmers were asked about the yields of crops they obtained per unit area and the price they sold them for in order to calculate income per unit area. Physical and social factors determining the types of crop they grew were also ascertained.

Provincial information about rice planted area, number of rice farming households, and the farm gate price of rice in the 2012/2013 growing season were obtained from online databases of the Office of Agricultural Economics and Department of Agricultural Extension, Thailand.

Data analysis

All of the *tambols* having multiple crops after rice, and the crop species grown, the area planted to each crop, and the numbers of households growing each of these crops were identified. The crops were then classified into 2 groups according to their characteristics: 1) field crops (non-perishable products, low water and nutrient requirements and extensive management) include peanut, field corn, cassava, crotalaria and mungbean) and 2) vegetable crops (perishable products, high water and nutrient requirements and intensive management) include sweet corn, chili, watermelon, cucumber, eggplant, yard-long bean, sweet potato, tomato, Chinese radish, Chinese cabbage, cabbage and other green vegetables). Percentages of multiple cropping area to total rice area, and rainfed rice farming households planting multiple crops to all rice farming households were calculated by using Excel spread sheets. The spatial distribution of multiple cropping according to the percentage of total rice area planted with multiple crops in each *tambol* was mapped by using the Arc-info GIS program.

5. Research Findings

5.1 Types of crops grown after the rice harvest in Khon Kaen province

Out of the 198 *tambols* in Khon Kaen province, 178 (90%) planted a crop after the harvest of rainfed rice. As is shown in Table 1, the area devoted to multiple cropping after rice was relatively small; multiple crops occupied only 10,384 ha, which is only 2.9% of the total rainfed rice area in the province. The share of farm households engaging in multiple cropping was considerably larger, however, with 16,184 households planting crops after rice, which is 10.9 % of the total number of rainfed rice farming households in the province.

There is considerable variation among *tambols* in terms of the share of the rice area that is multiple cropped. Most of the *tambols* (84%) planted less than 5% of the total rice area to a multiple crop. However, about 11% of the *tambols* planted multiple crops on from 5.01 to 20% of their total rice area while about 5% planted multiple crops on more than 20% of their total rice area. The spatial distribution of the multiple crops planted after the rice harvest is shown in Figure 1. *Tambols* having multiple crops on less than 5% of their total rice area are scattered throughout the province,

while tambols having multiple crops on 5-20% of their rice area are mostly located in the southern part of the province and tambols with a higher proportion of multiple cropped area are in the northern part of the province.

Field crops and vegetable crops are planted after the rice harvest in rainfed paddy fields in Khon Kaen province. About 81% of the total multiple cropping area is planted to field crops, including cassava, crotalaria, field corn, peanut, and mungbean. These crops occupied about 2% of total rice area. Vegetable crops, including sweet corn, chili, watermelon, cucumber, eggplant, yard-long bean, sweet potato, tomato, Chinese radish, Chinese cabbage, cabbage and other vegetables, occupied 19% of the multiple cropping area, or only about 0.5% of the total rice land (Table 2). Although the area occupied by field crops is much larger than that occupied by vegetable crops, the number of rainfed rice farming households growing vegetables is almost as large (7,374 households) as it is for field crops (8,810 households), with households growing vegetables as a multiple crop accounting for 45.6% of all farm households engaging in multiple cropping (Table 3).

5.2 Economic value of multiple cropping

Data from Table 4 show that total gross income per area of multiple crops grown after rice varied according to type of crop. Field crops, except field corn and peanuts, provided income lower than USD1,000 per ha. Vegetables generally had a much higher return than field crops, ranging from USD1,055-49,072 per ha. The variation in income per ha of different crops depends not only on the yields and prices of the different crop species, but is also affected by the purposes for which the crop is produced. Field corn, watermelon, tomato and chili were mostly grown under contract to produce hybrid seed. Hybrid vegetable seed production was first established by a few companies in a limited number of places in Northeast Thailand in the late 1970s but nowadays has spread to many additional places with many competing local and international companies (Rosset *et al.* 1999). Benziger (1996) indicated that contract farming is the program to help small farmers make a transition into high value-added crops. It provides revenues per area 6.5 times higher than are obtained by traditional farmers. In addition to contract farming, many other multiple cropping farmers engage in independent growing of vegetables such as yard long beans, eggplants, Chinese radishes, and cucumber to supply rapidly growing urban markets. These high value crops give gross returns ranging from USD 7,023-14,180 per ha.

When the total gross annual revenue generated by multiple crops after the rainfed rice harvest was calculated based on area planted to each species, it was found that about 32 million dollars were generated in 2013, which is an amount 3 times higher than the value of rice grown in the same field area (Table 4). Table 5 showed the different amounts of revenue generated by different multiple crops. Field crops, particularly mungbean, generated only 30-65% more revenue compared to vegetable crops which generated 65-98% more revenue than rice alone. The higher return per unit of land from crops grown after rice compared to rice mono-cropping has also been reported by Kar *et al.* (2006). The fact that growing vegetable crops provides the highest returns may explain the popularity among the farmers of vegetables as a multiple crop. Despite the high returns generated by vegetables, farmers still plant a much larger area to cassava, which provides much lower returns per unit land.

5.3 Possible factors associated with distribution of multiple crops grown after rice

Information from farmer interviews and field observation by the authors showed that physical factors, such as availability of irrigation sources, suitable soil texture and having a shallow water table, are the most important factors determining the presence of multiple cropping in an area. It was found that all vegetable crops, except sweet potato, heavily rely on the availability of irrigation. Farmers indicated that hybrid seed production requires having a farm pond for irrigation. However, the supply of water from farm ponds is very limited so the area that can support intensive cultivation is restricted accordingly. The water from the ponds is mostly used for supplemental irrigation of the main season rice crop during short-term droughts and to grow small quantities of vegetables and fruit on the bunds around the ponds (Ogura and Somsak 2002). If the water storage capacity of the ponds could be increased, then it might be possible to expand the area planted to high value multiple crops.

Besides farm ponds, streams, rivers, public water bodies, and shallow wells are other sources of water that farmers rely on for multiple cropping. Growing peanuts after rice without irrigation, depends on having a shallow water table and soil with good texture (Vichian and Aran 1990). Farmers also report that good soil texture is the main factor needed for growing sweet potatoes. Soil texture plays a significant role for the presence and availability of soil moisture and the availability of oxygen in root zone (Gines and Kaida 1982). Vichian and Aran (1990) found that soil type was one of the important factors affecting farmers' adoption of multiple cropping systems.

Availability of adequate labour supply is another important constraint on adoption of multiple cropping. Only those households that have sufficient labour power are likely to engage in cultivation intensive crops like vegetables and hybrid seeds. Cassava which requires relatively less labour can be planted by more farmers.

Availability of markets and institutional support were the next most important factors contributing to the existence of multiple cropping. This is especially the case with regard to contract farming of hybrid seed. Farmer skills are also a very important factor in high value specialty crop production. For example, production of hybrid tomato seed requires a good supply of highly skilled workers to emasculate the flowers (Wareerat 2014).

In the case of cassava, there appear to be no especially important physical or institutional determinants; instead, farmers adopt this multiple cropping system as an adaptive strategy to cope with losses of rice yield caused by drought, as is explained by Ali (1995).

Although individual factors may sometimes exert a determining influence on the occurrence of specific crops in multiple cropping systems, it is usually the case that multiple different factors play a role. For instance, in the case of crotalaria, farmers are supplied the seed by the Land Development Department, which provides them with a guaranteed market for their crop. But, in addition to such institutional support, only rice fields located in the lower part of the toposequence with good soil moisture and relatively loamy soil are suitable for this crop. Therefore, in order to be able to assess the possibilities of extending multiple cropping systems into other areas, we need to identify all of the interrelated factors affecting each crop.

6. Conclusions

Although still practiced on only a small share of the total area of rainfed rice, multiple cropping after rice is now widespread in Khon Kaen province. It is found in 90% of all tambols and is practiced by almost 11% of all rainfed rice farming households. The recent expansion of multiple cropping is part of the on-going agrarian transformation that is reshaping the economy and society of rural Northeastern Thailand (see first

paper, this issue). As part of this transformation, agriculture is simultaneously undergoing intensification and diversification. Farmers who formerly grew only a single low-yielding crop of glutinous rice in lowland paddy fields for home consumption, and cultivated cassava in upland fields to sell for cash, have greatly intensified their land use. They have intensified rice production by adopting new higher yielding varieties of glutinous rice, using part of their paddy area to grow non-glutinous rice for sale, shifting from plowing with buffalo to plowing with tractors and from hand harvesting to use of combine harvesters, and greatly increased their use of chemical fertilizers and pesticides, among other changes. At the same time, upland cropping has been diversified by adoption of new crops including sugarcane, eucalyptus, and rubber. The widespread adoption by farmers of multiple cropping after rice is part of this general trend to generate more cash income from their land. Although income earned from growing field crops after rice is relatively low, vegetable crops provide very high returns per hectare, making a substantial contribution to the economy of rural families.

Although multiple cropping after rice can be a successful strategy for improving the livelihoods of rainfed rice farmers, its further expansion in Khon Kaen province appears to be limited by many physical and economic factors. For example, only certain restricted areas within the province appear to be suitable for growing high value vegetable crops. Further investigation is needed to identify the locally specific factors (e.g., soil moisture, soil fertility, availability of supplemental irrigation sources, household composition and labor supply, and alternative local employment opportunities) which may facilitate or constrain the engagement of individual farm households in multiple cropping in different localities.

7. Tables and Figures

Table 1 Characteristics of multiple cropping after the rice harvest in rainfed paddy fields in Khon Kaen province in the 2012/2013 growing season

List	Amount
Total number of tambols in province ^a	198
Total number of tambols having multiple cropping ^b	178 (90%)
Total rainfed rice area (ha) ^c	360,641
Total multiple crop area (ha) ^b	10,384
Proportion of rainfed rice area planted with multiple crops after the rice harvest (%)	2.9
Total number of rainfed rice farm households in 2012/2013 ^c	147,779
Number of rainfed rice farm households planting multiple crops ^b	16,184
Proportion of households planting multiple crops to total number of rainfed rice farm households (%)	10.9

^aData are from the online database of Khon Kaen Provincial Office

^bData are from our questionnaire survey in 2013

^cData are from the online database of Office of Agricultural Economics

Table 2 Planted area of multiple crops grown after the rice harvest during dry season under rainfed condition in Khon Kaen province during 2012/2013

Crop types	Planted area (ha)	% of total rice area ^a	% of total multiple cropped area	Number of tambols planting multiple crop	% of tambols planting multiple crop
Field crops	8,398	2.08	80.86	174	97.76
Cassava	5,571	1.38	53.64	60	33.71
Crotalaria	2,254	0.56	21.7	43	24.16
Field corn	318	0.08	3.07	30	16.85
Peanut	169	0.04	1.63	38	21.35
Mungbean	86	0.02	0.83	3	1.69
Vegetable crops	1,988	0.48	19.14		
Sweet corn	466	0.11	4.48	109	61.24
Chili	410	0.10	3.95	70	39.33
Watermelon	338	0.08	3.26	31	17.42
Tomato	232	0.06	2.23	30	16.85
Sweet potato	97	0.02	0.94	6	3.37
Cucumber	89	0.02	0.86	53	29.78
Yard-long bean	89	0.02	0.86	74	41.57
Other vegetables ^b	77	0.02	0.75	14	7.87
Egg plant	69	0.02	0.66	46	25.84
Chinese radish	49	0.01	0.47	3	1.69
Cabbage	38	0.01	0.37	2	1.12
Chinese cabbage	32	0.01	0.31	3	1.69
Total	10,384	2.57	100	615	345.53

^a Includes both rainfed and irrigated rice areas. Data on the area of only rainfed rice are unavailable at tambol level

^b Other vegetables include Chinese kale, gourd, pumpkin, snake gourd, musk melon and cowslip creeper

Table 3 Number of rainfed rice farming households growing crops after rice during dry season under rainfed conditions in Khon Kaen province during 2012/2013

Crop types	Number of rainfed rice farming households growing multiple crop	% of rice farming households doing multiple cropping growing this crop
Field crops	8,810	54.44
Cassava	5,204	32.16
Crotalaria	2,282	14.10
Peanut	669	4.13
Field corn	564	3.48
Mungbean	91	0.56
Vegetable crops	7,374	45.56
Sweet corn	1,821	11.25
Chili	1,606	9.92
Yardlong bean	820	5.07
Cucumber	626	3.87
Tomato	555	3.43
Watermelon	504	3.11
Other vegetables ^a	477	2.95
Egg plant	469	2.90
Sweet potato	197	1.22
Chinese radish	127	0.78
Chinese cabbage	93	0.57
Cabbage	79	0.49
Total	16,184	100.00

^a Other vegetables include Chinese kale, gourd, pumpkin, snake gourd, musk melon and cowslip creeper

Table 4 Economic values of multiple crops grown after rainfed rice compared to main season rice in Khon Kaen province during 2012/2013

Crop types	Planted area (ha)	Gross income (USD/ha) ^a	Total gross value (USD) ^b
Field crops			
Cassava	5,571	788	4,389,948
Crotalaria	2,254	598	1,347,892
Field corn	318	4,614	1,467,252
Peanut	169	1,797	303,693
Mungbean	86	414	35,604
Vegetables			
Sweet corn	466	4,688	2,184,608
Chili	410	9,141	3,747,810
Watermelon	338	7,695	2,600,910
Tomato	232	49,072	11,384,704
Sweet potato	97	5,990	581,030
Cucumber	89	8,525	758,725
Yard-long bean	89	14,180	1,262,020
Other vegetables	77	7,023	540,771
Egg plant	69	14,063	970,347
Chinese radish	49	19,531	957,019
Cabbage	38	2,344	89,072
Chinese cabbage	32	1,055	33,760
Total	10,384	-	32,655,165
Main season rice grown on multiple cropped area	10,384	982 ^c	10,197,088

^a Calculated from the farmers' interview of crop production, farm gate price as of 2012

^b Calculated from gross income per area of each crop multiplied by planted areas.

^c Calculated from the report of rainfed rice yield and farm gate price from Office of Agricultural Economic and Department of Agricultural Extension, Thailand, respectively.

1 USD=32 Thai baht

Table 5 Gross income of rice and some multiple crops grown after rice under rainfed conditions in Khon Kaen province

Crop types ^a	Gross income of each crop (USD/ha)	Total income of the system (USD/ha)	% increase from rice mono-cropping
Main season rice ^b	982	982	0
Cassava	788	1,770	44.53
Crotalaria	598	1,579	37.84
Field corn	4,614	5,596	82.46
Peanut	1,797	2,778	64.67
Mungbean	414	1,395	29.66
Watermelon	7,695	8,677	88.69
Tomato	49,072	50,054	98.04
Corn	4,688	5,669	82.68
Chili	9,141	10,122	90.30
Sweet potato	5,990	6,971	85.92
Cucumber	8,525	9,507	89.67
Yard-long bean	14,180	15,161	93.53
Egg plant	14,063	15,044	93.48
Chinese radish	19,531	20,513	95.21
Cabbage	2,344	3,325	70.48
Chinese cabbage	1,055	2,824	65.24
Other vegetables	7,023	8,602	88.59

^a Multiple crops other than rice calculated from the farmers' interview of crop production, farm gate price as of 2012

^b Calculated from the report of rainfed rice yield and farm gate price from Office of Agricultural Economic and Department of Agricultural Extension, Thailand, respectively.

1 USD=32 Thai baht

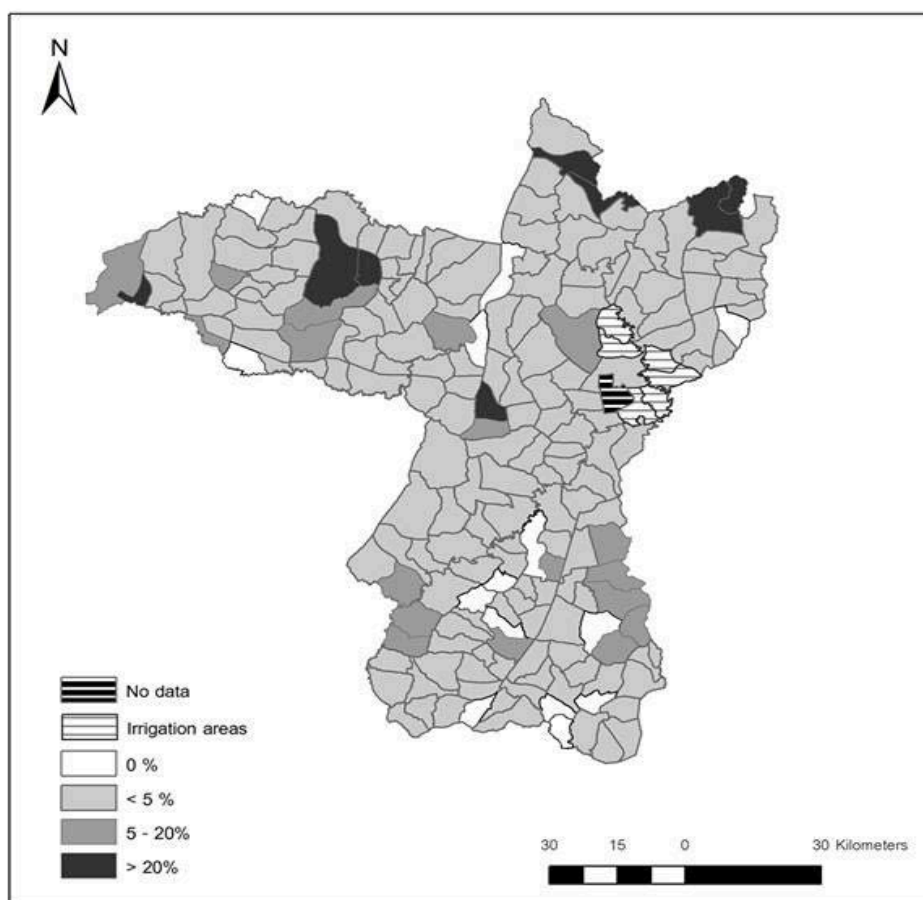


Fig. 1 Spatial distribution of multiple crop area to total rice area grown after rainfed rice in each tambol (sub-district) Khon Kaen province during 2012/2013

8. Summary of:

8.1. *paper has been accepted*

Title of the paper: Multiple cropping after the rice harvest in rainfed rice cropping systems in Khon Kaen Province, Northeast Thailand, Name of the journal: Southeast Asian Studies Vol. 6 (2).

8.2 Conference / workshop attendance

- (1) Oral presentation at The KKU-CSEAS Conference on Rural Northeast Thailand in Transition: Land Use, Farming Systems and Households, 16 September 2014, Faculty of Agriculture, Khon Kaen University.
- (2) Academic paper writing workshop during 26-28 November 2014 at Wishing Tree Resort, Khon Kaen.
- (3) Academic paper writing workshop during 12- 14 February 2016 at the Wishing Tree Khon Kaen Resort in Tha Phra Sub-District, Khon Kaen Province.

1. Title of Sub-project: Mountain agricultural systems in Northeast Thailand

2. Names and Affiliations of Researchers:

- (1) Ms. Sukanlaya Choenkwan Program on System Approaches in Agriculture, Faculty of Agriculture, KKU
- (2) Prof. Dr. A.Terry Rambo Program on System Approaches in Agriculture, Faculty of Agriculture, KKU
- (3) Prof. Dr. Hayao Fukui Program on System Approaches in Agriculture, Faculty of Agriculture, KKU
- (4) Dr. Arunee Promkhambut Program on System Approaches in Agriculture, Faculty of Agriculture, KKU
- (5) Dr. Jefferson Metz Fox Program on System Approaches in Agriculture, Faculty of Agriculture, KKU

3. Research Objectives

- 1) To divide the mountain area of Northeastern Thailand into several sub-zones
- 2) To describe characteristics of mountain areas and mountain agriculture in Northeastern Thailand
- 3) To classify types of agricultural systems practiced in the mountain area of the Northeast Thailand
- 4) To identify determining factors of the occurrence of different types of agricultural system in different areas

4. Research Methodology

4.1 Operational definition of ‘mountain’ for the research

For the purpose of this research on mountain agriculture in northeast of Thailand, mountains are defined in terms of the criterion of altitude. Mountains are any land area that rise higher than 300 meters above mean sea level (AMSL.). Although it might be preferable to use relative elevation, the topographic situation of the Northeast makes it very difficult to use this criterion, therefore absolute elevation is suitable for this situation.

4.2 Conceptual frameworks of the study

The conceptual framework can be divided into 2 parts;

- 1. Characteristics of mountain agriculture in northeastern Thailand [Figure 1].
- 2. Determining factors of occurrence of different types of agricultural systems in northeastern Thailand [Figure 2].

4.3 Selection of the study site

This research is focused on areas in northeastern Thailand that have an elevation higher than 300 meters AMSL [Map 1]. The study included all of the sub-districts in the region where the area with an elevation higher than 300 meters AMSL covers more than 50 percent of the total area. However, the small area of mountains along the Cambodian frontier has been excluded because of the security problem.

4.4 Research design

This research is divided into 2 sub-studies of three different levels [Figure 3]
Sub-study 1: Describe characteristic of mountain areas and mountain

agriculture of northeastern Thailand

Sub-study 2: Classify types of agricultural systems in the mountains

Sub-study 3: Identify determining factors of the occurrence of different types of agricultural systems in different areas

4.4.1 Sub-study 1: Describe characteristics of mountain areas and mountain agriculture of northeastern Thailand.

4.4.2 Sub-study 2: Classify types of agricultural systems

4.4.3 Sub-study 3: Identify determining factors of occurrences of different types of agricultural in different areas

5. Research Findings

The mountains in Northeastern Thailand cover an area of about 25,000 km², which is about 15 percent of the region's land surface. The mountains are divided into 4 mountain ranges: Northern Petchabun Range, Southern Petchabun Range, Sankamphaeng and Phu Phan. The mountains are very diverse in environment, culture and land use. Mountain agriculture is also very diverse at the crop level such as rice, maize, sugarcane, cassava, soybean, Job's tears, upland rice, rubber, eucalyptus, teak, orange, lychee, mango, custard apple, banana, sweet tamarind, longan, edible rattan, exotic fruits, vegetables, flowers, and mushroom. Field crops remain the main source of income but, in recent years, rubber has been an important crop generating high gross values in some sub-districts. Specialty crops (e.g. grapes, mushrooms, strawberries and temperate vegetables) generate high income and also serve as a magnet for tourism, but are grown in only a small area.

The Northeast mountain agriculture can be divided into 5 agricultural systems i.e. Field crop system, Fruit tree system, Tree plantation system, Specialty crop system and Agro-tourism system. Details of each agricultural system are described below.

(1.1) *Field crop system*

The field crop system is the main agricultural system that has been widely practiced for a long time in all of the villages. Cassava, maize, sugarcane, and rice are the main annual crops grown in this system. Cassava, maize, and sugarcane are planted to generate cash income, whereas rice is mainly grown for household consumption. However, surplus rice will be sold for cash income. Livestock are an integral part of the field crop system. Cattle are raised mainly for cash income. The cattle are grazed in the paddy fields during dry season whereas in the wet season, when rice is planted in the paddy fields, the cattle are grazed in the forest and around the houses.

The different species of crops often compete for the same land within the agricultural landscape so that farmers must select which crop should be planted each time. For instance, cassava, maize, and sugarcane can all be grown in upland fields while rice and sugarcane can both be grown in paddy areas. In recent years, some paddy fields have been changed to sugarcane because the price of sugarcane is much higher than rice and the expansion in the number of sugar mills has increased the demand for sugar leading the mills to carry out extension projects to expand the area of sugarcane.

The marketing component of the system is relatively simple. Farmers can sell their agricultural products directly to agricultural warehouses located scattered in the area, or they can sell to the middlemen who come to their farms and transport the crop to market.

(1.2) *Fruit tree system*

Many different kinds of fruit trees are grown, including sweet tamarind, mango, custard apple, longan, orange, and lychee. These crops are planted for the purpose of both generating cash income and for household consumption. Fruits grown mainly for consumption are planted close to the houses and paddy fields, whereas, fruit trees grown mainly for cash income are planted in larger plots on sloping land at moderate elevations. Different kinds of orchards and plantations are mostly grown on the same type of land form. During the last few years, some areas of sweet tamarind and mango trees have been replaced by rubber because of the high price of rubber. Some farmers directly sell their fruit to retail buyers in the market, while others sell them to middlemen who come to their farms.

(1.3) *Tree plantation system*

Tree plantations include rubber, eucalyptus and teak. However, rubber is the most widely planted species. All these trees are planted solely for generating cash income. Rubber is a newly introduced crop in the mountains. The area of rubber has been expanding rapidly in the past 10 years because until recently the price of rubber was very high but now the price of rubber is decreasing. Still, some farmers continue to expand their plantations because even if the price for latex is low, it is still higher than cassava or maize. However, there are some farmers who want to stop tapping the rubber because of the low price. The farmers can sell the latex every month or twice a month whereas maize or cassava are sold only once a year. Rubber trees take 7 years to mature but then can yield latex for about 30 years, whereas cassava and maize have to be replanted every year. Also the trunks of rubber trees can be sold as timber. The latex is sold as uncured balls to the middleman who is the highest bidder in a bi weekly auction.

(1.4) *Specialty crop system*

Specialty crops include grapes, shiitake mushrooms, exotic flowers and ornamental plants (e.g., marigolds, china pinks, roses, white Christmas flowers, hydrangeas, poinsettias, bromeliads, African violets, petunias, and phlox) and temperate vegetables (e.g., cabbage, broccoli, carrots, cauliflower, Chinese cabbage, Chinese radish, coriander, kale, kohlrabi, purple eggplant, cucumber and tomatoes). Dairy cows are also sometimes included in this system. These crops are mainly planted for the purpose of cash income. Most of them are grown in small plots scattered near settlement areas. The products are sold wholesale to middlemen who come from other places. These crops can be grown all year round. Since growing specialty crops is highly labor intensive and, in many cases, involves manual labor that cannot be done with machines, farmers must hire other villagers to work on their farms.

(1.5) *Agro-tourism system*

In this system, agriculture and tourism enjoy a symbiotic relationship, with each activity benefitting from the other. Specialty crop farms in the area serve as tourist attractions. Crops include grapes, exotic flowers and ornamental plants, Shiitake mushrooms, strawberries, macadamia nuts and temperate vegetables. Tourists are the main consumers, often buying products directly from shops on the farms or from local shops, restaurant or hotel providing for tourists. While local houses offering home stays, resorts and restaurants and catering tourists, they also provide a marketing channel for farmers to sell their agricultural products. Both specialty crop farms and tourist enterprises need high labor inputs, providing the opportunity for other villagers to work and gain income.

There are two distinct types of the Agro-tourism system. Firstly, relationship between agriculture and tourism is strong. Almost all of the farm plots are located

directly adjacent to home stay places and the relationship between agriculture and the home stay and restaurant sectors in this system is very close. Indeed, the presence of specialty crop plots is so important to attract tourists. Most of the home stay owners either rent or freely lend the use of the land around their houses to their domestic workers who use it to plant vegetables or mushrooms. The owners do this because having these nearby farms can attract tourists to stay with them. They also believe that having agricultural activities nearby makes the landscape of the home stay look more beautiful. The workers who rent or borrow the land can sell the products to tourists or middlemen, which provide a secondary source of income for the workers. For this type of the system, agriculture and tourism have to stay together. They cannot stay by without each other.

Secondly, relationship between agriculture and tourism is weak. Farm plots and resorts, homestays, hotels and restaurants are located separately. Agricultural products help to make landscape more beautiful and attract tourists to visit. Tourism enterprises get benefit from tourists coming to the areas. Some farmers can sell their products to tourist directly and get higher price than they sell wholesale. Some agricultural products like Shiitake mushroom, even it is not sold to tourist directly but it is sold to roadside stalls, resorts or restaurants to pass to tourists. This type of the Agro-tourism system, tourism and agriculture are not necessary to stay together. They can separate from each other. Tourism is an alternative marketing channel for farm products.

Factors associated with the occurrence of each type of agricultural system

As the Field crop systems were found in all studied villages, to find factors associated with its occurrence is excluded.

Each system generates 1 discriminant function. All functions are signification at 1% level ($p < 0.01$). Different agricultural systems have different statistically significant discriminating variables and different the most important factors of occurrence of the system (Table 1 and Table 2). The Fruit tree system mostly occurs in B5 climate and on the area close to national parks and the most important factor is distance to national parks.

Occurrence of the Tree plantation system is associated to high elevation and steep land. It is mostly found in poor soil and the area that water for agriculture sufficient only in rainy season. The Tree plantation system is located on area close to districts and main roads but far from national park. Distance to main roads is the most significant factor for the Tree plantation system.

Significant variables of the Specialty crop system and the Agro-tourism system are very similar. They are mostly found in B5 climate, best soil quality and close to districts. Slope is a statistically significant factor for both systems. The Specialty crop system prefers flat land but the Agro-tourism system prefers steep land. Distance to national park is only one crucial factor different in the Agro-tourism system. The Agro-tourism takes place in area close to national park. Slope and distance to national park are the most important factors for occurrences of the Specialty crop system and the Agro-tourism system respectively.

6. Conclusions

Although Thailand's northeastern mountains cover only a relatively small share of the northeastern region, they support diverse types of agriculture. Because of their distinctive environmental conditions, the mountains offer unique opportunities

for agricultural development, especially growing specialty crops, which can generate high income and serve as magnets for tourism. However so far, only small areas have been used for this purpose, and most of the agricultural land in the mountains is still used for low-value crops, which can be grown equally well in lowlands. Therefore, to develop agriculture in the mountains, farmer should be encouraged to take advantage of their unique agricultural environment by growing more specialty crops and establishing agro-tourism facilities. The discriminant analysis showed that high value systems as the Specialty crop system and the Agro-tourism system are found in areas with cool climate, good soil quality, high elevation, closeness to national parks, tourism spots or beauty scenery, and closeness to district towns or urban areas.

7. Tables and Figures

Table 1 Canonical Structure Matrix

Factors	Canonical Structure Matrix ¹			
	Fruit Tree	Tree Plantation	Specialty Crop	Agro-Tourism
Elevation		.405		
Slope		.168	.727*	-.396
Climate	.491		.318	.480
Quality of soil for agriculture		.601*	.591	.359
Sufficiency of water for agriculture		-.267		
Quality of road				
Distance to district		-.284	.403	.288
Time to district				
Distance to main road		-.425		
Distance to national park area	.899*	.043		.651*
Land tenure security				

¹Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions

* Largest absolute correlation between each variable and discriminant functions

Table 2 Standardized discriminant function coefficients

Factors	Standardized discriminating coefficients			
	Fruit Tree system	Tree Plantation system	Specialty Crop system	Agro-Tourism system
Elevation		.414		
		Slightly higher		
Slope		.180	.640	-.348
		Slightly steeper land	Flatter land	Steeper land
Climate	.440		.364	.433
	Mostly B5 climate ²		Mostly B5 climate ²	Mostly B5 climate ²
Quality of soil for agriculture		.599	.486	.454
		Poorer soil	Better soil ¹	Better soil ¹
Sufficiency of water for agriculture		-.226		
		Mostly sufficient only in rainy season		
Distance to district		-.277	.328	.378
		Closer to district	Closer to district	Closer to district
Distance to main road		-.663		
		Closer to main road		
Distance to nationalpark area	.872	.499		.587
	Closer to national park	Further from national park		Closer to national park

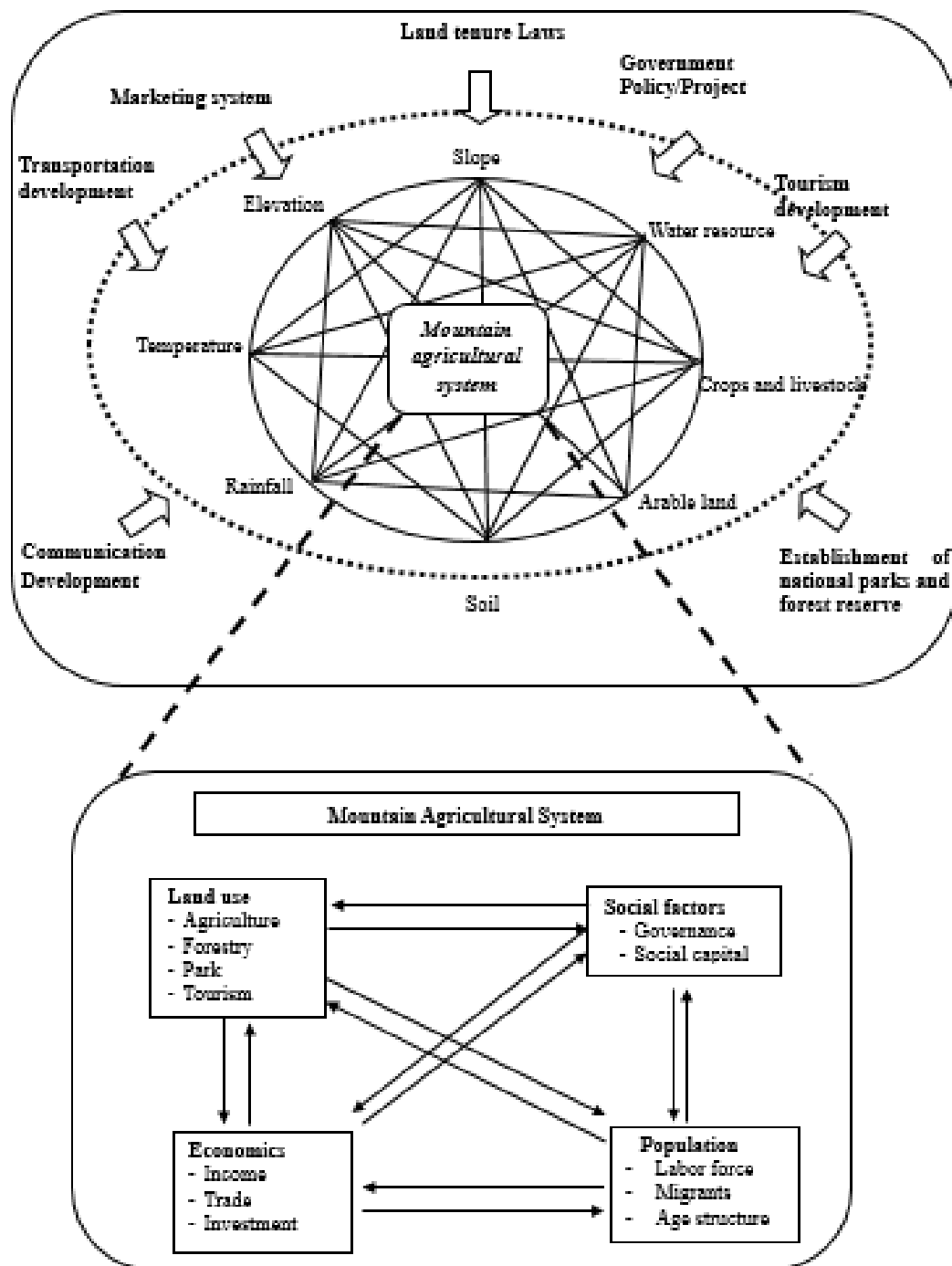


Figure 1 Conceptual framework of characteristics of mountain agriculture

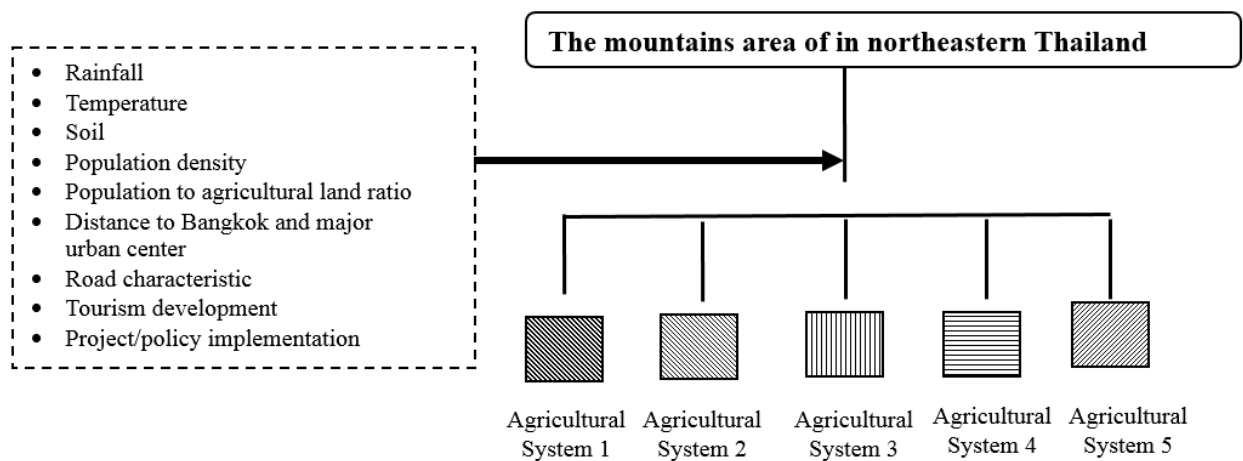
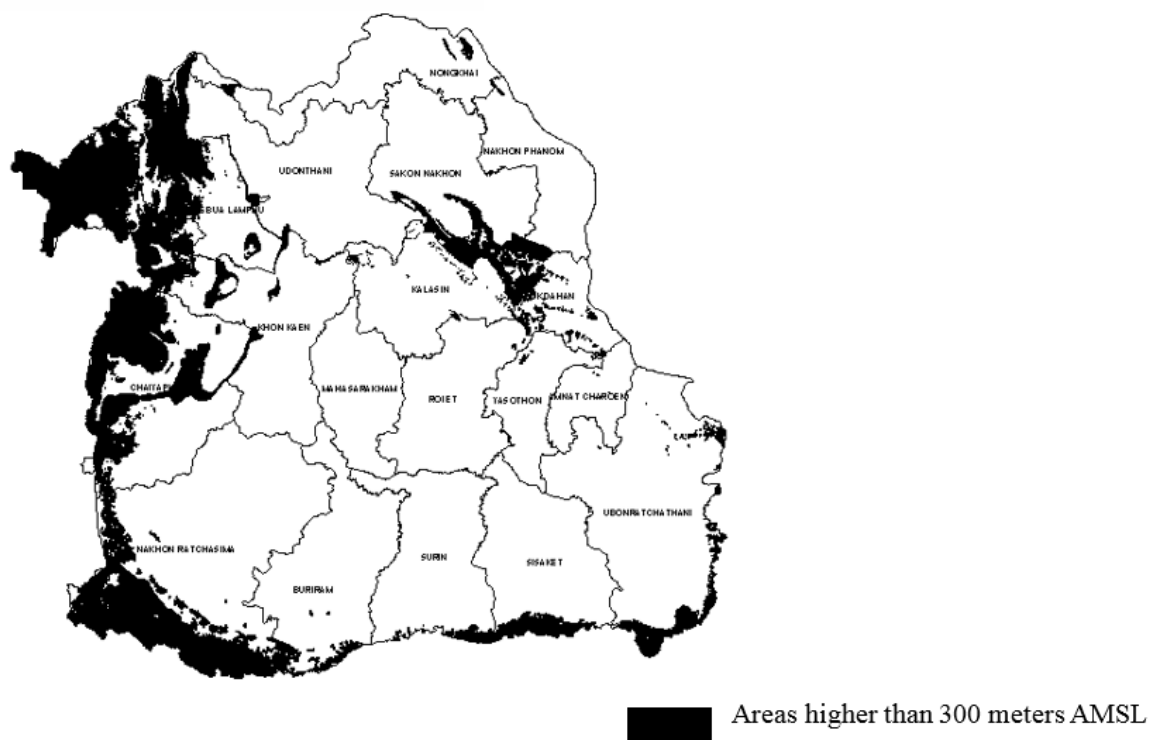


Figure 2 Conceptual framework of determining factors of occurring of different types of agricultural systems in mountain area in Northeastern Thailand



Map 1 Areas higher than 300 meters AMSL in Northeastern Thailand.

8. Accomplishments

8.1 Papers

a. papers that have been published

(1) Agriculture in the Mountains of Northeastern Thailand: Current Situation and Prospects for Development, Mountain Research and Development 34(2): 95-106 (2014), Impact Factor 0.91

(2) การใช้ประโยชน์ที่ดินทางการเกษตรบนพื้นที่ภูเขาของภาคตะวันออกเฉียงเหนือ, 43(4):626-634 (2015) Impact Factor 0.308

(3) Does Agrotourism Benefit Mountain Farmers? A Case Study in Phu Ruea District, Northeast Thailand, Mountain Research and Development, 36 (2): 162-172 (2016) Impact Factor 0.91

c. paper that has been submitted and is under review

(1) Using the niche concept to explain the spatial distribution of agricultural systems in the mountains of Northeast Thailand, Landscape and Urban Planning, Impact Factor 3.654

d. manuscripts not yet submitted to journals

(1) Agricultural systems in the mountains of Northeast Thailand, Journal of Mountain Science, Impact Factor 1.02

(2) Is local social organization a constraint on development of community-based tourism? Case study in a homestay village, Wang Nam Khiao district, Nakhon Ratchasima province, Thailand, Asia Pacific Journal of Tourism Research, Impact Factor 1.023

8.2 Conference / seminar / workshop attendance

(1) Oral presentation at TRF Seminar Series in Basic Research: The Agrarian Transformation in Northeast Thailand, 15 September 2014, Faculty of Agriculture, Khon Kaen University, in the title of Agricultural systems in mountains of Northeast Thailand.

(2) Academic paper writing workshop during 26-28 November 2014 at Wishing Tree Resort, Khon Kaen.

(3) Academic paper writing workshop during 12-14 February 2016 at Wishing Tree Resort, Khon Kaen

(4) Academic paper writing workshop during 18-20 November 2016 at Wishing Tree Resort, Khon Kaen

8.3 Completion of an academic degree

Completion of Ph.D. degree on 15 October 2015

8.4 Awards received

Postdoctoral training fellowship supported by KKU graduated school, February 2016 – January 2017

1. Title of Sub-project: Recent changes in agricultural land use in the riverine area of Nakhon Phanom Province, Northeast Thailand

2. Names and Affiliations of Researchers:

- (1) Dr. Sorat Praweenwongwuthi, Faculty of Agriculture and Technology, Nakhon Phanom University
- (2) Prof.Dr. Attachai Jintrawet, Center for Agricultural Resource System Research (CARSR), Faculty of Agriculture, Chiang Mai University and Faculty of Agriculture and Technology, Nakhon Phanom University
- (3) Prof. Dr. A.Terry Rambo Program on System Approaches in Agriculture, Faculty of Agriculture, KKU
- (4)

3. Research Objectives

To describe recent changes of agricultural land use and identify the factors influencing these changes in two districts along the bank of the Mekong River in Nakhon Phanom Province.

4. Research Methodology

1. Research Site

This study was conducted in Mueang and That Phanom districts in Nakhon Phanom Province (coordinates: Upper left 17.99 N, 103.96 E, Upper right 17.99 N, 104.86 E, Lower left 16.70 N, 103.96 E, and Lower right 16.70 N, 104.86 E) in the valley of the Mekong River (Figure 1). Neighboring provinces (going clockwise from the south) are Mukdahan, Sakon Nakhon, and Bueng Kan. To the northeast it borders Khammouan of Laos. The northern part of the province has both uplands and forest covered plains and is drained by the Song Kram and the smaller Oun rivers. The southern part is mostly flatland with the Kum River as its only notable river. The provincial capital, the city of Nakhon Phanom, is located directly on the bank of the Mekong.

Mueang Nakhon Phanom is the capital district of Nakhon Phanom Province. Mueang District is subdivided into 15 Sub-districts (*tambol*) which are further subdivided into 169 villages (*muban*). The city of Nakhon Phanom (*thesaban mueang*) covers all of Nai Mueang and Nong Saeng Sub-districts as well as parts of At Samat and Nong Yat sub-districts.

That Phanom District is in the southern part of Nakhon Phanom Province. The District is named after Wat Phra That Phanom, the most important Buddhist temple in the region. The district is subdivided into 12 Sub-districts, which are further subdivided into 142 villages. That Phanom Municipality covers parts of That Phanom and That Phanom Nuea sub-districts.

2. Data Sources

Land use maps for 2006 and 2010 of both districts were obtained in shapefile formats from the Land Development Department Office 4 in Ubon Ratchatani. These maps were made from unclouded and terrain corrected Landsat images in 2006 and 2010. The image processing and data manipulation were conducted using ERDAS® IMAGINE™ 8.6 and ArcGis 9.1. A handheld Garmin GPS eTrex® HC (12-15 m accuracy) was used to obtain the coordinates of the plots with the different types of land uses. Some ancillary data were also used as references in image processing (Land Development Department, 2010).

Information on the causes of some important types of land use changes in several localities was collected from local officials and farmers by holding focus groups. This

was done after the changes of land use were analyzed and several problematic types of change were identified, especially conversion of paddy fields to forests and forests to paddy fields.

3. Method of Analysis

Spatial analysis employing the Decision Support System Research and Development Network for Agricultural and Natural Resource Management (DSSARM)¹ Program was used to identify all plots that had been converted from one land use to a different use between 2006 and 2010. DSSARM images of two districts were analyzed by using a supervised classification method. This classification was used to compile Table 1.

5. Research Findings

1. Recent changes in agricultural land use

The changes in land use between 2006 and 2010 are presented in Table 1. It is readily evident that a great deal of change occurred during this five year period. In Mueang District, about one-eighth (12.1 percent) of the area (9,478 ha) was in different use in 2010 than it was in 2006. In That Phanom District, the magnitude of change was even greater, with more than one-fourth (27.3%) of the area (9,324 ha) changing uses between 2006 and 2010.

In Mueang District, there was a small decrease in the area under agriculture from 47,920 to 47,249 ha, a net loss of 671 ha, while in That Phanom District it increased from 25,323 to 26,298 ha, a net gain of 975 ha. The area of settlement increased in Mueang District by 1.5 times from 4,645 to 6,591 ha, which is a net gain of 2,306 ha; in That Phanom District, it increased by almost 1.3 times from 2,413 to 3,033 ha, for a gain of 620 ha. , Given these increases in the area of agricultural land in That Phanom District and the area of settlement in both districts, the decrease of natural forest is not surprising: it decreased in Mueang District from 22,089 to 19,483 ha for a net loss of 2,606 ha, while in That Phanom District it declined from 4,226 to 2,612 ha for a net loss of 1,614 ha.

In Mueang District in both 2006 and 2010 the four most important land uses in terms of area covered were rice, natural forest, settlement area, and water. In That Phanom District in 2006 they were rice, natural forest, orchards, and settlement area; in 2010 rice was still in the first place followed by rubber, natural forest, and settlement area.

In both districts there was a major shift from other land uses to rubber plantations. Rubber plantations expanded at the expense of rice, eucalyptus and specialty crops in Mueang District and orchards, cassava, specialty crops, rice and sugarcane in That Phanom District. In Mueang District the area of rubber increased by 23 times (from 59 to 1,353 ha) for a net gain of 1,295 ha, while in That Phanom District it increased by 22 times (from 246 to 5,497 ha) for a net gain of 5,251 ha. However, after the period under study, in 2011, a steep decline in price paid for latex

¹ DSSARMS is an integrated Geographic Information System (GIS) program developed for general users to enter and display data layer maps and data tables. Using this system requires a shorter learning period than a full-grown GIS program. It was developed by Visual Basic 6 and ArcGIS version 9.3 and designed to handle the spatial data in Geodatabase format. DSSARM was designed to ensure the effective uses of spatial and attribute databases in planning and management of agricultural and natural resources (Methi et al., 2003).

has led some farmers to begin shifting out of rubber into other crops.

Rice fields suffered significant losses of area in both districts, losing 1,100 ha in Mueang District and 735 ha in That Phanom District. A main cause of the decline in Mueang District was the expansion of urban settlements with 1,027 ha of paddy fields converted to settlement area. At the same time, however, 206 ha of settlement area were converted to paddy fields. This was land on the fringe of villages that may not have actually contained houses in 2006. Curiously, the area of rice fields in Mueang District lost 776 ha to natural forest but gained 1,522 ha from natural forest in this period. The rice fields that were converted to forest were in areas where the government ordered farmers to stop illegal cultivation of publicly owned forest land while the forest land that was converted to paddy fields was located in areas where the government had reclassified degraded forest land for agricultural uses.

Orchards also lost 410 and 2,580 ha respectively in Mueang and That Phanom districts while the area devoted to growing specialty crops (e.g., tomatoes, chilies, tobacco) also declined in both districts.

The area of eucalyptus plantation declined from 443 ha to 183 ha in Mueang District; most of this area was changed to natural forest and rubber. In That Phanom District it increased from 1,019 to 1,700 ha. This expansion was initially promoted by a private company primarily at the expense of natural forest, orchards, cassava, and rice paddies. Other land uses, such as grass land, showed small gains in area in both districts. Sugarcane was not planted in Mueang District whereas in That Phanom District it suffered a loss of area of almost two-thirds, dropping from 327 to 97 ha, with most of that area converted to rubber.

Water (swamps, fish ponds) lost 470 and 258 ha respectively in Mueang and That Phanom districts. Almost a half of water area in Mueang District was converted to settlement area whereas in That Phanom District was converted to grass land.

2. Factors influencing land use change

Based on our field observations and discussions with farmers we have identified several factors that have exerted an important influence on land use changes in our study site. These factors include 1) lack of secure land titles, 2) urban growth and expansion of housing estates and infrastructure (e.g., roads, public buildings, airports) into peri-urban areas, and 3) changes in the costs and benefits of growing different crops.

1) Lack of secure land titles

A dispute and a lawsuit over land ownership resulted in abandonment of agricultural land and its reversion to natural forest in Kham Toei Sub-district, Mueang District. There, in the late 1990s, there were approximately 160 ha of village community forest. An entrepreneur illegally cleared part of the forest for a rubber plantation. The villagers repeatedly asked the provincial officers to resolve the problem of overlapping claims to this land. Finally, in 2008, the Administrative Court declared the land to be public forest. Then, the entrepreneur filed an appeal with the Administrative Court to revoke the order but the case was later dropped although the conflict over ownership had not been resolved. Because of the lack of secure tenure the land has been abandoned and the area that had been cleared for rubber is reverting to natural forest.

2) Urban growth and expansion of housing estates and infrastructure into peri-urban areas

Nakhon Phanom Municipality and, to a lesser extent, the That Phanom district town have experienced considerable population growth in recent years, which has led to rapid expansion of the settlement areas. New housing estates and infrastructure

projects have occupied former agricultural land in the neighboring sub-districts which have been transformed from rural to peri-urban zones. This urban growth is a consequence of rapid economic growth that has accompanied the opening of the new bridge across the Mekong River to Laos, the expansion of Nakhon Phanom University (NPU), and the development of the Nakhon Phanom airport. Students attending the university, which has campuses in both Nakhon Phanom Municipality and That Phanom district town, have created a strong demand for new housing. The airport, which is located in Na Sai Sub-district on the outskirts of Nakhon Phanom City, was first opened in 1977. It has recently undergone a major expansion so it can serve as a transit point for passengers bound for neighboring countries via the new bridge. It also serves as the home base for NPU's International Aviation College. Many new restaurants, shops and service enterprises have developed to serve the airport's users. As a consequence of the employment opportunities offered by the airport and associated businesses, the population of nearby communities has expanded with new housing taking over land formerly used for agriculture. Also located in the sub-district is the Nakhon Phanom Municipality landfill which occupies the area of approximately 12 ha in Ban Sukkasem. This facility receives an average of 70 tons of waste each day. Located in close proximity to the landfill are a number of recycling businesses which occupy former farm land. Similar conversion of farm land to urban use is occurring in Ku Ru Ku Sub-district. This sub-district is home to The Nakhon Phanom Army Camp and the associated military hospital. Developers have bought agricultural land surrounding the camp to build housing for service personnel and hospital staff. The value of farm land has increased by as much as 30 times in 10 years.

3. Changes in the costs and benefits of growing different crops

Much of the land use change in both districts has resulted from the conversion of land from other uses, especially natural forest, orchards, and rice paddies, to rubber. This change was accelerated after 2006, as the pioneer farmers, who had planted small areas of rubber during the early 1990s, began to earn high profits, which influenced neighboring farmers to also plant rubber on their land. The decision-making of many farmers was more influenced by knowledge about rubber conveyed through their social networks, sometimes across the provincial boundary, than by government extension programs. According to interviews with rubber farmers, they heard about the success of rubber farmers in nearby Nong Khai and Bueang Kan Provinces. The increasing price of rubber and the higher cost of agricultural labor that reduced the profitability of rice cultivation at that time also provided farmers with incentive to convert their paddy fields into rubber plantation.

6. Conclusions

The land use system in our study area is quite dynamic, with very rapid changes of use in extensive areas occurring during the period of five years between 2006 and 2010. Two major changes are expansion of rubber and expansion of settlement areas in this study area.

Although at first glance it appears that rubber is expanding at the expense of all other uses, the reality on the ground is not so simple. It is true that the expansion of rubber plantations has often occurred at the expense of natural forests and paddy fields. Conversion of forest into rubber plantations is especially rampant in areas along the roads where the population is concentrated. In both Mueang and That Phanom districts, many farmers, whose livelihoods were once dependent on diversified agriculture, have become dependent on a mono-cultural system with

concomitant instability due to variable product prices. However, this shift reflects the fact that farmers have become highly sensitive to price changes of their products and altered their land use accordingly. This would have never occurred when they were subsistence-oriented peasants. In the past, rice was the most important crop for the northeastern farmers. They all preferred to grow their own rice, even though it was a low value crop, but now they are much more concerned with maximizing cash income from their land.

The shift of various types of land use to urban settlements has affected an even larger area than that affected by the expansion of rubber. Rapid development of the local economy, especially of the commercial and service sectors in the towns and cities, has resulted in the conversion of large areas of agricultural land to urban settlement. Many farmers who have sold their land to urban developers have left the agricultural sector and become dependent on non-farm income. Such change from farm land to urban settlement uses, because it is essentially irreversible, may have greater long-term impacts on land use than shorter-term conversion of land from one crop to another.

7. Tables and Figures

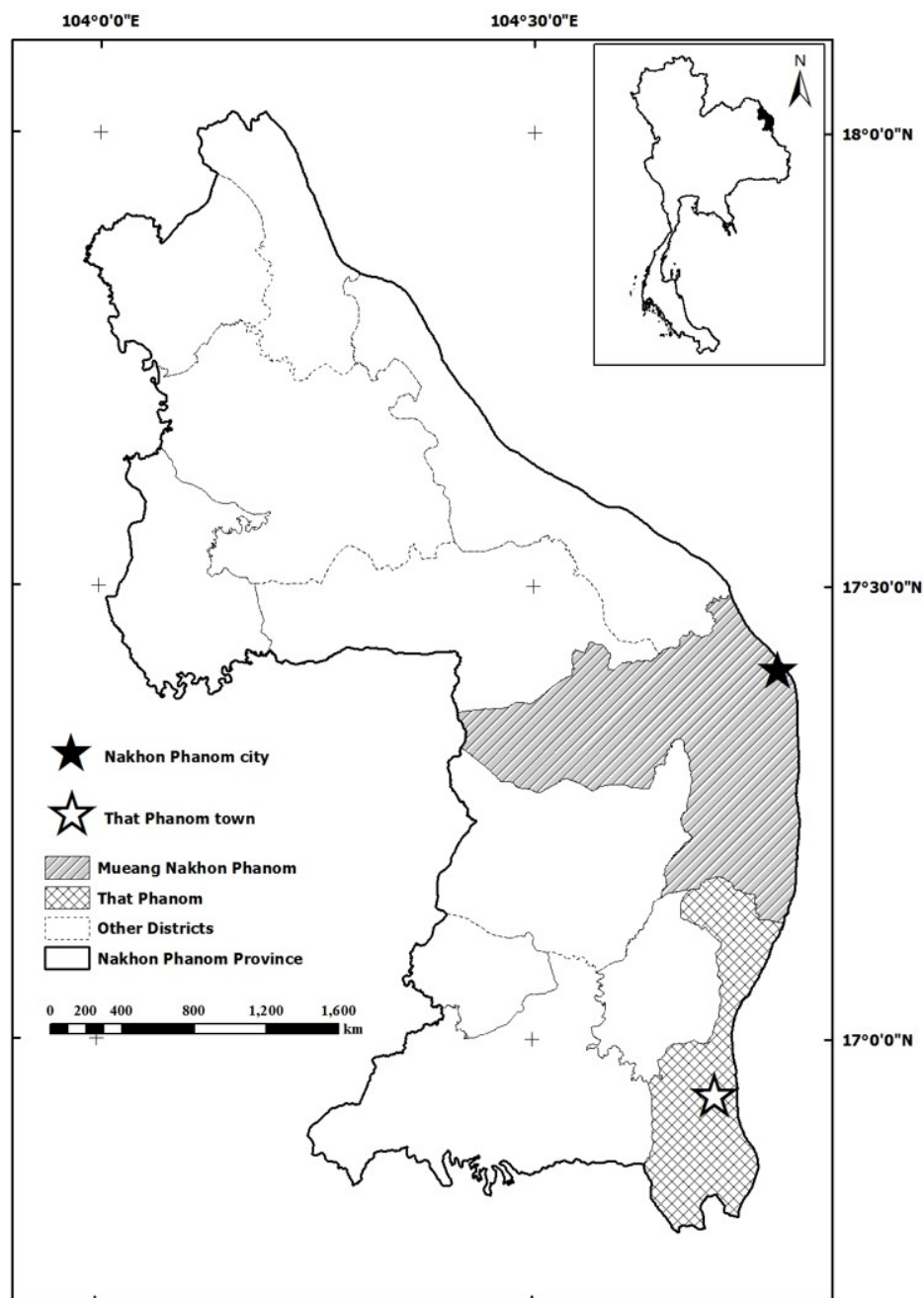


Figure 1: Map of Mueang and That Phanom districts, Nakhon Phanom provinces

Table 1.1: Changes in land uses from 2006 to 2010 in Meang districts, Nakhon Phanom Province

Mueang District	Land use in 2006	Land use in 2010									
		Cassava	Eucalyptus	Grass	Natural forest	Orchards	Rubber	Rice paddies	Settlement	special crops	Water
Eucalyptus	443		15		300		127				
Grass	30		17					13			
Natural forest	22,089	95	111		17,937	23	827	1,522	1,052	26	496
Orchards	497		14		77	10		47	348		
Rubber	59				59						
Rice Paddies	46,087	41	25	39	776	38	354	43,082	1,027	78	628
Settlement	4,645			29	58	17		206	4,277	30	27
Special crops	834			32	225		45	59	43	356	75
Water	3,440			145	52			59	203	12	2,970
2006 total	78,124										
Land use 2010 total	78,124	136	183	245	19,483	88	1,353	44,987	6,951	502	4,197

Table 1.2: Changes in land uses from 2006 to 2010 in That Phanom districts, Nakhon Phanom Province

That Phanom District	Land use in 2006	Land use in 2010										
		Cassava	Eucalyptus	Grass	Natural forest	Orchards	Rubber	Rice paddies	Settlement	special crops	Sugarcane	Water
Cassava	956	25	37	14			881					
Eucalyptus	1,019		829		134		56					
Grass	12				12							
Natural forest	4,226	64	652	11	1,939	23	1,312	131	37			57
Orchards	2,621	14	143		291		1,553	303	275		32	10
Rubber	246				12		234					
Rice Paddies	18,713	32	39		116		473	17,252	524	237		41
Settlement	2,413				61	18	13	198	2,096	27		
Special crops	1,441	20			46		723	84	81	470		18
Sugarcane	327	22		12			229				65	
Water	2,160			127			24	11	19	77		1,902
2006 total	34,134											
Land use 2010 total	34,134	175	1,700	163	2,612	40	5,497	17,978	3,033	811	97	2,028

8. Accomplishments:**8.1 Paper that has been accepted**

1. Recent changes in agricultural land use in the riverine area of Nakhon Phanom Province, Northeast Thailand, Southeast Asian Studies Vol. 6 (2).

8.2 Conference / seminar / workshop attendance

1. Oral presentation at TRF Seminar Series in Basic Research: The Agrarian Transformation in Northeast Thailand, 15 September 2014, Faculty of Agriculture, Khon Kaen University, in the title of Agricultural systems in mountains of Northeast Thailand.
2. Academic paper writing workshop during 26-28 November 2014 at Wishing Tree Resort, Khon Kaen.
3. Academic paper writing workshop during 12-14 February 2016 at Wishing Tree Resort, Khon Kaen.

1. Title of Sub-project: Factors influencing long term production of hybrid tomato seed under contract farming in Northeast Thailand

2. Names and Affiliations of Researchers

Student's name: Chalee Gedgaew

Advisors: Assoc.Prof.Suchint Simaraks and Prof. Dr. A. Terry Rambo

3. Research Objectives

- 1) To understand the situation of hybrid tomato seed production under contract farming in Northeast Thailand.
- 2) To identify the factors influencing on the dynamics of hybrid tomato seed production under contract farming in Northeast Thailand.
- 3) To identify the factors influencing on long term hybrid tomato seed production under contract farming in Northeast Thailand.
- 4) To elucidate the complex management and practices employed in hybrid tomato seed production by the long-term growers.
- 5) To assess the economic benefits to long-term growers under contract farming in Northeast Thailand.

4. Research Methodology

4.1 Research design

Technique of Rapid Rural Appraisal (RRA), in-depth semi-structured interviews, group interviews and questionnaires (general and economic information) were applied to study on hybrid tomato seed production under contract farming in Northeast Thailand. The study was divided into two phases:

1) Phase I: Situation of hybrid tomato seed production under contract farming in Northeast Thailand was stepwise designed as follows (Figure 1):

1.1) Preliminary surveying on hybrid tomato seed production under contract farming was conducted at the production site in Mueang District, Khon Kaen Province in order to understanding the present production situation.

1.2) Secondary data and documents related to hybrid tomato seed production in Thailand and overseas were collected and analyzed in order to understanding the production and marketing situations at world level. In addition, secondary data from Agricultural Extension office at the provincial and district levels in Northeast Thailand were collected and analyzed in order to identify initial production sites.

1.3) Both individuals and groups were semi-structured interviewed. Snowball technique was used to identify the key informants, e.g., agricultural officers of District and Province Agricultural Extension Office, agricultural officers of Sub-district Municipality, staff of seed companies, village headmen, villagers and the growers in each production site. Semi-structured interview (SSI) sub-topics with non-participant observation were designed for primary data collection. Along the survey sub-topics were adjusted to capture all relevant data and information on hybrid tomato seed production under contract farming in Northeast Thailand. Main sub-topics were historical development and factors influencing the dynamics of hybrid tomato seed production under contract farming.

2) Phase II: Study on factors influencing long term production and the dynamics of hybrid tomato seed production under contract farming in selected site was stepwise designed as follows (Figure 2):

2.1) Data of the situation of hybrid tomato seed production under contract farming in Northeast Thailand were used to identify the selected study site (detail of site selection is in 4.2).

2.2) Secondary data and documents of the selected study sites were collected and analyzed. In addition, both individuals and groups semi-structured interviews were conducted. Main sub-topics were agricultural system and the historical development of hybrid tomato seed production in these sites. Snowball sampling technique was used to identify the key informants who know about the village information, e.g., village headmen and the villagers.

2.3) Identify long-term contract growers who had been producing hybrid tomato seeds for more than 10 years and the former growers who ceased the production.

2.4) Short questionnaire was designed for data collection at household level. Then, the questionnaire was tested, verified and improved.

2.5) Data on the long-term growers and the former growers was collected.

2.6) Data of the situation of hybrid tomato seed production under contract farming in Northeast Thailand were used to identify the selected study site (detail of site selection is in 4.2).

2.7) Secondary data and documents of the selected study sites were collected and analyzed. In addition, both individuals and groups semi-structured interviews were conducted. Main sub-topics were agricultural system and the historical development of hybrid tomato seed production in these sites. Snowball sampling technique was used to identify the key informants who know about the village information, e.g., village headmen and the villagers.

2.8) Identify long-term contract growers who had been producing hybrid tomato seeds for more than 10 years and the former growers who ceased the production.

2.9) Short questionnaire was designed for data collection at household level. Then, the questionnaire was tested, verified and improved.

2.10) Data on the long-term growers and the former growers was collected.

2.11) Group interview of the long-term growers and group interview of the former growers were conducted in order to verify the collected data.

2.12) Study site

2.12)1. Northeast region, the snowball sampling technique was used to identify sites where hybrid tomato seed productions exist.

2.12)2. Village level, Lat Na Phiang and Wang To village in Mueang District of Khon Province, this study site was purposive selected where long-term growers and former growers exist.

2.13) Data analysis

All qualitative data were put into ATLAS.ti7 to make primary documents, codes and quotations. Then, data analysis procedure followed on the phenomenological data analysis steps of Creswell (2007). Besides, Microsoft Excel was used for descriptive statistics analysis, i.e., percentage, mean and standard deviation.

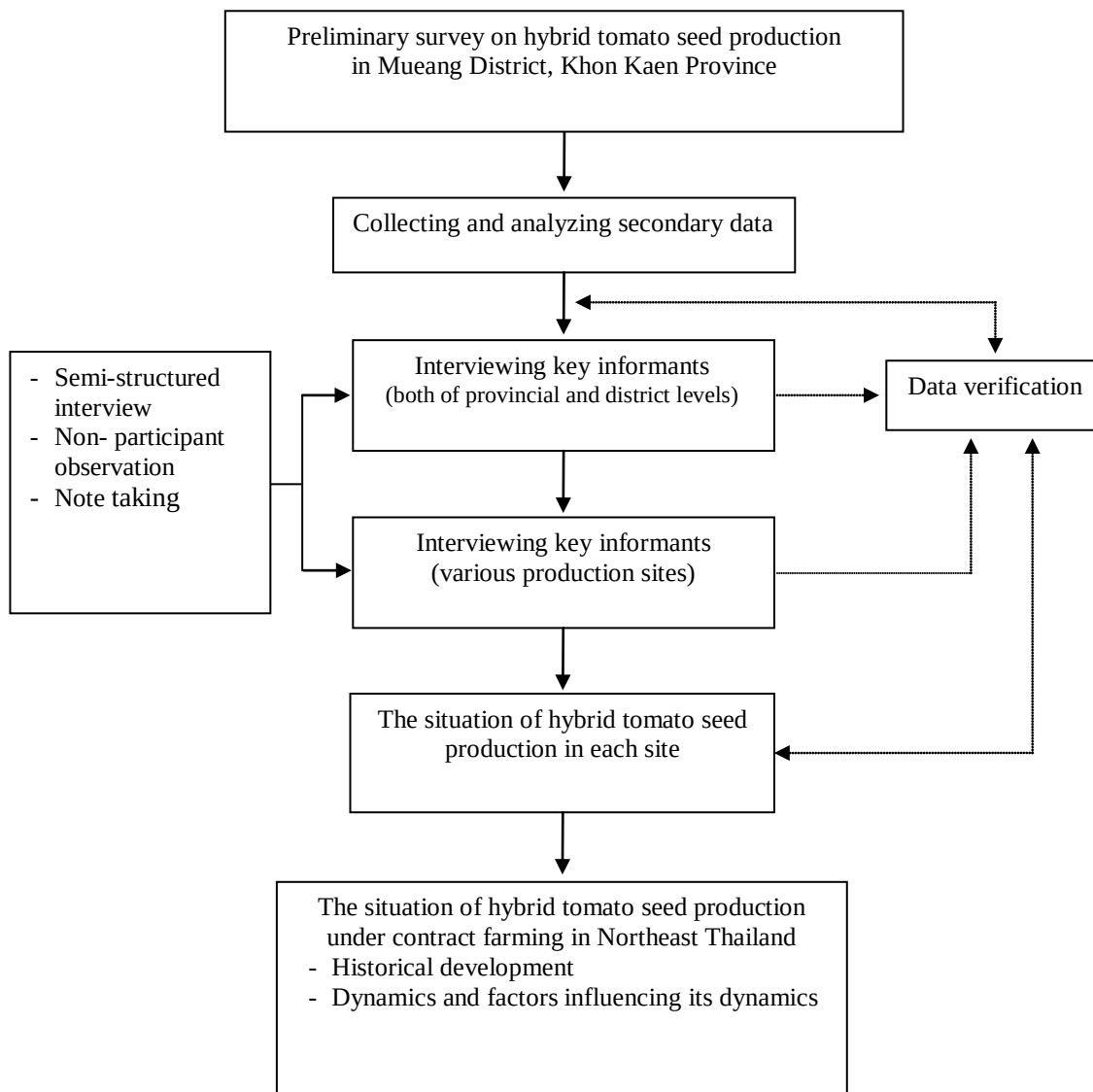


Figure 1 Process designed for Phase I study

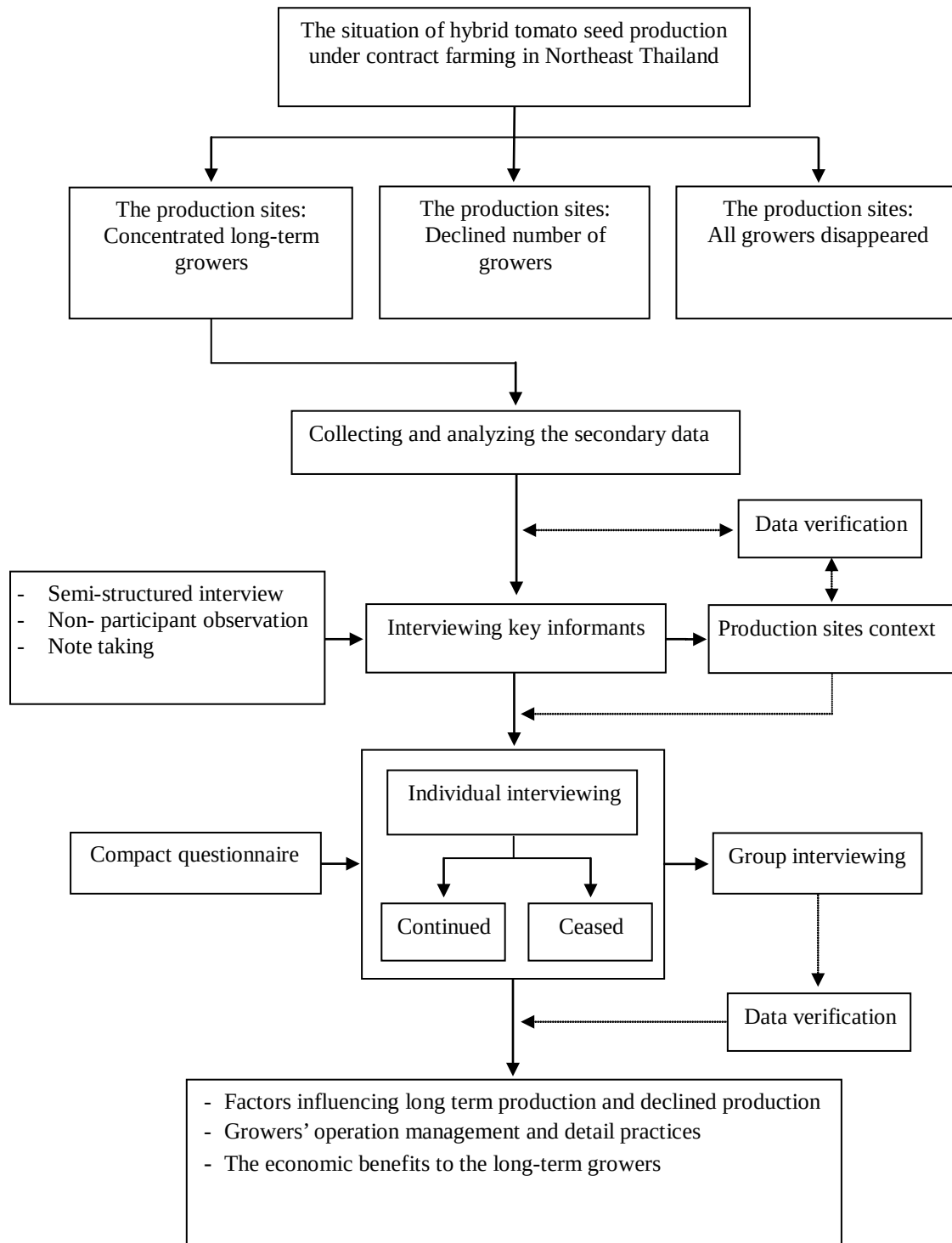


Figure 2 Process designed for Phase II study

5. Research Findings

5.1 The situation of hybrid tomato seed production under contract farming in Northeast Thailand

Since 1976 hybrid tomato seed production was firstly started at a village in rain-fed area of Ban Phai District, Khon Kaen Province, four phases development of hybrid tomato seed production in Northeast Thailand can be recognized; 1) Phase I (late 1970s) by a transnational seed company, 2) Phase II (1980s) transnational seed company joint ventured with local (Thai) seed companies, 3) Phase III (1990s) relocation of the production from Taiwan to Northeast Thailand and 4) Phase IV (2000-2014) relocation of production sites within the Northeast region.

Hybrid tomato seed production under contract farming in Northeast Thailand was established and developed by private sector with little involvement from Thai government agencies. The contract seed production system has been classified as employing the centralized model. It is a two way relationships between the growers and the seed companies. It does not involve intermediaries such as brokers, area seed agents, farmer's organizations, NGOs and state agencies.

Although hybrid tomato seed production used to be initially adopted by a large number of farmers in many villages in both in rain-fed and irrigated area, in recent years it is continued only by some farmers in a smaller number of villages where are mostly in rain-fed areas.

5.2 The factors influencing on the dynamics of hybrid tomato seed production under contract farming in Northeast Thailand

There were positive and negative factors influencing the continuation of hybrid tomato seed production. These factors included: benefits gained by grower, the company-growers relations, tedious work, suitable environment, kind of tomato cultivars, labor supply, grower's personal characteristics, advanced technology and government policy. However, the decision of growers to continue or discontinue production is influenced by both the benefit gained from production and their relations with the seed companies. The local availability of highly skilled household and hired workers also influences the concentration of production in certain sites.

5.3 The factors influencing on long term hybrid tomato seed production under contract farming in the study site

Several different favorable and unfavorable factors influencing continuation of hybrid tomato seed production included grower's personal characteristics, company involvement, suitable environment, advanced technology, tomato seed production conditions, labor supply, and distance from the urban area. These factors interact to determine the amount of income that growers gain from seed production. Earning a high income from producing tomato seeds is a powerful factor for the growers to begin and continue hybrid tomato seed production. However, knowledgeable and skillful growers are vital factors sustaining long term tomato seed production. Without such knowledge and skills their production may not bring about satisfaction economic gain due to declined quality production volume and the companies may not maintain their contracts with the growers in this site. However these growers are not aware of their own capacity but take it as a grant. Besides, grower's personal characteristics stand out as an important factor for long term production. This resulted in the companies' leniency and flexibility with the growers to sustain their mutual benefits.

5.4 The operation management and practices of hybrid tomato seed production under contract farming of the long-term growers in the study site

Hybrid tomato seed production under contract farming is much more complex and tedious in terms of labor involvement as compared to commonly planted cash

crops such as sugarcane, rice and cassava by the small holders in the Northeast. The long-term growers can adapt, accept and conform to the seed companies' requirements in production process with advanced technologies, crop management practices and technical practices. They can apply their own experiences and become the knowledgeable and skillful growers which led to sustain long term hybrid tomato seed production and relationship with the involved companies. Their capability is a magnet attracting many seed companies, local and international, to operate with leniency with these long-term growers in order to obtain quality products.

5.5 The economic benefits to long-term growers under contract farming in the study site

On average, the long-term growers earned total revenue of US\$ 31,657.0, economic profit of 7,997.4 and cash income of 24,075.2 per hectare which were higher than for commonly cultivated cash crops such as rice, sugarcane and cassava. The return on labor per man-day was US\$ 13.0 which was higher than the daily minimum wage from farm and non-farm job, US\$ 8.8 per day.

6. Conclusions

Hybrid tomato seed production under contract farming has evolved as part of the on-going agrarian transformation of Northeast Thailand. It is an alternative that the farmers can increase their income through agriculture intensification and specialization. However, there are both positive and negative factors influencing hybrid tomato seed production under contract farming.

Income from hybrid tomato seed production under contract farming was higher than commonly cultivated cash crop such as rice, sugarcane and cassava. Moreover, the return on labor was higher than the daily minimum wage of laborers in both farm and non-farm jobs. This is an important influencing factor for the long-term growers to join and continue the production. On the other hand, knowledgeable and skillful growers are vital factors sustaining long term hybrid tomato seed production. Without such knowledge and skills their production may not bring about satisfaction economic gain due to declined quality production volume and the companies may not maintain their contracts with the growers in this site. However these growers are not aware of their own capacity but take it as a grant. This is why the companies operate with leniency and flexibility with the growers. This research report was able to point out the above positive impacts which are contrary to many reports that pointed out negative impacts.

7. Accomplishments:

7.1 Paper has been accepted:

1. Title: "Trends in Hybrid Tomato Seed Production under Contract Farming in Northeast Thailand". Southeast Asian Studies Vol. 6 (2).

7.2 Papers will be submitted to the journal:

1. Title: "*Factors influencing long term tomato seed production under contract farming in a rain-fed area in Northeast Thailand*" which on the process of written and edited to published by Journal of the Agriculture, Food, and Human Values Society (impact factor = 2.222).

2. Title: "*Hybrid tomato seed production under contract farming in Northeast Thailand: Growers' complex practices and the economic worthiness*" which on the

process of written and edited to published by Khon Kaen Agriculture Journal, Khon Kaen University (impact factor = 0.308).

7.3 Conference / seminar / workshop attendance

	M/D/Year	Place	Duty	Activities/Purpose
1	Feb 11, 2014	Khon Kaen University	Oral Presentation	Seminar on Northeast Thailand in Transition: Landscape, Livelihood and Life.
2	Sep 16, 2014	Khon Kaen University	Oral Presentation	The KKU-CSEAS Conference on Rural Northeast Thailand in Transition: Land Use, Farming Systems and Households.

7.4 Completion of an academic degree

Ph.D.'s thesis dissertation was successfully defended on the 18th January 2017.

1. Title of Sub-project: Rural Households in the Context of Agrarian Transformation in Northeast Thailand

2. Names and Affiliations of Researchers

Researchers	Affiliation
Ms. Yuko Shirai	Program on System Approaches in Agriculture, Faculty of Agriculture, KKU
Prof. Dr. A. Terry Rambo	
Prof. Dr. Fukui Hayao	
Associate Prof. Dr. Suchint Simaraks	

3. Research Objectives

This study has five main objectives:

3.1 To investigate the distance that villagers travel to access local non-farm jobs and the number of rural villagers who commute to these employment places in Northeast Thailand.

3.2 To examine the impact of local non-farm employment on the number of out-migrants, household structures and agricultural activities of rural villages in Northeast Thailand.

3.3 To identify the types of household structures and their relative frequency in rural villages in Northeast Thailand.

3.4 To identify the different income sources, both agricultural and non-agricultural, of different types of household structures in rural villages in Northeast Thailand.

3.5 To analyze the contribution of different sources of income to the economies of different types of household structures in rural villages in Northeast Thailand.

4. Research Methodology

4.1 Study Sites

4.1.1 The study sites in Northeast Thailand

This research was conducted in three main sites which include (1) Nong Ben village in Khon Kaen Province, (2) a large sample of villages surrounding a cluster of factories in Nam Phong District in Khon Kaen Province, and (3) another sample of villages surrounding a large factory in Kalasin Province (Figure 1).

4.1.2 Study site for a pilot study to identify the structural types of rural households and their income sources

A pilot study was conducted in Nong Ben village in Khon Kaen province. The village is located approximately 20 km from Khon Kaen municipality to the northeast of National Highway No. 2 (Figure 2). Nong Ben village is one of 10 villages in Non Thon sub-district. Nong Ben was a single village until 2006 when it was divided into two administrative villages, each with its own headman. The author had previously surveyed the livelihood activities of 337 households in the village in 2006 and has made repeated visits to the village since then. Therefore, this village was purposely chosen as it was considered suitable to obtain accurate information within a limited time that could be used to understand the types of rural household structures and their income sources.

4.1.3 Study site for assessing the impact of local non-farm employment on the

number of out-migrants, household structures and agricultural activities

In order to ascertain the distance that workers commute to their local non-farm employment places and the number of villagers who commute on a daily basis to local non-farm employment places, large samples of villages located at varying distance from a large factory clusters in Khon Kaen and Kalasin Provinces were selected (Figure 3).

In March 2014, there were 4,181 registered industrial employers with 53,594 employees in Khon Kaen province (Office of Industry in Khon Kaen Province). Of these 130 employers had more than 50 employees and these employers account for a total of 37,329 employees, 69.7% of the total industrial employees in the province. Nam Phong district has the second highest number of employees of local industries after Muang district, where the city of Khon Kaen is located in and there are many job opportunities in the service sector. Three local factories that have more than 1,000 employees each from a cluster of industries in Nam Phong district. These are a Panasonic factory, Siam Cement Group (SCG) factory, and the Khon Kaen Sugar Mill. They hire mostly local people as their workers. Therefore, the area centered around these three factories was selected for the study in Khon Kaen Province.

The East-West Economic Corridor runs through Isan from Mukdahan through Khon Kaen to Myanmar via Kalasin province. A preliminary survey found approximately 100 industrial sites along this corridor with several large factories observed in Kalasin province. In this province, there were a total of 578 registered industries with 5,214 employees, and 16 industries had more than 50 employees each in 2015 (Department of Industrial Works in Thailand, 2015). They account for 42% of the local industrial employees in the province. “Asia Modify” and “Ingredion” are modified starch factories using cassava as raw material and they employ 105 and 115 workers respectively. The area centered around these two factories was selected for the study in Kalasin Province.

The research in these two study sites is designed as follows. First, I interviewed key informants in villages located at 5 km intervals from the factory clusters in the study areas. Information including the number of people commuting to these factories and other places of employment as well as other information about the demography, out-migrants and agricultural activities in the villages was obtained. This initial investigation found that the number of villagers working in the factories dropped off rapidly with increasing distance of the workers’ villages from the site of employment. Thus, I identified 20 km as being the critical distance beyond which few people traveled to these work locations. Therefore, the study areas in Khon Kaen and Kalasin were demarcated as being within a 20 km radius around the industrial clusters (Figure 3).

4.2 Data Collection and Sampling Plan

4.2.1 Identifying the structural types and different income sources of rural households in Nong Ben village

At the beginning of this field study, group discussions were conducted several times with around 20 villagers participating each time in the village. Topics included land use and village boundaries, history and the annual cycle of agricultural and cultural activities, previous and current situation of non-farm employment, use of remittances and people’s livelihoods both in the past and present time. Secondary data for the village, such as area of agricultural land, types of agricultural activities, and household registration data including names and ages of all household members, were obtained from several government offices in Khon Kaen including the Provincial

Office, Non Thon Sub-District Office, Provincial Agricultural Office, and Community Development Office.

Detailed information on the composition and sources of income of each of the 303 households residing in the village were obtained in multiple extended interviews with the village headmen and confirmed when necessary by checking with the individual households. Data collected include the type of household structure, type of household income sources from agriculture and non-agriculture, number of household members, area of agricultural land and types of agricultural activities, number of migrants, sex, age, marital status, occupation and relationship of each household member including migrants. This information was used to classify the households into several groups that were used to select the sample households for a more detailed survey.

Based on the preliminary information obtained from the village headmen on sources of income, the 303 village households were divided into 4 groups according to their types of livelihoods: 1) only agriculture (24 households); 2) both agriculture and non-agriculture (222 households); 3) only non-agriculture (41 households); and 4) economically inactive (16 households), and random samples of households were selected from each group. Initially it had been planned to interview a sample of households representing approximately 20% of each household group. This was done for household group 2, but only six households classified as belonging to group 3 were available for interviewing. Regarding the sample household size for groups 1 and 4, the total populations in each group is small so I tried to interview as many households in each group as possible. In total eight households for group 1 (33%) and six households for group 4 (38%) were available for interviewing. Consequently, the final sample included 8 households that were engaged only in agriculture, 41 households that were engaged in both agriculture and non-agriculture, 6 households that were engaged only in non-agriculture, and 6 economically inactive households, for a total sample of 61 households. Each sample household was interviewed to obtain detailed information about the type of household structure, engagement in agricultural and non-agricultural employment, number of members, number of migrants, sex, age, occupation and relationship of each household member including migrants, amount of remittances, types of agricultural and non-agricultural activities, area of agricultural land, household assets such as a TV or motor vehicle, income from agricultural and non-agricultural activities, and amount of debt.

4.2.2 Analyzing the influence of local non-farm employment on the number of out-migrants and agricultural activities in Khon Kaen and Kalasin provinces

Within the study areas there are 244 and 378 villages in Khon Kaen and Kalasin respectively. A sampling plan was designed to collect data from a subset of these villages. To determine the sample size needed to have statistically significant results at a 95% confidence level, the formula (Toishi, 2004: 63) was employed.

$$n = N / (E/k * E/k * (N-1)/P(100-P) + 1)$$

The minimum random sample size that provides a 95% confidence level was 44 villages in both study areas. Therefore, 44 randomly selected villages inside the study areas were surveyed to ascertain the number of villagers who commute daily to these local industries as well as those who work in other local non-farm employment sectors and those who have migrated from the villages to work in other provinces or abroad.

4.2.3 Exploring the impact of local non-Farm employment on household structures and agricultural activities in Khon Kaen

A more detailed survey of the effect of local non-farm employment on rural household structures and their income sources was conducted in two sample villages in the study area in Khon Kaen province. These sample villages were selected from the 44 villages in Khon Kaen that were initially investigated. The villages were purposely selected based on the criterion of having similar sized populations, land areas, land forms and topography, and agricultural systems, but differing in the number of workers employed in local industries. One village (High Employment Village) was chosen that had many local industrial workers (>15% of the labor force); and one village (Low Employment Village) was chosen that had few local industrial workers (<15% of the labor force) (Figure 4).

Based on the preliminary information, households in High Employment Village were classified into two groups: Group 1 was made up of the 47 households having one or more members employed in local industries. Group 2 included 24 households that did not have any members employed in local industries or other local non-farm job. Households in Low Employment Village were also classified into 2 groups: Group 3 included the 99 households having one or more out-migrants and Group 4 included the 23 households having no out-migrants. Initially it had been planned to interview 20 households randomly selected from each group. This was done for groups 3 and 4 but only 16 households classified as belonging to Group 2 were available for interviewing, one of which was found to have been misclassified and actually belonged to Group 1. Consequently, the final sample sizes for these groups were 21 households from Group 1 and 15 households from Group 2.

4.3 Data Analysis

All data were entered into Microsoft Excel to make a data-base and SPSS version 21 (SPSS 21 for windows, IBM Corporation, Armonk, NY, USA) was used for analysis. Google Earth was used for measuring distances between villages and locations of employers. ArcGIS version 10.1 (ESRI) geographical information software was used to generate a map.

5. Research Findings

5.1 Findings from the large sample survey in Khon Kaen and Kalasin study sites

The numbers of local non-farm workers and out-migrants

There are 2,430 locally commuting workers in the Khon Kaen sample villages, of which 1,535 people from 43 villages work in regular wage jobs and 895 people from 40 villages are casual hire wage workers (one village has no regular wage workers and four villages have no casual hire wage workers). In the sample villages in Kalasin there are 2,641 employees, of which 645 people from 43 villages commute to work in regular wage jobs and 1,996 people from 43 villages commute to work as casual hire wage workers (one village has no regular wage workers and one village has no casual hire wage workers). The average of 36 regular wage workers per village in Khon Kaen is more than two times greater than the average of 15 workers per village in Kalasin. However, in the villages in Kalasin there are more people engaged in casual hire wage works (46 workers) than in Khon Kaen (22 workers). The mean total number of regular and casual workers per village is similar in the two study areas, with 55 workers per village in Khon Kaen and 60 workers per village in Kalasin. All of the study villages in both study areas have villagers who have left to work in other places, but there is a large gap in the number of out-migrants between the two study

areas. The total number of out-migrants is much greater in the Kalasin study area than in the Khon Kaen study area, 4,856 out-migrants and 2,023 out-migrants respectively. Thus, a much larger mean number of out-migrants per village is found in the Kalasin study area (110) than in the Khon Kaen study area (46).

The commuting distance and the means of transportation of regular wage workers

There are two means of transportation employed by regular wage workers² for commuting from their villages to employment sites: 1) by using the worker's own means of transportation (e.g., motorbike or pickup truck) or 2) by bus or van operated by the employer. There are five factories in Khon Kaen and two factories in Kalasin that provide bus service to their employees.

Table 1 shows the number of workers commuting to regular wage employment by distance and the mode of transportation. Almost all workers in both provinces use their own means of transportation to commute to work at sites that are less than 20 km from their villages, whereas the majority of those commuting on employer-operated buses work at sites located more than 20 km from their villages. The majority of workers (56.0% in Khon Kaen and 69.6% in Kalasin) reside less than 10 km far from the site of employment, and they mostly use their own means of transportation. Some residing in villages more than 10 km but less than 20 km from the place of work may use the bus services, but the majority use their own means of transportation. The majority of the commuters using employer-operated buses reside more than 20 km away from their working places.

Relationship between the commuting distance and employment

The mean one-way travel distance of all regular wage workers is 14.6 km in the Khon Kaen study area and 9.8 km in the Kalasin study area. When the villages in the Khon Kaen study area were categorized into two groups according to the average commuting distance of their residents who are regular wage workers (group 1 < 15 km, and group 2 ≥ 15 km) and those in Kalasin are also divided into two groups (group 1 < 10 km, and group 2 ≥ 10 km) a statistically significant difference (at the $p < .001$ level) in the mean number of regular wage workers was found between the group; villages closer to the employment site and the group farther from the employment site, with the group of closer villages having more regular wage workers than the more distant group of villages (Table 2). However, the difference is not significant in the Kalasin study area.

Influence of the availability of local non-farm jobs on out-migration

Statistical significance of the difference between the two study areas in local non-farm employment and out-migration is summarized in Table 3. The most significant ($p = .000002$) is in out-migration. In regular employment, too, the difference is quite significant ($p = 0.002$). In casual employment, the difference is much less significant ($p = .087$) and in the sum of regular and casual employment, the difference is insignificant ($p = .797$). In order to investigate the relationship between different types of local non-farm jobs and out-migrants, the data from both study areas were combined and the shares of regular and casual hire wage workers and out-migrants in the total labor force were calculated. The result shows negative correlation ($r = -.22$,

² Since commuting distance of casual hire wage workers especially construction workers can vary each day, it is impossible to determine the commuting distance of them. Thus, only the case of regular wage workers and their distances are presented.

$n=86$, $p=.034$ level) between the regular wage workers and out-migrants, but there is no association ($r=.001$, $n=83$, $p=.996$) between the casual hire wage workers and out-migrants. These analyses suggest that a determinate of out-migration, and possibly the decisive one, is the existence of opportunities to obtain regular non-farm employment for those residing in a village. The more opportunity for regular wage work and ultimately, the more people who engage in such jobs, the lower the number of out-migrants.

Impacts of local non-farm employment opportunity and out-migration on agriculture:

Regular wage workers

The villages with households that have a small share of regular wage workers tend to have more diversified agricultural activities. Households in this type of village may have more time for doing agriculture including raising large livestock. The villages with households that have a larger share of regular wage workers tend to have less diversified agricultural activities. Moreover, this village type has many households which do not have any agricultural land in part at least because villagers have sold their land to factories or people who have migrated in to the villages to commute to the factories. With regards to agricultural land use, the villages that have a smaller share of regular wage workers use more land for growing rice than the villages that have a larger share of regular wage workers.

Casual hire wage workers

The villages with households that have a smaller share of casual hire wage workers tend to have a larger mean size of agricultural land and also have more diversified agricultural activities including raising large livestock. This may reflect a strategy of the villagers to keep agricultural land to do different types of agricultural activities as a buffer against insecure income from casual hire wage jobs. Land use does not show a notable difference between the two types of villages according to the difference in the share of casual hire wage workers.

Out-migrants

The villages with households that have a larger share of out-migrants tend to raise large livestock and also have more diversity in their agricultural activities than the villages with a smaller share of out-migrants. The main difference in land-use is that the villages that have a larger share of out-migrants grow more rice than the villages that have a smaller share of out-migrants.

5.2 Findings from High and Low Employment Villages in Khon Kaen study area

Differences in household structures between the villages

As is shown in Table 4, extended households are the most common type in both villages, representing 40.5% of all households in High Employment Village and to 30.3% in Low Employment Village. Although the extended household is the most common structural type in both study villages, there are actually two quite distinct types of extended households which we will refer to as complete and incomplete extended households. *Complete extended households* are the common vertical extended type that was already described above. *Incomplete extended households* can be composed of (1) the parent(s), their divorced child and her/his children, or (2) the parent(s), their unmarried children and their grandchild or grandchildren without their parents. The complete extended household type has the potential to persist for a

considerable length of time as a large horizontally and/or vertically extended domestic group, whereas the incomplete extended household type has a greater possibility of turning into a truncated household at some stage. The mean size of households that are complete extended is larger (5.8 persons) than the mean size of households that are incomplete extended (4.3 persons). Complete extended households constitute a slightly higher share (67.3%) of all extended households in High Employment Village than in Low Employment Villages (62.2%).

The share of nuclear households is much higher (33.9%) in High Employment Village than in Low Employment Village (19.7%). Truncated (26.2%) and skipped generation (23.8%) households are much more common in Low Employment Village than in High Employment Village where they are 16.5% and 9.1% respectively (Table 4).

The differing frequencies with which different types of households occur in the two villages are reflected in differences in their mean household sizes. The mean size of households is larger (4.0 persons) in High Employment Village than in Low Employment Village (3.3 persons). On average, nuclear and extended households, which are more common in High Employment Village, are larger (3.3 and 5.3 persons respectively) than skipped generation and truncated households which are more common in Low Employment Village (3.4 and 1.8 persons respectively).

Relationship of out-migration with household structure

The number of out-migrants from Low Employment Village is much larger (220) than from High Employment Village (162) and the share of households having at least one out-migrant is considerably higher (81.1%) in Low Employment Village than in High Employment Village (65.2%). When data for both villages on the types of households from which out-migrants have originated are combined together it is evident that less than half (44.6) of nuclear households have any out-migrants whereas most of skipped generation (95.0%) and truncated (80.8%) households have at least one out-migrant (Table 5). The association between out-migration and household type is also clearly revealed in the sample household data in Low Employment Village where the majority (87.5%) of nuclear households and half of extended family households do not have any out-migrant members whereas all truncated households and almost all (88.9 %) skipped generation households have out-migrant members.

5.3 Findings from Nong Ben village

Types of economic activities of different types of households

The 303 households in Nong Ben were classified into four types according to their economic activities: 1) do agriculture only; 2) do both agriculture and non-agriculture; 3) do non-agriculture only; and 4) are economically inactive (Table 6). Of these, 7.9% are engaged only in agriculture, 73.4% are engaged in both agriculture and non-agricultural activities, 13.5% are engaged only in non-agricultural activities, and 5.2% of households are economically inactive. According to the survey of 61 sample households in Nong Ben, about 24% have members who received a monthly salary.

The types of economic activities vary according to the structure of households. Extended family households are most likely (85.1%) to be engaged in both agricultural and non-agricultural activities, with equal shares (6.6%) of these households doing agriculture only and non-agriculture only, and 1.7% being economically inactive. Nuclear family households have the next highest share (80.8%) doing both agricultural and non-agricultural activities, 15.9% doing only non-agriculture, 2.2% doing agriculture only, and 1.1% being economically inactive.

Skipped generation extended vertical family households are mostly (68.7%) engaged in both agricultural and non-agricultural activities, with equal shares (11.4%) of the households engaged in only non-agricultural activities and economically inactive, and 8.5% doing only agricultural activities. Truncated family households display a very different pattern of economic activities from other types of households with only 39.6% doing both agricultural and non-agricultural activities, 25.9% doing non-agricultural activities only, 19.0% only doing agriculture, and 15.5% economically inactive. This may reflect the fact that truncated family households have the highest share of people aged 60 years or older, who are more likely to have retired from non-farm employment but may continue to engage in part-time agriculture on their own farms.

The differences in economic activities among the different types of households may reflect differences in their age structures and education levels with household types having a higher proportions of younger and better educated working-age members being more likely to engage in non-agricultural activities.

Types of agricultural activities of different types of households

Although at least some households of each structural type are engaged in agricultural activities, they differ to some extent in the specific types of agricultural activities in which they engage. Extended family households have the highest share engaged in cultivation of rice (89.3%), cash crops (38.5%), other crops (24.6%), and livestock raising (21.3%). Nuclear family households have the second highest level of involvement in cultivation of rice (79.5%), cash crops (34.1%), other crops (14.7%) and livestock raising (10.2%). Skipped generation extended vertical family households cultivate rice (77.1%), cash crops (31.4%), other crops (17.1%), and raise livestock (5.7%). Truncated family households have the lowest engagement in agriculture, with only 55.2% cultivating rice, 17.2% having cash crops, 8.6% having other crops and 10.3% raising livestock.

The distinctions between the agricultural activities of the different types of households are more clearly revealed in data from the sample survey of 61 households. Extended family households have the most diverse agricultural activities, including cultivation of rice, cassava, sugarcane, rubber, other crops, and raising buffalo and swine. On the other hand, nuclear family households engage in fewer kinds of agricultural activities being limited to planting rice, cassava, rubber and other crops. These differences do not appear to be related to differences in the size of landholdings but may reflect significant differences in the availability of labor in the different household types. The extended family type households have the largest average number of members (5 persons per household) with almost half (49.2%) of their members being of working-age. It should also be noted that most household members in extended family households are still in their physical prime for work, with a median age of 38 years. Moreover, compared to other types of households, a greater proportion of extended family households (60.9%) own agricultural machines which augment their working capability.

Income sources of different types of households

Agricultural income

Sample household data show that the truncated family households earned 33.3% of their total annual gross income from agriculture, which was the highest share of any household type and extended family households gained 26.5% of their income from agriculture. Skipped generation and nuclear family households gained very low shares

their income from agricultural sources, representing only 15.1% and 12.1% respectively.

Non-agricultural income sources

Non-agricultural sources contributed more than two-thirds of the income of all household types. These sources can be classified into five types: local non-farm jobs; self-employment; remittances; pensions; and government support. The local non-farm jobs can be further divided into three categories: 1) casual hire wage workers (e.g., construction workers and doing piecework at home such as sewing pillow cases or mattresses and making fermented fish); 2) regular wage workers (i.e., receiving a salary every week or every month from a private sector employer); and 3) salaried government employees (i.e., receiving a monthly salary from a government job). The kinds of self-employment are diverse, including running a beauty shop, grocery shop, motorcycle repair shop, collecting vegetables from villagers and selling in the market, renting out agricultural machines, collecting and selling recyclable goods, and building and selling pre-fabricated pavilions. The different types of households show major differences in the share of their income they derive from different non-agricultural sources (Figure 5).

Shares of income from different sources

According to the sample household data, the total annual gross income from non-agricultural sources exceeds the income gained from agriculture for all types of households, but distinct differences among different types of households are evident. The nuclear family households gain by far the greatest share of their total income (87.9%) from non-agricultural sources, followed by skipped generation extended vertical family households (84.9%), extended family households (73.5%) and truncated family households (66.7%). Thus, for all household types agricultural income contributes only a relatively small share of total household income. The shift from agricultural to non-agricultural sources of income for rural households that we have observed in Nong Ben appears to be a common pattern in the whole Northeastern Region (Funahashi, 2006; Grandstaff, 2008; Keys, 2010; Kuchiba, 1990; Podhisita, 1990; Rigg, 2005; Rigg and Salamanca, 2009 and 2011; Rigg *et al.*, 2012; and Rigg *et al.*, 2014). Indeed, rural households in Northeast Thailand are hardly unique in this shift from dependence on agricultural to non-agricultural income sources; worldwide the proportion of the labor force in agriculture and the contribution of agriculture to Gross National Product have both declined in countries at all income levels (Bernstein, 1992:5) as employment opportunities in factories, offices and the service sector have been growing, leading many rural villagers to move into the cities while many others stay in their villages but commute to local non-farm jobs. Consequently, the importance of non-farm income has been increasing even in farming households, in the developing world in general (Lewis, 1959; Owusu, 2009; and Tama, 2006).

Income and debt

The different types of household also display considerable differences in levels of income and indebtedness. The survey of sample households found that nuclear family households have the highest mean annual per capita gross income (94,207 baht $\approx$ US\$2,707), followed by truncated family households (66,429 baht $\approx$ US\$1,909), extended family households (55,084 baht $\approx$ US\$1,583) and skipped generation extended vertical households (54,941 baht $\approx$ US\$ 1,579). The nuclear family

households have the highest mean annual net income per capita (38,206 baht $\approx$ US\$1,098), followed by extended family households (23,344 baht $\approx$ US\$671) and truncated family households (17,453 baht $\approx$ US\$501), while the skipped generation extended households had the lowest net income per capita (5,570 baht $\approx$ US\$160).

Many households of all types are in debt to a greater or lesser extent, although the extent of indebtedness varies greatly among the different types. According to the sample household data, 60.0% of truncated households and 42.1 % of nuclear type households have no debts whereas 74.0% and 77.8% of extended and skipped generation extended households are in debt. In the case of skipped generation extended vertical family households, two-thirds (66.7%) have debts exceeding 100% of their annual net income, followed by extended family households (47.8%), nuclear family households (36.8%) and truncated family households (20.0%) (Table 7). The skipped generation extended vertical households are in the worst economic situation, having the highest level of indebtedness and the lowest amount of income with which to repay their debts.

6. Conclusions

This study's findings show a decline in the contribution of agriculture to household income and a growing share of income coming from non-agricultural sources. This study has also finds that income from local non-farm work, both regular and casual employment, is an important factor that is associated with changes in rural villages and households. One significant finding is that if local non-farm jobs are accessible to rural villages, e.g., are located within a threshold distance of 20 km for commuting purposes, villagers are more likely to engage in these non-farm activities than villagers who reside farther away from employment sites. The number of out-migrants is smaller in the households that have more members who are engaged in local non-farm regular wage jobs than in the households that have fewer members who are engaged in that type of work. Other aspects of the influence of availability of local non-farm employment on the changes in the rural villages are seen in types of household structures, variety of income sources and agricultural activities and land-use (Figure 6).

Khon Kaen and Kalasin provinces, where this study was conducted, offer different opportunities to the villagers who commute to work in local non-farm jobs. The Khon Kaen study area has a larger mean number of regular wage workers per village than the Kalasin study area, but the Kalasin study area has a larger mean number of casual hire wage workers per village than the Khon Kaen study area. This is because more than 4,000 industrial employers are registered in Khon Kaen, whereas fewer than 600 industrial employers are registered in Kalasin. This showed that the availability of casual hire wage work has little or no impact on the number of out-migrants from these villages, but the availability of regular wage work has a negative impact on out-migration. Absence of the opportunity for regular local non-farm wage work, especially jobs in large industrial enterprises, is a factor that influences the number of local residents who migrate to get jobs outside of the region.

Household structures in rural villages are strongly influenced by the differing availability of local non-farm employment and the impact this has on the number of people migrating to other areas. The study of two sample villages in Khon Kaen clearly showed that the village with a large number of households having members with local non-farm employment had a smaller number of out-migrants. In this village almost three-quarters of all the households were of the extended and nuclear household types. In the village with only a small number of households having

members employed in local non-farm work, there was a greater number of out-migrants, and half of all households were of the skipped generation and truncated household types.

Different types of households engage in different economic activities, but all household types depend to a greater or lesser extent on income from non-agricultural sources. Even truncated type households, which have the most reliance on agricultural income of any of the household types, derived only one-third of their total income from farming. Skipped generation and truncated household types, which are mostly composed of elderly people with larger mean numbers of out-migrants per household than other types of households, are characterized by low levels of income and very high level of indebtedness and were highly dependent on remittances as their main source of income.

Besides having impacts on out-migration and household structure and income source, development of local residents in local industries is seen in the study areas to have impacts on rural agriculture and land-use. The villages with households that have a small number of regular wage workers and casual hire wage workers tend to have more diversity of agricultural activities including raising more large livestock such as cattle and buffalo than the type of village that have many regular and casual wage workers. This leads to the conclusion that in villages where people have less opportunity to work in local non-farm jobs, the villagers spend more time doing agriculture. However, it appeared that it is engagement in regular local non-farm employment, but not casual hire employment, that most negatively impacts agriculture. In villages where many people are engaged in casual hire wage work, more agricultural land remains under cultivation and it is used for practicing varieties of agricultural activities, which might be a strategy that the villagers use in order to help buffer the insecure nature of income that they receive from casual hire wage jobs. However, in villages where many residents engage in regular wage work, some agricultural land has been used for shops and factory construction or to build houses on, and people tend to use many land for growing sugarcane. The impact of out-migration on agricultural land-use was that the villages that have a larger share of out-migrants grew more rice than the villages that have a smaller share of out-migrants. The villages with a larger share of out-migrants also had more diversity in their agricultural activities than the villages with a smaller share of out-migrants.

Although this study has documented that rural industrialization has had a profound impact on rural villages in the study areas, these villages may not be representative of the rural sector in the whole Northeast region. Future trends in rural household livelihoods in Northeast Thailand are highly dependent on the course of economic development there. Since the industrial sector in the region still remains small, this suggests that there are more opportunities available for investors and for the government to promote local industrialization and rural economic development. The rural people in Isan might gain more opportunity to access local non-farm employment if rural industrialization is accelerated. If this happens it is possible that rural out-migrants may return to their natal villages and young adults may remain in the rural areas. At the same time, agricultural land in rural areas may become scarcer due to the expansion of local economic development. The question may become whether people in Isan continue to do agriculture as a part-time farmer or decided to sell their farm land to business investors or to large farm operators. Further investigation is necessary in order to assess the way rural villagers may move forward and to inform policymakers and government agencies who debate development pathways in Southeast Asia as well as to determine the extent to which the findings of this study are applicable to

other part of Isan and more widely throughout Southeast Asia.

7. Figures and Tables

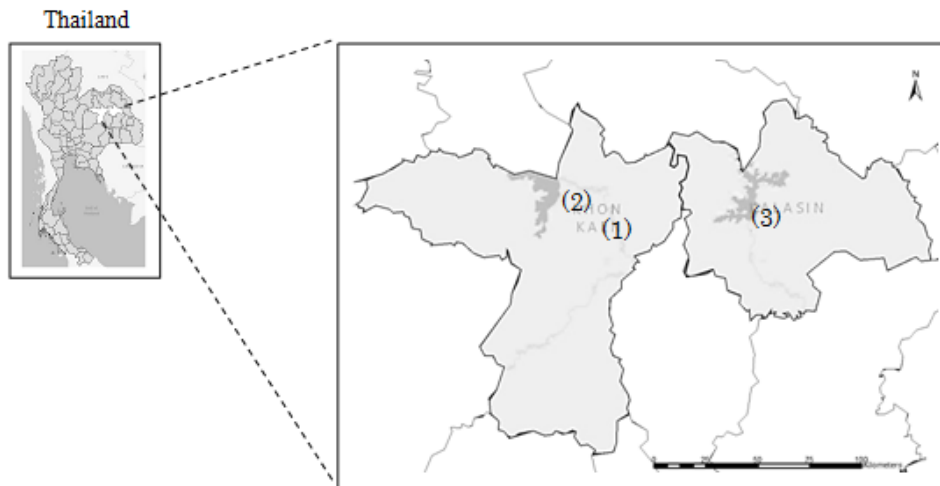


Figure 1. Map showing locations of study areas in Khon Kaen and Kalasin provinces.

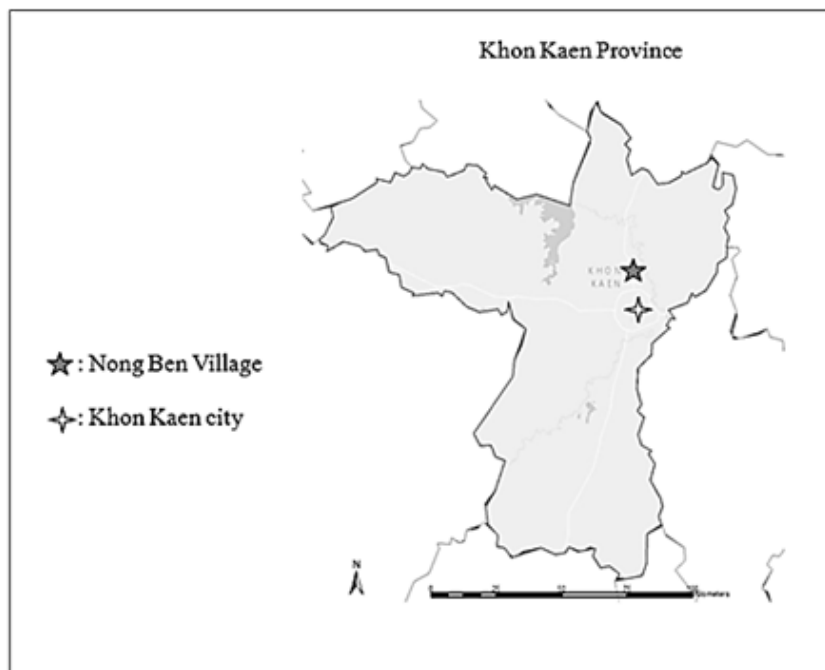


Figure 2. Location of Nong Ben village.

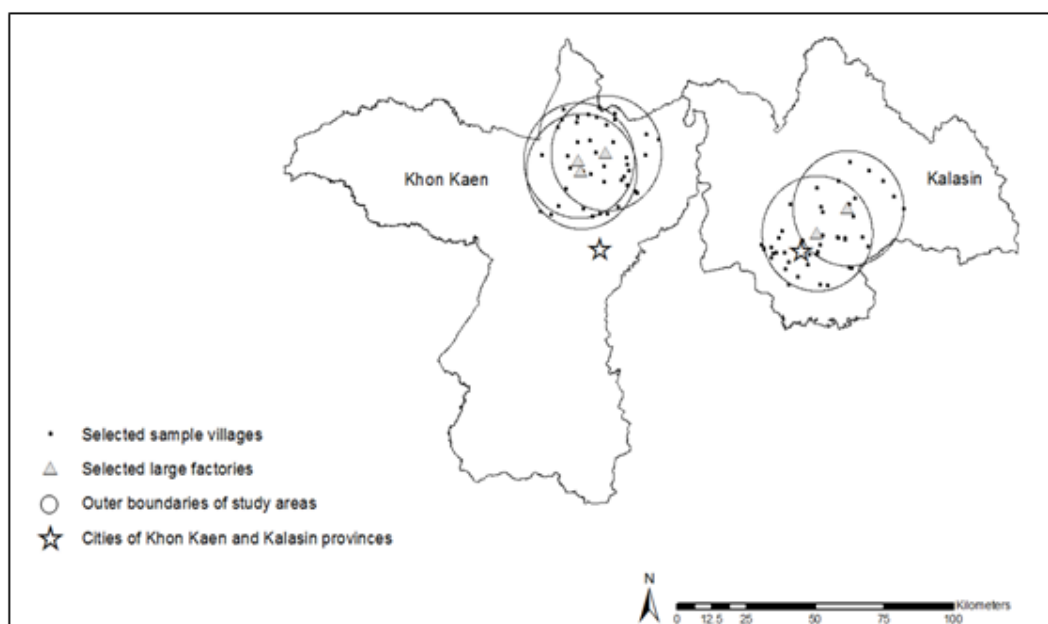


Figure 3. Map showing locations of large samples of villages located at varying distance from a large factory clusters in Khon Kaen Province and Kalasin provinces.

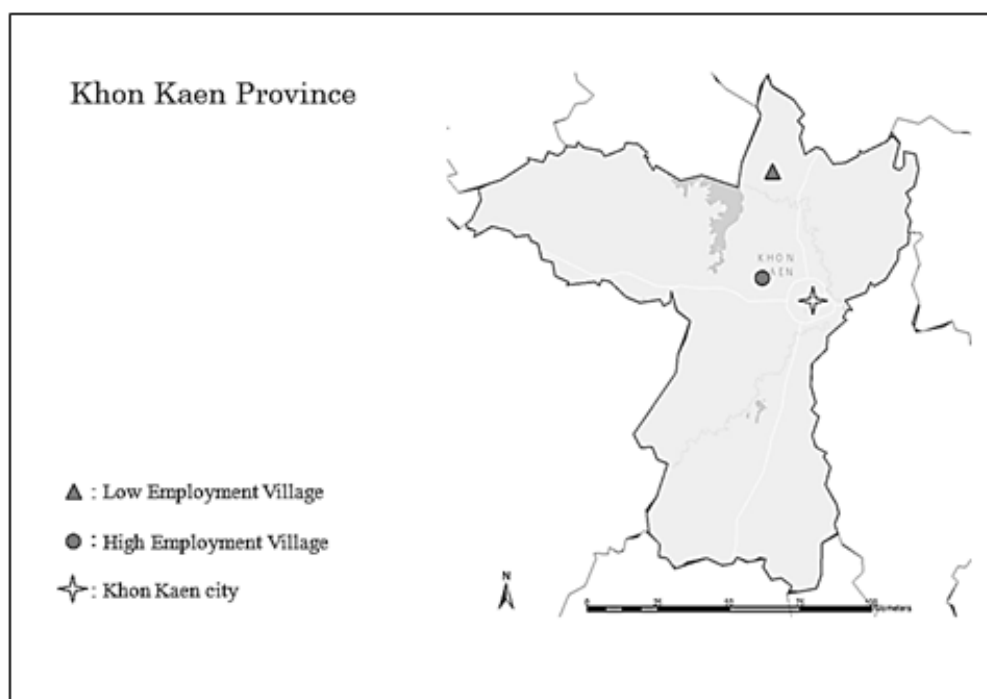


Figure 4. Location of High and Low Employment Villages.

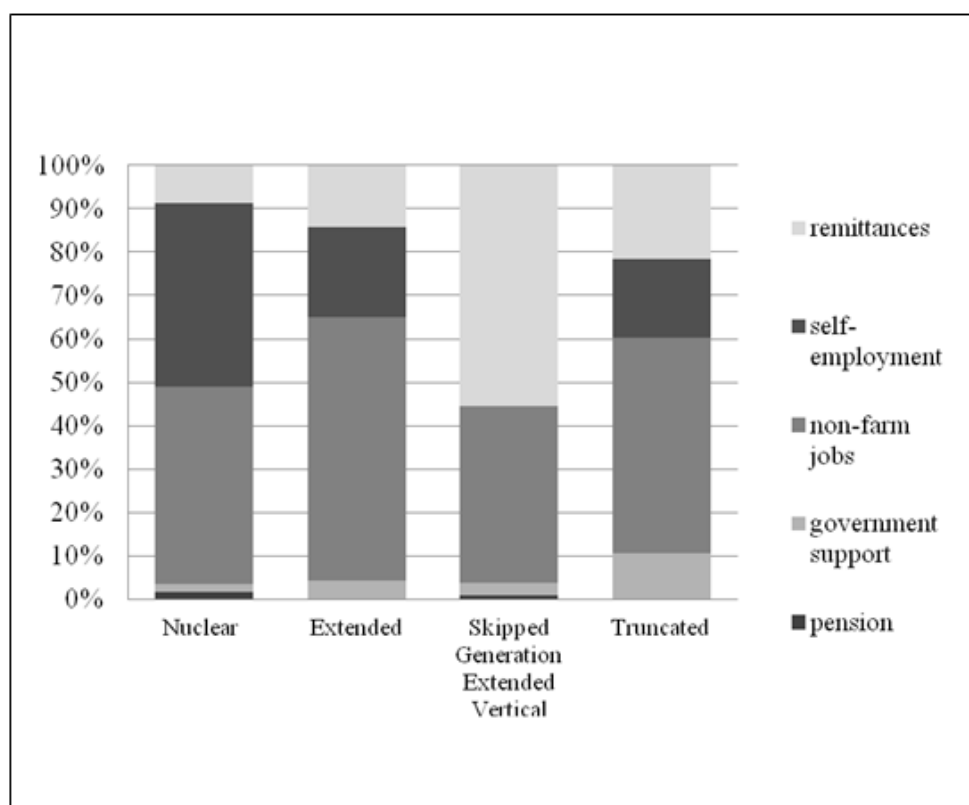


Figure 5. Share of income derived from different non-agricultural sources by different types of households in Nong Ben Village.

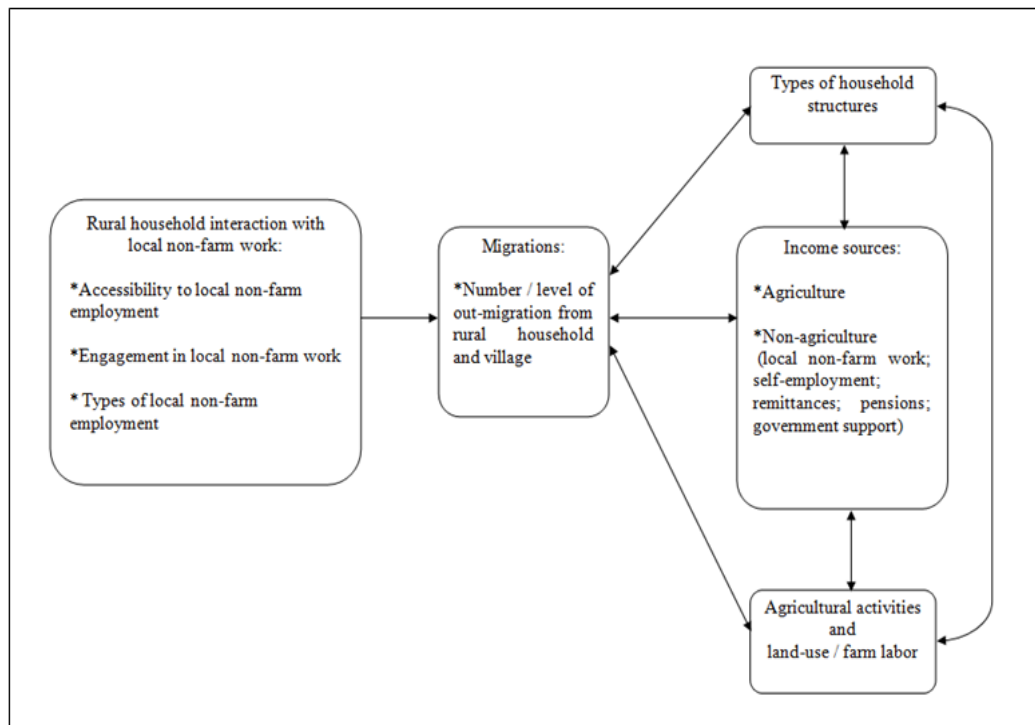


Figure 6. Relationship between rural household access to local non-farm employment and migration, household structure, income sources and agricultural activities and land-use.

Table 1. Number (%) of villagers commuting to different local non-farm employment sites by different modes of transportation in the two study areas.

Study area	Mode of commuting	Commuting distance			
		<10km	10km≤ – <20km	≥20km	Total
Khon Kaen study site	By their own means of transportation	794 (72.0)	223 (20.2)	86 (7.8)	1,103 (100.0)
	By company bus	65 (15.0)	126 (29.2)	241 (55.8)	432 (100.0)
	Total	859 (56.0)	349 (22.7)	327 (21.3)	1,535 (100.0)
Kalasin study site	By their own means of transportation	449 (71.8)	126 (20.2)	50 (8.0)	625 (100.0)
	By company bus	0	2 (10.0)	18 (90.0)	20 (100.0)
	Total	449 (69.6)	128 (19.8)	68 (10.5)	645 (100.0)

Table 2. Mean number of residents per village commuting to different local non-farm employment sites and the mean distance per village to those sites in each study area.

Study area	Distance	Mean number of commuters to different local non-farm employment sites* $\bar{X}$	
Khon Kaen study site	< 15km (close to employment sites)	49.2	*t-test ** (p = .001)
	≥15km (far from employment sites)	10.0	
Kalasin study site	< 10km (close to employment sites)	16.9	*t-test (p = .136)
	≥10km (far from employment sites)	11.3	

Note: t-test ** = Significant difference at the p = 5 % level

Table 3. Mean numbers of all local non-farm workers, casual hire wage workers and out-migrants per village in the two study areas.

Study area	Mean number of all local non-farm workers* $\bar{X}$	Mean number of casual hire wage workers* $\bar{X}$	Mean number of regular wage workers* $\bar{X}$	Mean number of out-migrants* $\bar{X}$
Khon Kaen study site	55.2	22.3	35.7	45.9
Kalasin study sites	60.0	46.4	15.0	110.3
*t-test	(p = .759)	* (p = .082)	** (p = .002)	** (p = .000002)

Note: t-test ** = Significant difference at the p = 5 % level

t-test * = Significant difference at the p = 10% level

Table 4. Number (%) of households with different types of household structure in the study villages.

	Household structure *			
	Nuclear	Extended	Skipped generation	Truncated
High Employment Village (n = 121 households)	41 (33.9)	49 (40.5)	11 (9.1)	20 (16.5)
Low Employment Village (n = 122 households)	24 (19.7)	37 (30.3)	29 (23.8)	32 (26.2)

* Chi-square test ** (p = .001)

Table 5. Different types of households (number and %) as the source of out-migrants in the study villages.

Household status	Household structure*			
	Nuclear	Extended	Skipped generation	Truncated
Have one or more out-migrants (n = 178 households)	29 (44.6)	69 (80.2)	38 (95.0)	42 (80.8)
Do not have any out-migrants (n = 65 households)	36 (55.4)	17 (19.8)	2 (5.0)	10 (19.2)
Total (n = 243 households)	65 (100.0)	86 (100.0)	40 (100.0)	52 (100.0)

* Chi-square test ** (p = .000)

Table 6. Number of sample households from different livelihood groups.

	Livelihood groups				Total
	1. Only agriculture	2. Both agriculture and non-agriculture	3. Only non-agriculture	4. Economical ly inactive	
Total number of households	24	222	41	16	303
Number of selected sample households	8	41	6	6	61
Percentage of all households in livelihood group	33.3	18.5	14.6	37.5	20.1

Table 7. Debt as a share of net income of different types of households in Nong Ben village (n = 61).

Debt as a share of net income	Type of Household Structure			
	Nuclear (n =19)	Extended (n =23)	Skipped Generation Extended Vertical (n =9)	Truncated (n =10)
No Debt	8 (42.1%)	6 (26.1%)	2 (22.2%)	6 (60.0%)
1 to 50 %	3 (15.8%)	4 (17.4%)	1 (11.1%)	1 (10.0%)
51 - 100%	1 (5.3%)	2 (8.7%)	0	1 (10.0%)
> 100%	7 (36.8%)	11(47.8%)	6 (66.7%)	2 (20.0%)
Total	19 (100%)	23 (100%)	9 (100%)	10 (100%)

8. Accomplishments:

8.1 Papers

a. papers that have been published

1. Yuko Shirai and A. Terry Rambo. 2014. Urban Demand for Wild Foods in Northeast Thailand: A survey of edible wild species sold in the Khon Kaen municipal market. *Ethnobotany Research & Applications*. pp. 113-130.
Available from: www.ethnobotanyjournal.org/vol12/i1547-3465-12-113.pdf.
2. Yuko Shirai and A. Terry Rambo. 2017. Household Structure and Sources of Income in a Rice-Growing Village in Northeast Thailand. *Southeast Asian Studies* Vol. 6 (2).

c. papers that have been submitted and are under review

1. Yuko Shirai, Jefferson Fox, Stephen J. Leisz, Hayao Fukui, and A. Terry Rambo. n.d. The Influence of Local Non-Farm Employment on Rural Household Structure in Northeast Thailand. *Journal of Rural Studies* (impact factor: 2.4).
2. Yuko Shirai, Stephen J. Leisz, Jefferson Fox and A. Terry Rambo. Does Rural Industrialization Reduce Out-Migration? Commuting Distance, Levels of Local Non-Farm Employment and Out-Migration in Rural Villages in Northeast Thailand. *Applied Geography* (impact factor: 2.5).

d. manuscripts not yet submitted to journals

1. Yuko Shirai, Stephen J. Leisz, Jefferson Fox and A. Terry Rambo. Factory Workers and Farmers: The Influence of the Availability of Local Non-Farm Employment on Agricultural Activities in Rural Villages in Northeast Thailand. *Journal of the Human Environment* (impact factor: 2.6).

8.2 Conference / seminar / workshop attendance

	M/D/Year	Place	Duty	Activities/Purpose
1	Feb 11, 2014	Khon Kaen University	Oral Presentation	Seminar on Northeast Thailand in Transition: Landscape, Livelihood and Life.
2	Sep 16, 2014	Khon Kaen University	Oral Presentation	The KCU-CSEAS Conference on Rural Northeast Thailand in Transition: Land Use, Farming Systems and Households.
3	Jan 11-13, 2016	East-West Center, Honolulu, Hawaii	Oral Presentation	Workshop for the project on "Forest, agriculture, and urban transition in Mainland Southeast Asia (MSEA): Synthesizing knowledge and developing theory.
4	Nov 26-28, 2014	Wishing Tree Resort, Khon Kaen	Participant	Writing workshop for the young lectures and graduate students participating in the TRF Basic Research Project on the Agrarian Transformation in Northeast Thailand.
5	Feb 12-14, 2016			
6	Nov 18-20, 2016			

8.3 Completion of an academic degree

Ph.D.'s thesis dissertation was successfully defended on the 14th September 2016, and completed revision has been accepted by the Graduate School of Khon Kaen University.

1. Title of Sub-project: Roadside stalls: Are roadside stall beneficially viable for farm households?

2. Names and Affiliations of Researchers

Student's Name: Waramon Maijaroen

Committee:

- 1) Assoc. Prof. Dr. Suchint Simaraks Program on System Approaches in Agriculture, Faculty of Agriculture, KKU.
- 2) Prof. Dr. A. Terry Rambo Program on System Approaches in Agriculture, Faculty of Agriculture, KKU.
- 3) Asst. Dr. Passakhon Nuntapanich Program on Agricultural Technology, Faculty of Agriculture, Ubon Ratchathani Rajabhat University.
- 4) Dr. Arunee Promkhumbut Program on System Approaches in Agriculture, Faculty of Agriculture, KKU.

3. Research Objectives

- 1) To understand the systems of roadside stalls selling agriculture produce in Northeast Thailand.
- 2) To identify different types of roadside stalls.
- 3) To compare proportion of household income from different types of roadside stalls.

4. Research Methodology

For the purposes of this study, roadside stalls were defined as small temporary or semi-temporary structures that sell produce or products from agriculture that are located along the roadside (not including stalls that function as restaurants). Only stalls making up clusters consisting of at least 4 roadside stalls were included in this study.

The survey was conducted along main roads in the region. These included three types of roads classified by the Department of Highways as national highways, provincial roads and secondary roads. All of the national highways and the provincial roads in the Northeast were surveyed along with those frequently travelled secondary roads connecting provincial cities to each other.

The survey was carried out between November 2014 and January 2015. The first author drove along each selected route in a private vehicle and stopped at every cluster of stalls encountered along the way. The location of each cluster was determined using a handheld Global Positioning System (GPS) device and photograph were taken of the stalls. At each cluster of stalls key informants were interviewed. Criteria for selecting Key Informants were that they had been among the first persons to establish stalls in their clusters, they lived in the neighboring communities, had good knowledge about stalls and cluster development and knew about all the other cluster members. Three to five KIs for each cluster were selected for semi-structure interview s. Sub-topics were developed and adjusted to fit each specific site of each cluster for SSI. A total of 148 KIs were interviewed from 47 clusters on 5 routes.

5. Research Findings

There are 47 clusters with a total of approximately 1,100 stalls along the surveyed routes (figure 1). The number of stalls fluctuates from day to day and from season to season. It is highest on national holidays followed by weekend days

(Friday-Sunday) while work days (Monday-Thursday) have the lowest number of operating stalls. Variation in the number of operating stalls reflects market demand as the result of the volume of travelling customers. Therefore there are regular sellers and non-regular sellers operating the stalls.

Most of the products sold in the stalls are fresh agricultural products such as jujube, pineapples, yam beans, coconuts, oranges, bananas, watermelons and cantaloupes. Processed agricultural products such as boiled sticky corn, sticky rice roasted in bamboo sections, Isaan sausage, boiled sweet potatoes and pineapple jam. Almost all of the products sold in each roadside stall cluster are locally produced.

Stalls in different geographical location of the NET sell different kinds of agricultural products. Bananas, bamboo shoots, mushrooms, torch, pumpkins, local and temperate fruits and vegetable, and non-timber forest products are found in the mountainous zone (altitude > 300 meter) due to climatic and ecological advantages. Jujubes, tamarinds, melons, sticky corn, and jicama are sold in stalls the lowland zone. Stalls on the mountains generally carry a greater variety of products than the stalls in the lowlands.

Figure 2 shows the times when different clusters of stalls were established. Most were established quite some time ago with the mean being 17.2 years ago. The stalls on national highways have existed for the longest time with a mean age of 27.5 years. Stalls on provincial and secondary roads were generally established more recently with mean ages of 16 and 16.6 years respectively.

Distributions of the roadsides stall, on the national highway (Mittraphap Road), there are only 4 roadside stall clusters but the average number of stall per cluster is the highest (66.3 stalls per cluster) as is the mean number of stalls per kilometer (0.73 stalls/kilometer) of any type of road. On provincial roads, there are 22 roadside stall clusters with a total of 393 stalls, averaging 17.9 stalls per cluster and an average of 0.4 stalls per kilometer of road. On secondary roads there are 21 roadside stall clusters with a total of 403 stalls, averaging 19.2 stall per cluster and only 0.24 stalls per kilometer of road (table 1). Even though the roadside stalls are wholly distributed on every types of roads but the highest number of stalls is still located on the highway and mountainous zone (tourist attraction sites).

The distribution of roadside stall clusters is not related to the number of traffic lanes as indicated table 2. Two and four traffic lane roads have more number of stalls than six traffic lane road. Actually roadside stall is illegal but this raw is not regularly enforced.

6. Conclusions

Roadside stalls are found along national highway, provincial roads and secondary road in the Northeast but there are more number of stalls in the mountainous and low land zones. In the low land zone most of the stalls carry only fewer variety of primary agricultural products, while in the mountainous zone most of the stalls carry more variety of primary agricultural products. According to Choenkwan et al (2014) reported that in the mountainous zone ecological environment and weather allow farmers to grow more variety of tropical as well as temperate high value crops and at the same time it is a tourist attraction site.

7. Tables and Figures

Table 1 Distribution of roadside stall clusters on different types of roads

Type of road	Total length of roads (Km)	Mean no/ of stalls/km.	No. of clusters	No. of stalls	Percentage of total no of stalls	Mean no. of stalls/ cluster
National	363	0.73	4	265	25	66.25
Provincial	974	0.4	22	393	37	17.86
Secondary	1,671	0.24	21	403	38	19.20
Total	3,008		47	1,061	100	

Table 2 Number of traffic lanes and concentration of roadside stalls

Number of traffic lanes	Number of roadside stall clusters	Percentage of clusters	Number of stalls	Percentage of stalls
2	19	40.4	265	24.9
4	23	48.9	711	67.0
6	5	10.6	85	8.0
Total	47	100	1061	100

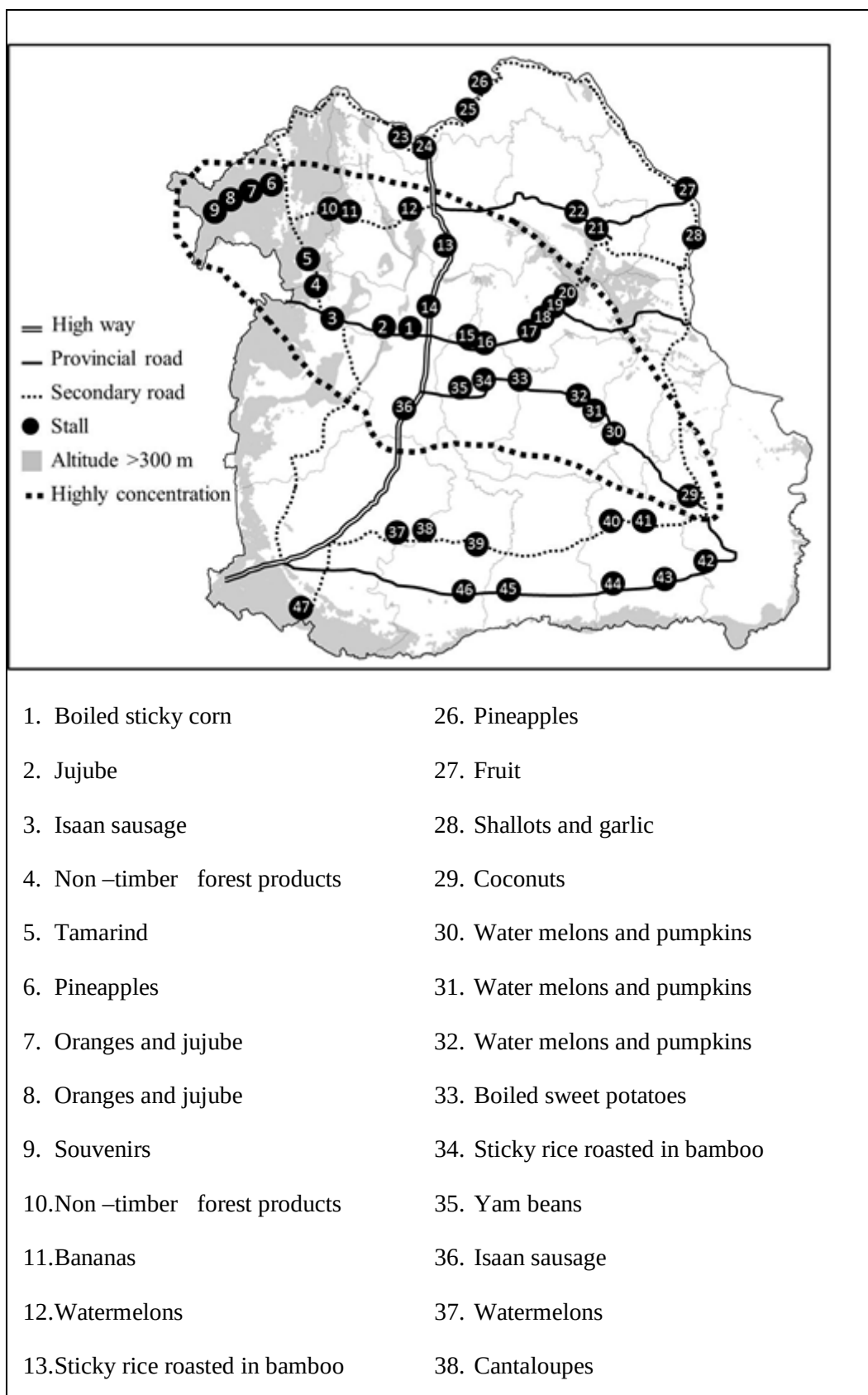


Figure 1 Locations of roadside stall clusters and list of products they sell in Northeast Thailand

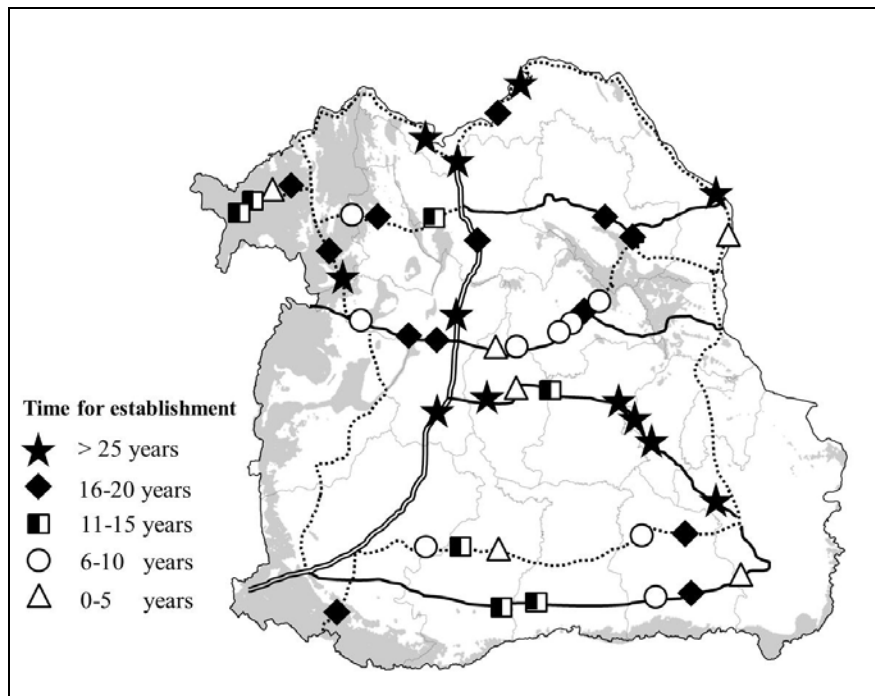


Figure 2 Roadside stall cluster time of establishment

8. Accomplishments:

8.1 Paper will be submitted:

The title of paper: Spatial distribution of roadside stalls selling agricultural products in Northeast Thailand (expect to submit to Singapore Journal of Tropical Geography, impact factor 1.085)

8.2 Conference / seminar / workshop attendance:

1) Poster presentation at TRF Seminar Series in Basic Research: The Agrarian Transformation in Northeast Thailand, 15 September 2014, Faculty of Agriculture, Khon Kaen University, in the title of roadside stalls: as alternative marketing outlets for farmer's products in Isaan, Preliminary Study.

2) Academic paper writing workshop during 26-28 November 2014 at Wishing Tree Resort, Khon Kaen.

3) Academic paper writing workshop during 12- 14 February 2016 at the Wishing Tree Khon Kaen Resort in Tha Phra Sub-District, Khon Kaen Province.

4) Academic paper writing workshop during 18- 20 November 2016 at the Wishing Tree Khon Kaen Resort in Tha Phra Sub-District, Khon Kaen Province.

1. Title of Sub-project: Spatial variations in the density of trees in paddy fields in different parts of the Northeast Region

2. Names and Affiliations of Researchers

Dr. Moriaki Watanabe

Dr. A. Terry Rambo

Dr. Patma Vityakon

Dr. Hayao Fukui

3. Research Objectives

- 1) To investigate spatial variability of density of trees in paddy fields in the whole Northeast Region of Thailand
- 2) To investigate spatial variability in the density, area of canopy cover and origins of trees in paddy fields at the community (village) level of Northeast Thailand.
- 3) To investigate factors influencing the density of trees in paddy fields in whole Northeast Region of Thailand.
- 4) To investigate factors influencing the density, area of canopy cover, and origins of trees in paddy fields at the community level of Northeast Thailand.

4. Research Methodology

This study was conducted at both macro (regional) and micro (village) levels. The macro level survey was conducted utilizing high resolution satellite images downloaded from Point-Asia in order to understand spatial variability in the occurrence of trees in paddy fields in Northeast Thailand. The micro level survey was conducted in Khok Kwang village, Khok Ngam Sub-district, Ban Fang District, Khon Kaen Province in order to understand spatial variability in the occurrence of trees in paddy fields at the community level.

Data were collected from primary and secondary sources. The secondary data were collected from the available literature, government data bases, and high resolution satellite images downloaded from Point Asia and Google Earth. A limitation of Point Asia images is that they are not date stamped making it difficult to know the year and season when the images were taken. According to Point Asia Dot Com Co., Ltd., all of the images were taken in 2003-2007.

5. Research Findings

The macro level survey was conducted utilizing high resolution satellite images and found that the mean density of trees in paddy fields in the whole region was 12.1 trees/ha. In general, the northern part of the region had much lower densities of trees than the southeastern part. Tree density was found to be influenced by multiple factors including 1) the history of land development, 2) topography, 3) access to natural forest resources, 4) amount of annual rainfall, and 5) landholding size. However, there is considerable co-variation among these factors making it difficult to determine their relative importance.

The micro level survey was conducted in one rural community, Khok Kwang village, Khok Ngam sub-district, Ban Fang district, in Khon Kaen province, utilizing high resolution satellite images and interviewing of key informants from the village while observing their fields. It describes spatial variations in the density, canopy cover, and origin of trees in paddy fields within the village and identifies key factors influencing such variation. It was found that the history of

land development, topography, and types of crops are main influencing factors. It was also found that recent changes in agriculture, notably intensification of rice production in the lower paddies and replacement of rice with sugarcane in both lower and upper paddies, are factors leading to a decline in tree density, cutting down of larger canopied forest survivors, and planting of trees with smaller canopies.

Both macro and micro level surveys revealed a declining trend of the density of trees in paddy fields. If this trend continues, the vast “invisible forest” represented by trees in paddy fields may truly disappear, with negative consequences for the livelihoods of the villagers, loss of biodiversity, and reduced ability of the rural ecosystem to sequester carbon.

Besides, the landscape of paddy fields with high tree densities, as seen in the southeastern region of northeast Thailand, including Ubon Ratchathani and Amnat Charoen provinces, is also found in Pakse in Southern Laos. Mean density of trees in paddy fields around Pakse was 20.0 trees/ha in 2006 and 18.6 trees/ha in 2013. Mean tree density in paddy fields located in the high-density grid cells had substantially decreased from 2006 to 2013.

6. Conclusions

The study was conducted in order to ascertain the spatial variability of density of trees in paddy fields and to identify factors influencing density of trees in paddy fields at both macro and micro levels. The target of the macro level survey was the whole Northeast Region of Thailand and that of the micro level survey was a single community, Khok Kwang village, in Khon Kaen Province. The study yielded new findings relating to: 1) spatial variations in the density of trees in paddy fields at the regional and the community levels, 2) factors influencing the density of trees in paddy fields, and 3) temporal changes in the density of trees in paddy fields.

7. Tables and Figures

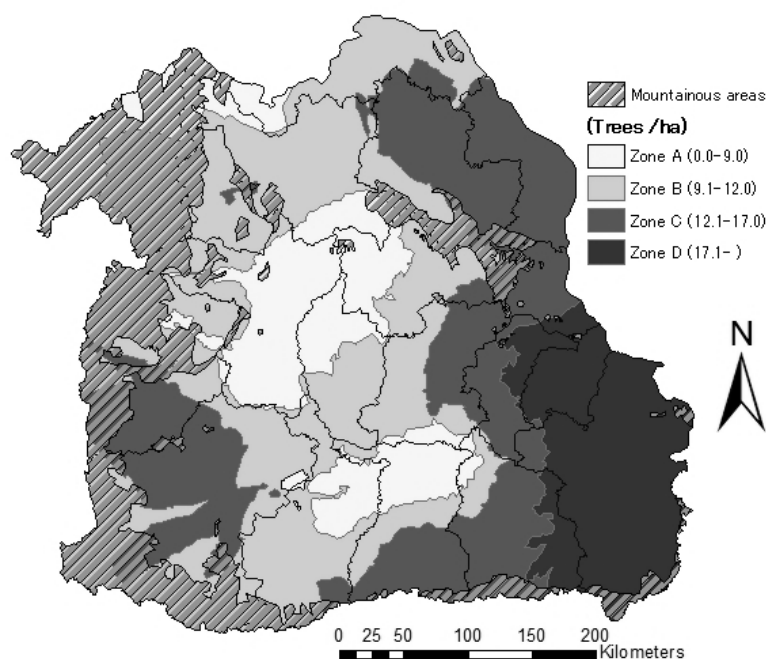


Figure 1: Zoning map of mean density of trees in paddy fields in Northeast Thailand

Table 1. Relationship between the agrarian transformation and the decrease in tree density in paddy fields in Khok Kwang village

Agrarian Transformation		Reasons to use	Benefit of using	Change in significance of trees in paddy fields	Effect on tree density
Changes in technology of rice production	The use of chemical fertilizer	Low soil fertility	Higher yield of rice	Litter fall from trees is less important.	Cutting trees in paddy fields
	The use of Irrigation pump	Unstable rainfall	More stable rice production	Trees have a negative impact on rice yields.	
	Mechanization	Shortage of labor	Saving labor and time	Trees interfere with use of tractors and combine harvesters.	
Replacement of rice with cash crops		Farmers' increased need for cash to buy consumer goods	Higher cash income	Sugarcane and cassava are less shade tolerant.	

8.1 Papers

a. papers have been published

1. Watanabe, Moriaki, Patma Vityakon, and A. Terry Rambo. "Can't See the Forest for the Rice: Factors Influencing Spatial Variations in the Density of Trees in Paddy Fields in Northeast Thailand." *Environmental management* 53.2 (2014): 343-356. Impact factor: 1.72.

2. Watanabe, Moriaki, Patma Vityakon, and A. Terry Rambo. "Factors Influencing Variations in the Density, Extent of Canopy Cover, and Origin of Trees in Paddy Fields in a Rainfed Rice-farming Village in Northeast Thailand". *Southeast Asian Studies* Vol. 6 (2).

8.2 Conference / workshop attendance

The result of micro level survey was presented at "Rural Northeast Thailand in Transition: Land Use, Farming Systems and Households" to be held at faculty of agriculture of Khon Kaen University on 16 September, 2014.

8.3 Completion of an academic degree

Ph.D. degree, 2014 March.

1. Title of Sub-project: A Comparative Ecological Study of Homegardens of Different Ethnic Groups in the Sakon Nakhon Basin, Northeast Thailand, and Some Related Groups in Vietnam

2. Names and affiliations of researchers

Researchers	Affiliation
Ms. Pijika Timsuksai	Sakon Nakhon Rajabhat University (former CHE Ph.D. student of Program on System Approaches in Agriculture, KKU)
Dr. A. Terry Rambo	Program on System Approaches in Agriculture, Faculty of Agriculture, KKU
Dr. Hayao Fukui	
Dr. Suchint Simaraks	

3. Research Objectives

To assess the extent to which different horizontal structural patterns of homegardens are associated with different ethnic groups in Northeast Thailand and Vietnam.

4. Research Methodology

Research approach

This study was designed to collect systematic data on the horizontal structure of homegardens of samples of households in rural communities representing the 8 ethnic groups included in this study. Because our preliminary observations revealed considerable variation in the structural characteristics of the homegardens of different households within the same ethnic community, we sought to analyze the data in such a way that would identify central tendencies without losing sight of the range of variation within each group. Therefore we employed a method devised by anthropologists to describe the modal personality structures of different cultures [14, 15]. Modal personality structure has been defined as “...the body of character traits that occur with the highest frequency in a culturally-bounded population. Modal personality is a statistical concept rather than the personality of an average person in a particular society” [16]. This approach is suitable for identification of central tendencies in populations that are internally heterogeneous. When applied to the study of homegardens, the goal is to identify those structural characteristics (e.g., organic or geometric form, lineal or polycentric planting patterns) that are found in the largest share of gardens of sample households belonging to each of the ethnic groups. Although our focus is on identification of modal tendencies, the frequencies with which alternative characteristics occur in each ethnic group sample are also shown.

Selection of ethnic groups

The northeastern region of Thailand is ethnically relatively homogeneous with members of the Thai Lao ethnolinguistic group (commonly referred to simply as “Lao”) forming the majority of the population [17]. However, the Sakon Nakhon Basin in the northern part of the region where we did this study has unusual ethnic diversity. The Lao, along with the Kalaeng, Nyaw, and Phu Thai, belong to the Southwestern group, the Yoy to the Northern group of the Tai language family, and the Viet (Thai Vietnamese) belong to the Vietnamese branch of the Mon-Khmer language family (Figure 1). The Cao Lan are a Tai speaking group in the Midlands of northern Vietnam who belong to the Central group of the Tai language family. They have had little or no contact with the Tai communities in Thailand for several hundred years. The Kinh (ethnic Vietnamese) in central Vietnam are the ancestral population

of the Viet group in Northeast Thailand from whom they have been geographically isolated for more than a century.

There has been relatively little ethnographic research on most of the Tai groups. All of the Tai speaking groups are believed to have settled in the Sakon Nakhon Basin in the early nineteenth century after the Siamese army forcibly relocated them there from their homes in Laos [18]. Most of the Viet came to the area in the latter half of the nineteenth century, first fleeing the persecution of Catholic converts by the Vietnamese emperor Minh Mang and then escaping from the French colonial occupation of their homeland in central Vietnam. Later they were joined by refugees from the Indochina War in the late 1940s and after 1975 [19, 20]. The Cao Lan migrated into northern Vietnam from southern China several centuries ago [21, 22] and the Kinh (ethnic Vietnamese) are indigenous to central Vietnam.

Selection of study sites

The study sites in Northeast Thailand were selected from rural villages representing the 5 Tai groups (Kalaeng, Lao, Nyaw, Phu Thai, and Yoy) and the Viet, all found within a relatively small area within the Sakon Nakhon Basin. In Vietnam, a Cao Lan village in a remote part of Tuyen Quang province was selected for study [23] along with a Kinh village in the district in Ha Tinh province from which the Viet living in Northeast Thailand had originally come. Knowledgeable local researchers and government officials were consulted in order to identify all of the villages inhabited by each ethnic group. The study villages were then selected on the basis of being located in a rural area, ethnically homogeneous, and having homegarden production mainly for household consumption. Semi-structured interviews were then conducted with village headmen and other villagers in order to confirm that the communities actually met the selection criteria. The locations of the study villages are shown in Figure 2. Table 1 presents information on the environmental and social characteristics of the study communities.

Selection of sample households in each community

Maps showing the location of all households in each village were drawn with the assistance of the village headman and/or village members who then drew a transect line across the center of the settlement area in order to provide a basis for sampling representative households. Starting from the first house at the beginning of the transect line, every house on both sides of the line that met our selection criteria was interviewed until a sample of 20 households (17 in the Cao Lan village) was achieved. For a household to be included in the sample, it had to meet the following criteria: 1) it had a homegarden, 2) its members identified themselves as belonging to the ethnic group under study, 3) it had been resident in the village for a minimum of two generations, and 4) an adult member was available, willing to be interviewed, and mentally capable of responding to questions. This work was done in accordance with the principles outlined in the Declaration of Helsinki, although the Thai university agricultural faculties with which the authors are affiliated do not have any institutional requirements for approval of non-medical human research of this type. In the case of our study, adult farmers were interviewed about the structure and functioning of their homegardens, but no sensitive, personal, or health-related information was collected. Before we began data collection from villagers, the study was explained to the village head and his permission obtained to do interviews in the village. Before conducting each individual interview, the purpose of the research was explained to the farmers and their verbal permission obtained to ask them questions and measure their gardens.

It was explained that their participation was voluntary and they could opt out of the study at any time. All data in the paper are anonymous and cannot be traced to any particular individual informants. Although the sampling procedure does not meet the criteria of strict randomness, it did minimize the likelihood of unconscious bias on the part of the researchers influencing selection of sample households.

Data collection and recording

Data were collected by means of semi-structured interviews with adult members of sample households and by direct observation and measurement of structural characteristics. Horizontal structure was recorded on sketch maps and by taking photographs.

Data for the structural characteristics of all sample homegardens for each community were recorded in an Excel database which was used to compile comparative tables of garden structural characteristics for all of the study sites.

Data analysis

Because there are no standardized approaches for classifying horizontal structural dimensions of homegardens, we were compelled to develop our own analytic system. This system includes four different horizontal structural dimensions (Figure 3):

- Shape of planting areas or plots: *Geometric* forms include plots or beds with square, rectangular, or circular shapes. *Organic* forms include planting areas with irregular or curvilinear shapes.
- Definition of the boundary of the planting areas or plots: Boundaries can be *sharp* and clearly marked or *indeterminate* and ill-defined.
- Arrangement of individual plants within planting areas or beds: Individual plants can be planted in parallel lines (*lineal*) or in multiple clusters of plants (*polycentric*).
- Species composition within each plot: Planting areas or beds can be planted with only a single kind of plant species (*mono-species*) or with a mixture of two or more different species (*multi-species*).

Each homegarden of all of the sample households from each ethnic group was classified in terms of the extent to which it manifested the alternative characteristics for each dimension. For example, the shapes of all of the planting areas within a garden were classified as being either geometric or organic and the surface area covered by each of these forms calculated. The garden was then categorized as to whether it was all geometric, >50% geometric, >50% organic, or all organic. The characteristic (e.g., all or mostly geometric) that was found to occupy more than 50% of the area in the largest number of gardens was selected as being modal for that structural dimension for that ethnic group. These data were then used to make a cluster analysis using the SPSS statistical package version 16.0 (SPSS Inc. Released 2007. SPSS for Windows, Chicago, SPSS).

5. Research Findings

Detailed information on the frequency of occurrence of different characteristics for each of the 4 horizontal structural dimensions for the sample of homegardens of each of the ethnic groups is presented in Table 2. Each of the ethnic groups has a single clearly dominant characteristic for each of the 4 structural dimensions (with the exception of the Yoy, for which equal shares [45%] of gardens have all mono-species and all multi-species planting patterns within beds). Table 3 presents the modal

structural characteristics for each group. The modal patterns for each group are as follows:

Cao Lan: Organic shaped planting areas, indeterminate boundaries, polycentric planting pattern, multi-species composition (although 39% have all or mostly mono-species composition).

Kalaeng: Organic shaped planting areas, indeterminate boundaries (although 40% have mostly sharp boundaries), polycentric planting pattern, multi-species composition (although 35% have all mono-species composition).

Lao: Organic shaped planting areas, indeterminate boundaries, polycentric planting pattern (although 35% have lineal patterns), multi-species composition (although 50% have all or mostly mono-species composition).

Nyaw: Organic shaped planting areas, indeterminate boundaries, polycentric planting pattern, multi-species composition (although 35% have mono-species composition).

Phu Thai: Geometric planting areas, sharp boundaries, lineal planting pattern, mono-species composition. However, 35% of Phu Thai gardens have organic or mostly organic shapes, 25% have indeterminate or mostly indeterminate borders, and 30% have polycentric planting patterns.

Yoy: Organic shaped planting areas, indeterminate boundaries, polycentric planting pattern, equal percentages of all mono-species and all multi-species composition.

Kinh: Geometric planting areas, sharp boundaries, lineal planting pattern, mono-species composition.

Viet: Geometric planting areas, sharp boundaries, lineal planting pattern, mono-species composition.

Organic shaped planting areas, indeterminate boundaries, and polycentric planting patterns are modal for the Cao Lan, Kalaeng, Lao, Nyaw, and Yoy, while for the Phu Thai, Kinh, and Viet geometric forms with sharp boundaries and lineal planting patterns are modal (although a sizable minority of Phu Thai gardens have organic or mostly organic shapes, indeterminate or mostly indeterminate borders, and polycentric planting patterns). Planting of multiple species in the same planting area is modal for the Cao Lan, Kalaeng, and Nyaw, and while the Phu Thai, Kinh, and Viet have mono-species planting areas and the Yoy and Lao have equal shares of gardens with mono- and multi-species beds.

Figure 4 is a graphic comparison of the modal patterns of each of the groups. The patterns of all Tai groups, with the exception of the Phu Thai, are quite similar to one another, although the Cao Lan pattern is the most distinct and does not fully overlap with the other Tai patterns. The Kinh and the Viet patterns are almost identical while the Phu Thai pattern is closer to that of the Vietnamese groups than it is to the other Tai groups.

Figure 5 presents a hierarchical cluster analysis of the modal structural

characteristics of the homegardens of the 8 ethnic groups. They cluster into two main types: Type I (Cao Lan, Kalaeng, Lao, Nyaw, and Yoy) and Type II (Phu Thai, Kinh and Viet). Within Type I, the Cao Lan are a separate sub-type while the Phu Thai are a separate subtype within Type II. Homegardens of Type I are characterized by having predominantly organic shapes, indeterminate boundaries of planting areas, polycentric planting patterns, and multi-species composition within planting areas. Homegardens of Type II have geometric shapes, sharp boundaries, lineal planting patterns, and mono-species composition of planting areas. However, the Phu Thai homegardens, although they belong to Type II, are less homogenous than those of the Vietnamese groups and show resemblance to Type I in some regards. Thus, although geometric shapes, sharp boundaries, lineal planting patterns, and mono-species composition are modal, organic shapes, indeterminate boundaries of planting areas, and polycentric planting patterns are also encountered in a considerable minority of their gardens.

6. Conclusions

Study findings suggest a close linkage between ethnicity and the structure of homegarden agroecosystems. Most of the Tai groups share a common structural pattern for their homegardens while both of the Vietnamese groups share their own common structural pattern. This close association between ethnicity and agroecosystem structure represents what Richard O’Conner [41], in his study of ethnic competition in the history of Southeast Asia, has referred to as an “agro-cultural complex.” These complexes have persisted through time and space and retained their integrity, even when the ethnic groups on which they are based have migrated into different environments and encountered strong acculturative pressures from neighboring populations having different ethnic identities and distinctive agroecosystem models.

The existence of such strong and durable links between ethnic identity and agroecosystem structure has important implications for research on agricultural development. Agricultural research has been heavily dominated by economic and technological concerns, reflecting the assumption of agricultural scientists and government policymakers that farmers, regardless of their ethnic identity, will always tend to adopt agricultural structures and practices that provide optimum economic returns [27]. To the extent, however, that agroecosystem structures reflect the cultural models of the farmers, adoption of improved technology may be constrained by its compatibility with these models. It is possible, of course, that homegardens, which are mostly small plots used to meet household subsistence needs, are more likely to conserve traditional cultural patterns because they are less subject to market pressures to maximize productivity than cash-cropping components of agroecosystems. However, this is not necessarily the case since we know that even modern American commercial farmers are influenced by cultural factors, as shown, for example, by their initial resistance to adoption of economically beneficial sustainable agriculture partly because this system was associated in the popular imagination with “hippies” [43]. Therefore, assessing the ways in which the cultural beliefs and values of farmers from different ethnic groups influence their choice of appropriate agricultural structures and practices should have an important place on the research agenda of agricultural researchers and policymakers in developing countries.

7. Tables and Figures

Table 1. Characteristics of study villages of different ethnic groups

Ethnic group	Yoy	Phu Thai	Nyaw	Lao	Kalaeng	Cao Lan	Viet	Kinh
Location (province, district, sub-district)	Sakon Nakhon, Akat Umnua y, Akat Umnua y	Sakon Nakhon, Waritchaphum, Waritchaphum	Sakon Nakhon, Ponnakaew, Baan Paen	Sakon Nakhon, Song Dao, Tha Sila	Sakon Nakhon, Kud Bak, Kud Bak	Tuyen Quang, Son Duong, Dong Loi	Nakhon Panom, Muang Nakhon Panom, Nong Yat	Ha Tinh, Huong Khe, Huong Lien
Geographic coordinates¹	17° 36'00.8 3"N 103° 58'42.8 1"E	17° 16'52.0 6"N 103° 39'11.8 1"E	17° 11'41.8 3"N 104° 13'20.7 6"E	17° 14'38.0 3"N 103° 21'57.9 4"E	17° 04'09.3 4"N 103° 47'00.4 0"E	17° 22'12.8 0"N 104° 21'41.0 3"E	17° 22'38.0 9"N 104° 45'45.1 0"E	18° 03'46.0 4"N 105° 45'21.9 4"E
Elevation (m amsl)¹	152	193	166	214	212	169	156	83
Topographic setting²	River bank	Hilly	Gently slopping	Hilly	Hilly	Mountain valley	Gently slopping	Mountain valley
Land suitability³	Loamy sand, infertile soil, good drainage	Loamy sand, infertile soil, good drainage,	Loamy sand, infertile soil, poor drainage	Sandy loam, infertile soil, moderately well drained	Loamy sand, infertile soil, good drainage,	Clay loam, infertile soil, well drained	Sandy loam or sandy clay loam, low to moderate infertile soil, poor drainage	Clay loam, infertile soil, well drained
Area (ha)⁴	50	488	760	536	800	120	202	40
Population⁴	510	1,058	556	655	788	76	520	376
Population density (no.)	1,020	220	70	122	100	63	260	940

of people /km²)								
No. of households⁴	118	335	189	198	218	20	118	102
Main purpose of homegardens⁵	100% subsistence	55% subsistence, 45% commercial	100% subsistence	95% subsistence, 5% commercial	100% subsistence	100% subsistence	40% subsistence, 60% commercial	100% subsistence

Sources: ¹GPS records of author; ²Observation by author; ³ Land Development Department (<http://giswebldd.ddd.go.th/>)(except for Cao Lan and Kinh groups from <http://www.fao.org/ag/Aqp/AGPC/doc/Counprof/vietnam/vietnam.htm>); ⁴Village headman; ⁵ Samples of 20 homegardens (17 for the Cao Lan) in each village

Table 2. Comparison of horizontal structural characteristics of homegardens of different ethnic groups in Northeast Thailand and Vietnam (% of gardens displaying characteristic) (n=20, except 17 for Cao Lan)

Structural dimension	Alternatives (%)	Tai groups						Vietnamese groups	
		Yoy	Phu Tai	Nyaw	La o	Kalae ng	Cao Lan	Viet	Kinh
Shape of planting areas	All Geometric	15	45	10	15	25	0	70	60
	>50% Geometric	0	20	5	5	0	0	15	25
	>50% Organic	15	15	30	5	0	28	0	15
	All Organic	70	20	55	75	75	72	15	0
Boundary definition of planting area	All Sharp	20	50	15	15	0	6	95	75
	>50% Sharp	5	25	20	5	40	0	0	10
	>50% Indeterminate	15	5	40	5	0	22	0	10
	All Indeterminate	60	20	25	75	60	72	5	5
Arrangement of individual plants within planting areas	All Lineal	15	5	15	15	25	11	75	55
	>50% Lineal	15	65	5	20	0	4	5	45
	>50% Polycentric	0	0	15	0	0	7	5	0
	All Polycentric	70	30	65	65	75	78	15	0
Species composition within planting area	All Mono-species	45	55	35	45	35	22	95	90
	>50% Mono-species	10	30	0	5	0	17	0	10
	>50% Multi-species	0	5	10	0	0	0	0	0
	All Multi-species	45	10	55	50	65	61	5	0

Table 3. Comparison of modal structural characteristics of homegardens of different ethnic groups in Northeast Thailand and Vietnam (% of homegardens with all or >50% of their area displaying each characteristic) (n=20, except 17 for Cao Lan)

Dimension	Tai groups						Vietnamese groups	
	Yoy	Phu Thai	Nyaw	Lao	Kalaeng	Cao Lan	Viet	Kinh
Shape of planting area	Organic (85%)	Geometric (65%)	Organic (85%)	Organic (80%)	Organic (75%)	Organic (100%)	Geometric (85%)	Geometric (85%)
Boundary definition of planting areas	Indeterminate (75%)	Sharp (75%)	Indeterminate (65%)	Indeterminate (80%)	Indeterminate (60%)	Indeterminate (94%)	Sharp (95%)	Sharp (85%)
Arrangement of individual plants within planting area	Polycentric (70%)	Lineal (70%)	Polycentric (80%)	Polycentric (65%)	Polycentric (75%)	Polycentric (85%)	Lineal (80%)	Lineal (100%)
Species composition within planting area	Mono-species (55%)	Mono-species (85%)	Multi-species (65%)	Mono-species (50%) Multi-species (50%)	Multi-species (65%)	Multi-species (61%)	Mono-species (95%)	Mono-species (100%)

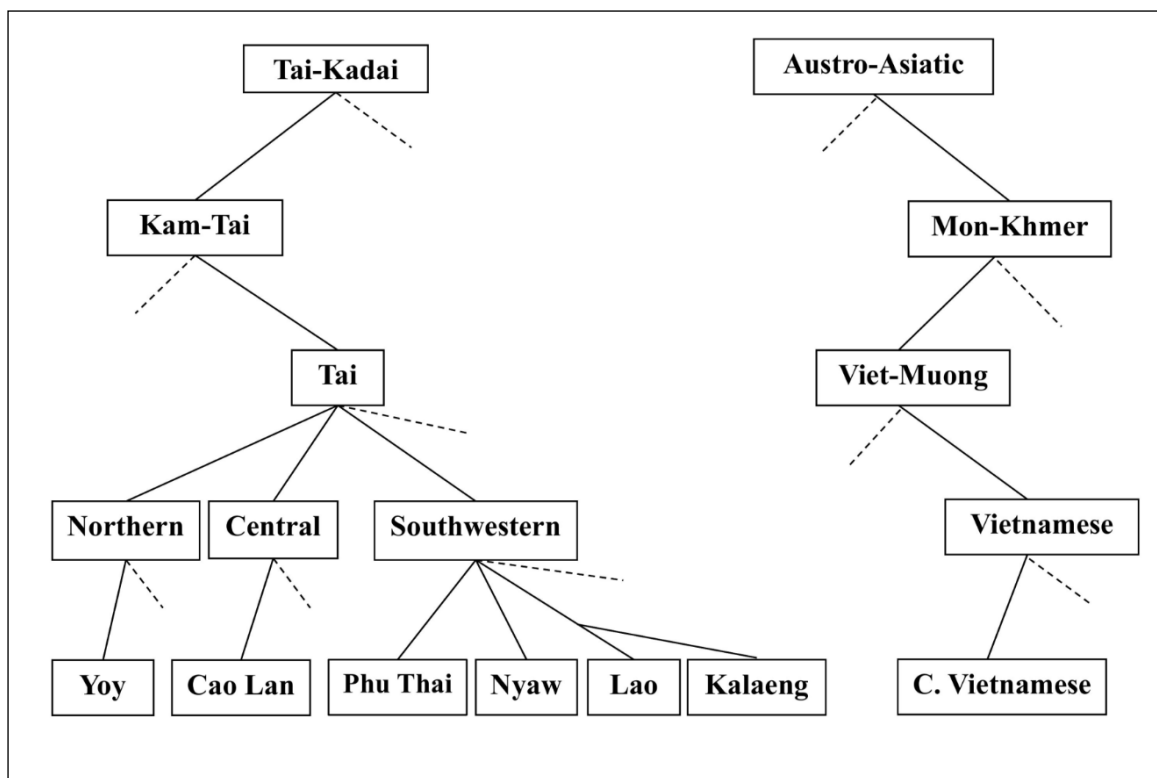


Figure 1: Ethnolinguistic taxonomy of groups in Northeast Thailand and Vietnam.

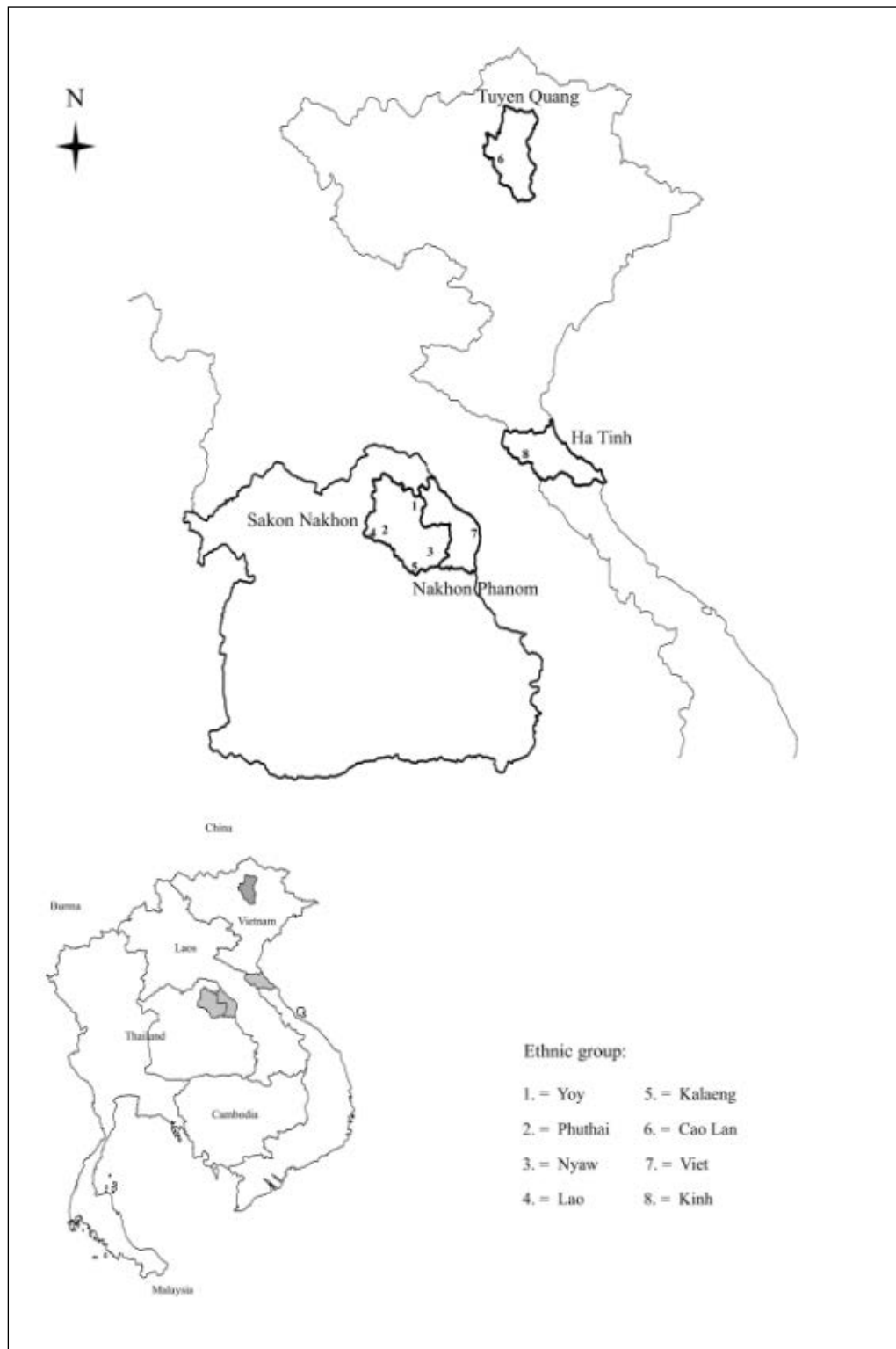


Figure 2: Map showing location of study villages in Northeast Thailand and Vietnam.

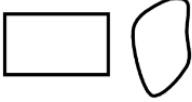
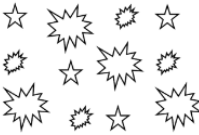
Dimensions	Alternative characteristics	
Shape of planting area	Geometric 	Organic 
Boundary definition	Sharp 	Indeterminate 
Arrangement of individual plants within plot	Lineal 	Polycentric 
Species composition within plot	Mono-species 	Multi-species 

Figure 3: Classification system of horizontal structural characteristics of homegardens.

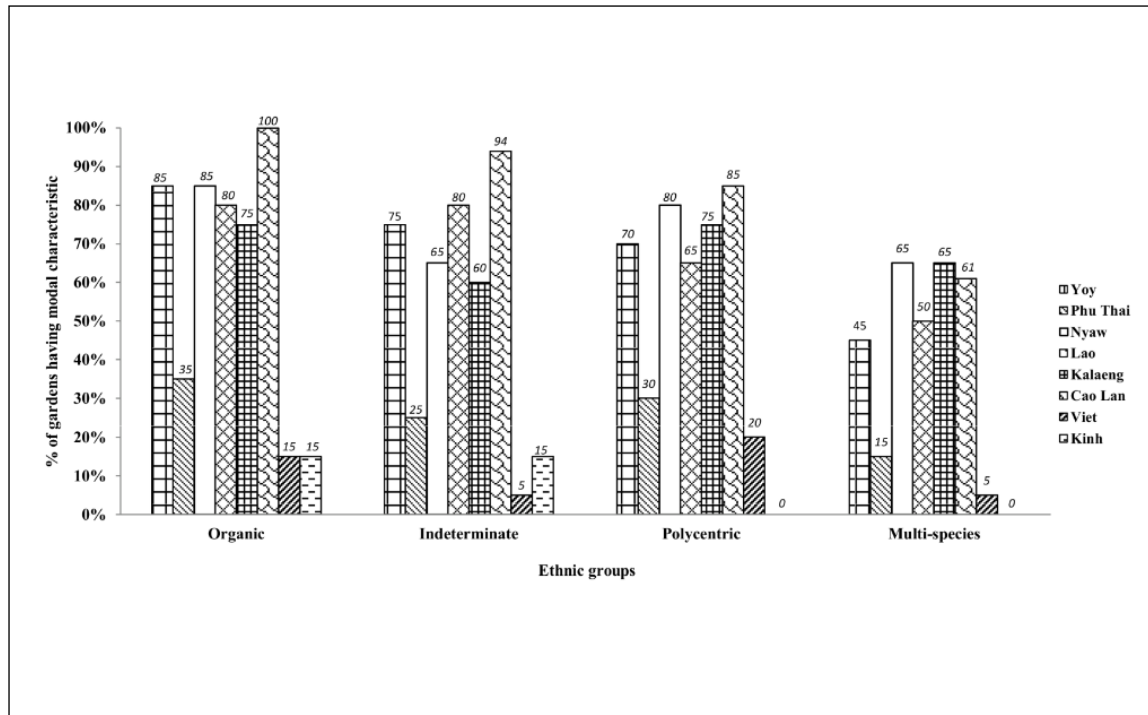


Figure 4: Comparison of modal structural patterns of homegardens of different ethnic groups in Northeast Thailand and Vietnam (% of gardens having modal characteristic).

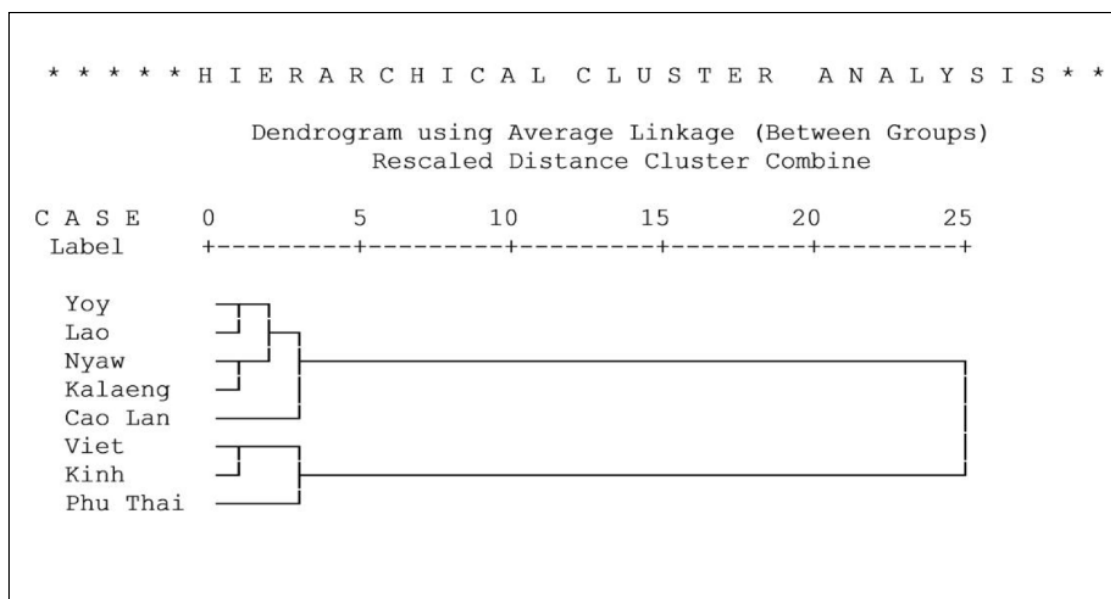


Figure 5: Hierarchical cluster analysis based on percentages of modal characteristics of structural dimensions of homegardens of ethnic groups in Northeast Thailand and Vietnam.

8. Summary of:

8.1 papers have been published

	Name of journal	Impact factor	Title of paper	Authors
1	Southeast Asian Studies, the Journal of Kyoto University	SCOPUS but no impact factor	Homegardens of the Cao Lan, a Tai-Speaking Ethnic Minority in Vietnam's Northern Mountains	Pijika Timsuksai, Nguyen Dinh Tien, and A.Terry Rambo
2	Khon Kaen Agriculture Journal	TCI: 0.176	A comparative study of the ecological structures of homegardens of different ethnic groups in Northeast Thailand	Pijika Timsuksai, and A.Terry Rambo
3	PLOS ONE	3.534	The influence of culture on agroecosystem structure	Pijika Timsuksai and A.Terry Rambo

8.2 Conference / workshop attendance

- (4) Oral presentation at TRF Seminar Series in Basic Research: The Agrarian Transformation in Northeast Thailand, 15 September 2014, Faculty of Agriculture, Khon Kaen University.
- (5) Academic paper writing workshop during 26-28 November 2014 at Wishing Tree Resort, Khon Kaen.
- (6) Academic paper writing workshop during 12-14 February 2016 at Wishing Tree Resort, Khon Kaen

8.3 Completion of an academic degree

Completion of Ph.D. degree in 2014.

1. Title of Sub-project: Soil classification systems and farmer knowledge about soil management in Northeast Thailand

2. Names and Affiliations of Researchers

Student's Name: Ms. Sujitra Yodda

Committee: Prof. Dr. A. Terry Rambo

3. Research Objectives

- 1) To describe variation in soil naming and classification among individual and community in Thai-Lao group in Northeast Thailand.
- 2) To relate name and classification of soil to management practices.

4. Research Methodology

4.1 Selection of study sites

Select several Thai-Lao rice growing villages with similar soil condition.

4.2 Selection of sample farmers in each study site

A minimum of 10 farmers will be selected in each village.

Criteria for selection of sample farmers (for interviews):

- 1) They are at least 60 years of age because older people are more likely to retain traditional knowledge.
- 2) They are actively engaged in farming so have current experience with soil management.
- 3) The plots they farm are located in all different parts of the toposequence and include all different types of soil in the village.
- 4) They were born in the study villages or have lived there for more than 20 years.

4.3 Interviews with sample farmers

Each of the farmers included in the sample will be individually interviewed about their naming classification of soil and knowledge of soil management practices in their own plots. At the same time, samples of types of soil identified by farmers will be collected for laboratory analysis. These interviews about soil naming and knowledge of soil management practices will always be conducted in the farmers' fields where both the farmers and the researcher can observe the actual soil because if we interview about soil classification in their houses farmers cannot see the real soil in their field and their answers to questions may not reflect the real situation in their fields.

Sub topics for interviews with farmers:

- 1) What do you call the soil in this plot?
- 2) How do you distinguish this type of soil from other types of soil in the landscape?
- 3) Is this type of soil good or bad for growing rice? Why is it good (or bad) for them.
- 4) How long have you cultivated this soil? Have you noticed any changes in it over this period of time? If so, what are the changes? What do you think has caused this change?
- 5) Do you do anything to try to change this soil?" (for example, input manure or fertilizer) And when?

4.4 Identification and naming of soil type

After all members of the village sample have been interviewed, the individual asked to identify type of soil and give name to them for the sample of their own plots and same repeated including the sample other individual by showing the samples soil. A preliminary identify naming of soil will be prepared that includes all the different types of soil in the study site. Samples of soil of each names type will be shown to each of the informants, even if they do not have them on their own land, and see if they all use the same names for the same types.

4.5 GPS recording of location of farmer plots

A GPS unit will be used to obtain the coordinates of each farmer's plot.

4.6 Soil sampling

For each type of soil identified by a farmer, several soil samples will be taken in different randomly selected about 10 parts of the plot. These samples will be taken, from the top 15 cm of the soil surface by spade, mixed together into a single composite sample, and air dried before storing.

4.7 Soil analysis

In the laboratory, each composite sample will be analyzed and described in terms of color (using standard soil color charts), texture and organic matter (OM) content.

4.8 Data management and analysis

During each interview with sample farmers, the responses of each individual farmer to questions will be recorded on a separate standardized data recording form. Data from the form for each of the farmers along with analysis of soil samples from their plots will be incorporated into an Excel data base. Separate data bases will be created for each study site.

5. Research Findings

5.1 Study site

This research was carried out in Non Ku village, a rain-fed rice-growing community inhabited by Thai Lao farmers. The village is located in Sawathee sub-district, Mueang district, Khon Kaen province (latitude 16°30'37"N and longitude 102°39'56"E) which is approximately 25 km. from Khon Kaen municipality. Non Ku community has 260 households and a total population of 987 persons of which 476 are males and 511 are females.

The village is one that was established more than a century ago. According to a sign board about the history of the village which was set up by the village headman, the settlement was founded in 1909 C.E. when 5 households migrated from nearby Sawathee village to find new land to farm. Its name of Non Ku reflects the fact that the settlement is located on high land ("Non") and contains the ruins of an ancient Khmer temple ("Ku").

The settlement area of the village is located on high land (195 meters asl.), which is about 10 meters higher than the paddy fields to the west and south of the settlement area. The settlement area covers 76 ha, the paddy fields cover 472 ha, and upland crops (sugarcane and cassava), are grown on a small upland area covering 23 ha. Forest covers 42 ha also in the uplands.

All of the soil in the village is classified by the Land Development Department as

soil series map scale 1: 100,000 belonging to the Roi-et series. In the description of the top soil (0-25 cm.) is loamy sand or sandy loam with a brown color or brown mixed with gray and a pH of 5.0-6.5. The Roi-et series has low organic matter and moderate soil fertility.

According to climatological data from the nearest weather station at the Khon Kaen airport, which is approximately 22 km. from the village, for the 30 year period 1981-2010, the annual mean temperature is 26.9 °C, with a mean minimum of 22.3 °C and a mean maximum of 32.8 °C. The mean relative humidity is 72%, with a mean minimum of 52% and mean maximum of 88%. The mean annual rainfall is 1,246.8 millimeters, with a low of 936.5 mm. in 2005 and a high of 1,780.6 mm. in 2008 (Northeastern Meteorological Center [Upper Part], 2013)

5.2 Identification of soils by individual farmers

Sixteen soil samples were collected from the fields of 11 farmers. Altogether, the farmers assigned 14 different names to these samples. The general name for soil used by all of the sample farmers was *din* (which is coterminous in meaning with the English word “soil”). Specific types of soil are named according to texture, e.g., *din sai* (sandy soil), *din sai pon ruan* and *din ruan pon sai* (loam), *din nieow pon sai* (clayey loam), and *din nieow* (clayey soil), color, e.g., *din dam* (black soil), taste and edibility, e. g., *din prieow* (sour soil, an edible clay) and *din kin* (edible soil), and softness (*din tom*) (soft soil). Names based on texture are in some cases modified with color terms, e.g., *din sai dam* (black sandy soil) and *din dam pon sai* (black-colored loam) or softness, e.g., *din sai pon tom* (soft sandy soil). The soil in termite mounds, which has high concentrations of clay, organic matter and nutrients due to the activities of the insects, is called *din pon* (termite mound soil). No samples of this type of soil were collected from the farmers’ fields so it is not included in the analysis of their soil classification system.

5.3 Comparison of soil identifications and naming among the sample farmers

Although every farmer was able to assign a name to every soil sample, they frequently failed to agree about the names they assigned to the different samples (Table 1). For some samples, e.g., sample number 1.4 and 11.1, all informants applied the name *din sai* (sandy soil) but for other samples there was much less agreement. Thus, sample 6.1, which the laboratory analysis classified as a brown loam, was given 7 different names and sample 1.3, a dull brown loam, was assigned 6 names.

The extent of inter-informant consensus about soil names appears to vary according to the texture of the different samples. As is shown in Figure 1, levels of agreement are highest for coarse textured soils with all informants calling the two samples with the coarsest textures by the same name (*din sai* or sandy soil). There is also a relatively high level of consensus about the names of the soils with the finest textures. In generally there is much less agreement about the names of soils composed of complex intermixtures of sand, silt and clay.

5.4 Soil taxonomies used by the farmers

In order to understand their soil classification system, farmers were asked to sort the 16 soil samples into larger groups according to their similarities and differences. Two different patterns emerged from this exercise: six farmers divided the soil samples into 4 large groups and five farmers divided the soil samples into 3 large groups (Figure 2). Two farmers who divided the soil into 4 groups further divided 1 group

into 2 sub-groups and 2 of the farmers who divided the soil into 3 main groups further sub-divided one group into 2 sub-groups.

5.5 Farmer knowledge about soil management

Suitability of different types of soil for growing crops

The farmers think that *Din Dam* would be best for growing rice. However, the small areas covered with this soil type are reserved for planting crops. The farmers also consider *Din Nieow* to be good for growing rice but none of them have paddy fields with this soil; Of the 3 types of soil actually used for growing rice, *Din Nieow Pon Sai*, and *Din Ruan Pon Sai* are judged to be about equally suitable. *Din Nieow Pon Sai* and *Din Ruan Pon Sai* are favored because they are both soft, easy to plow and allow expansion of the rice roots. *Din Sai*, on the other hand is considered much less suitable because it has low fertility and poor water retention. Farmers also say that *Din Sai* is “hot” because they have observed that rice plants grown in *Din sai* show more signs of wilting in the afternoon than those growing in other soils. The small area of *Din Dam*, which is considered to have high fertility, is only used for gardens., *Din Sai* is also used for growing vegetables around the rim of farm ponds but is not considered to be so good for this purpose because of its low fertility and poor water retention which requires farmers to water the plants twice per day in the morning and evening. Some areas covered by *Din Nieow* are used as the sites of wells because wells dug in clayey soil do not collapse easily.

Cultivation practices used for different soils

Regardless of soil types all of the farmers plow their paddy fields two times and harrow them once. *Din Sai* is more difficult to plow than *Din Nieow Pon Sai* and *Din Ruan Pon Sai* when inundated deeply it becomes like quicksand.

Harrowing of *Din Sai* is done in only 1 pass because if the harrow passes over it more than once it quickly becomes too compact, making insertion of the rice seedlings during transplanting difficult. *Din Ruan Pon Sai* receives 2 or 3 passes of the harrow but *Din Nieow Pon Sai* receives many passes to make the soil soft.

Din Sai plot must be transplanted immediately after harrowing because all the soil quickly becomes compact after it is harrowed. *Din Nieow Pon Sai* and *Din Ruan Pon Sai* can be transplanted 1-3 days after harrowing because these soils are softer.

During the growing season paddy fields with *Din Sai* must be checked on a daily basis because the water level decline more quickly than fields of *Din Nieow Pon Sai* and *Din Ruan Pon Sai*, requiring more frequent supplementary irrigation.

All of the farmers apply a mixed chemical fertilizer as well as cow manure, buffalo manure, pig manure and chicken manure to improve soil fertility. The majority of farmers input manure in the dry season. Different the farmers used chemical fertilizer with different formulas of to improve soil fertility but they do not seem to vary the formula or quantity of fertilizer according to the type of soil.

Formerly, farmers burned the straw and stubble left in the paddy fields after the rice harvest. But some farmers observed that soil in burned fields became difficult to plow for the next rice. This was true for all of the 3 types of soil (*Din Nieow Pon Sai*, *Din Ruan Pon Sai* and *Din Sai*) in the paddy fields. So the farmers discontinued the practice of post-harvest burning and left the straw to decompose in the fields. They also apply manure during the dry season which also helps to soften the soil making it easier to plow.

6. Conclusions

We found in general the low level of agreement on soil taxonomy among the sample farmers. Therefore, we could say that soil taxonomy may not be shared by all villagers but it is basically shared only within family or kin group. However, there was a good agreement on certain types of soil, e.g., very sandy soils. The sandy soils occur widely and require some special care in land preparation, which is the common knowledge of villagers. The good agreement about the taxonomy of this type of soil is considered to be related to the shared experience of management of it. In such case, the family-level taxonomy becomes to be shared across different families suggesting the possible process from the personal experience to shared culture.

7. Tables and Figures:

Table 1 Extent of inter-informant agreement about the names assigned to soil samples

Sample no (scientific description)	Most used name	Second most used name	Third most used name	Fourth most used name	Fifth most used name	Sixth most used name	Seventh most used name
1.1 (brown loam)	<i>Din Ruan</i> <i>Pon Sai</i> (5)	<i>Din Tom</i> (3)	<i>Din Sai</i> <i>Pon Nieow</i> (1)	<i>Din</i> <i>Nieow</i> (1)	<i>Din</i> <i>Sai</i> (1)		
1.2 (brownish black sandy loam)	<i>Din Dam</i> (8)	<i>Din Sai</i> <i>Dam</i> (1)	<i>Din Sai</i> <i>Pon</i> <i>Nieow</i> (1)	<i>Din</i> <i>Ruan</i> (1)			
1.3 (dull brown loam)	<i>Din Nieow</i> <i>Pon Sai</i> (3)	<i>Din Ruan</i> <i>Pon Sai</i> (3)	<i>Din Sai</i> (2)	<i>Din</i> <i>Pon</i> (1)	<i>Din</i> <i>Dam</i> <i>Pon</i> <i>Sai</i> (1)	<i>Din</i> <i>Nieow</i> (1)	
1.4 (bright yellowish brown sand)	<i>Din Sai</i> (11)						
2.1 (dull yellow orange silty loam)	<i>Din Nieow</i> <i>Pon Sai</i> (5)	<i>Din</i> <i>Nieow</i> (2)	<i>Din Ruan</i> <i>Pon Sai</i> (2)	<i>Din Sai</i> <i>Pon</i> <i>Nieow</i> (1)	<i>Din</i> <i>Tom</i> (1)		
3.1 (dull brown loam)	<i>Din Ruan</i> <i>Pon Sai</i> (5)	<i>Din</i> <i>Nieow</i> (2)	<i>Din Tom</i> (2)	<i>Din</i> <i>Prieow</i> (1)	<i>Din</i> <i>Nieow</i> <i>Pon</i> <i>Sai</i> (1)		
3.2 (light brownish gray clay)	<i>Din</i> <i>Nieow</i> (7)	<i>Din</i> <i>Prieow</i> or <i>Din Kin</i> (4)					
4.1 (dull brown sandy loam)	<i>Din Sai</i> (6)	<i>Din Sai</i> <i>Dam</i> (4)	<i>Din Sai pon</i> <i>Tom</i> (1)				
5.1 (dull orange sandy loam)	<i>Din Sai</i> (5)	<i>Din</i> <i>Nieow</i> <i>Pon Sai</i> (2)	<i>Din Nieow</i> or <i>Din Dam</i> (1)	<i>Din Sai</i> <i>Pon</i> <i>Nieow</i> (1)	<i>Din</i> <i>Sai</i> <i>Pon</i> <i>Ruan</i> (1)	<i>Din</i> <i>Ruan</i> (1)	

6.1 (brown loam)	<i>Din Nieow Pon Sai</i> (2)	<i>Din Tom</i> (2)	<i>Din Nieow</i> (2)	<i>Din Ruan Pon Sai</i> (2)	<i>Din Dam</i> (1)	<i>Din Sai Dam</i> (1)	<i>Din Sai Pon Nieow</i> (1)
7.1 (brown sandy loam)	<i>Din Sai</i> (7)	<i>Din Sai Pon Ruan</i> (1)	<i>Din Dam Pon Sai</i> (1)	<i>Din Ruan Pon Sai</i> (1)	<i>Din Nieow Pon Sai</i> (1)		
8.1 (bright brown sandy loam)	<i>Din Nieow Pon Sai</i> (6)	<i>Din Ruan Pon Sai</i> (3)	<i>Din Nieow</i> (1)	<i>Din Tom</i> (1)			
9.1 (dull yellowish brown silty loam)	<i>Din Nieow Pon Sai</i> (4)	<i>Din Ruan Pon Sai</i> (3)	<i>Din Tom</i> (3)	<i>Din Nieow</i> (1)			
10.1 (dull yellowish brown sandy loam)	<i>Din Ruan Pon Sai</i> (5)	<i>Din Nieow Pon Sai</i> (2)	<i>Din Tom</i> (2)	<i>Din Ruan</i> (1)	<i>Din Nieow</i> (1)		
10.2 (grayish brown clay loam)	<i>Din Nieow</i> (10)	<i>Din Prieow or Din Kin</i> (1)					
11.1 (dull orange loamy sand)	<i>Din Sai</i> (11)						

Note: the numbers inside the parentheses are the numbers of respondents using each name

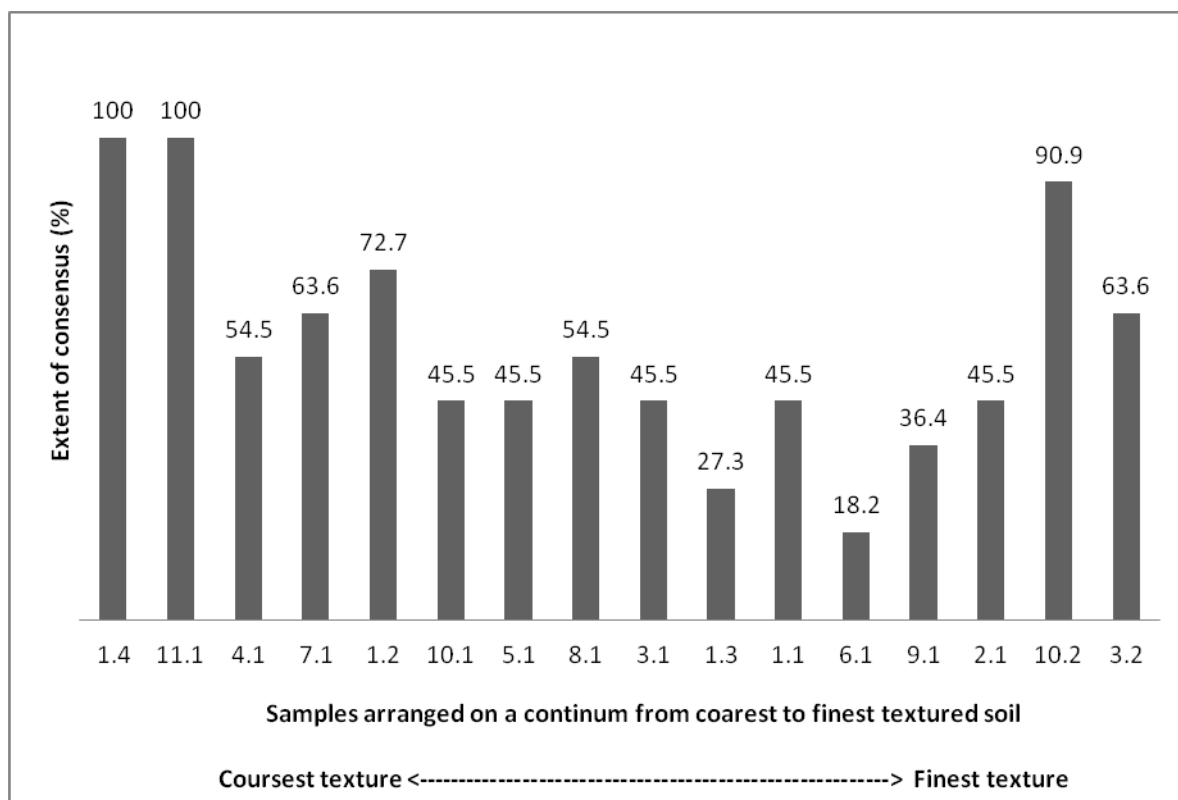
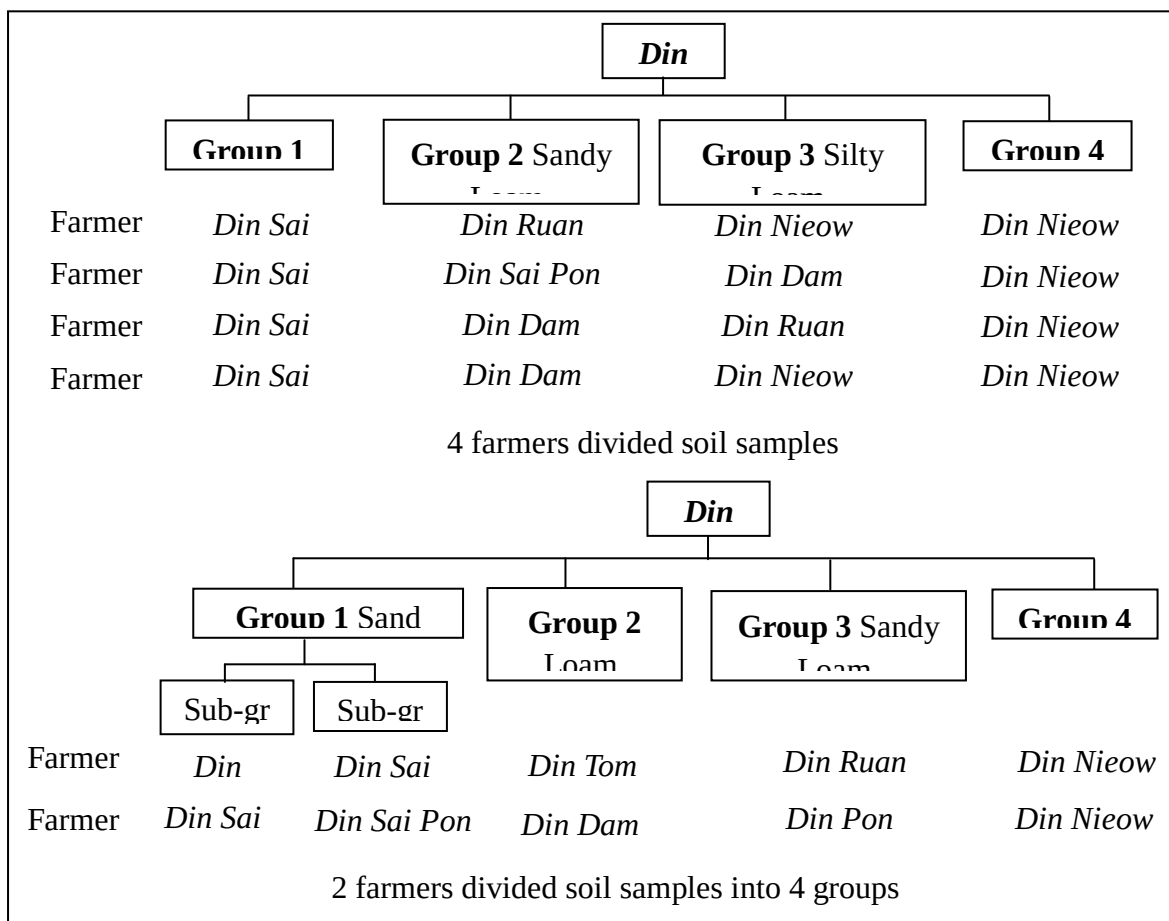


Figure 1 Relationship between soil texture and extent of inter-informant consensus about names of different soil samples



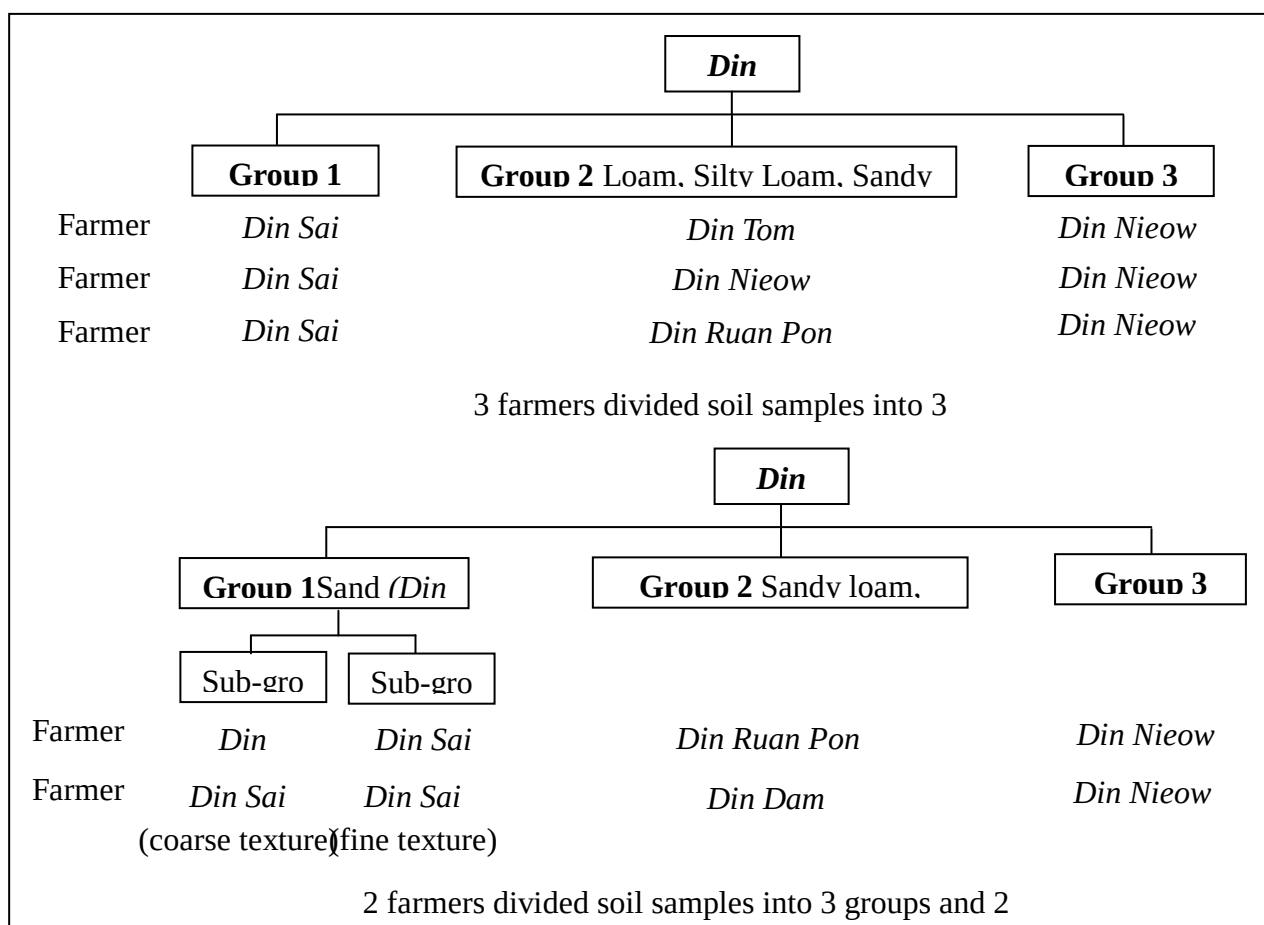


Figure 2 Soil grouping by farmers

8. Accomplishments:

8.1 Paper will be submitted:

The title of paper: An Assessment of Inter-informant Agreement about Soil Names and Classification among Thai-Lao Farmers in a Rain-fed Rice-growing Village in Northeast Thailand. Journal of Geoderma and impact factor of 2.855.

8.3 Conference / seminar / workshop attendance:

1) Poster presentation at TRF Seminar Series in Basic Research: The Agrarian Transformation in Northeast Thailand, 15 September 2014, Faculty of Agriculture, Khon Kaen University, in the title of Indigenous Soil Classification Systems in Northeast Thailand; Preliminary Study.

2) Academic paper writing workshop during 26-28 November 2014 at Wishing Tree Resort, Khon Kaen.

3) Academic paper writing workshop during 12- 14 February 2016 at the Wishing Tree Khon Kaen Resort in Tha Phra Sub-District, Khon Kaen Province.

4) Academic paper writing workshop during 18- 20 November 2016 at the Wishing Tree Khon Kaen Resort in Tha Phra Sub-District, Khon Kaen Province.

1. Title of Sub-project: Homegarden agroecosystems of the Vietnamese in Northeast Thailand and Central Vietnam

2. Names and Affiliations of Researchers

Mr. Nguyen Dang Hoc	Lecturer, Vietnam National University of Agriculture
Prof. Dr. A. Terry Rambo	Lecturer, Program on System Approaches in Agriculture, Faculty of Agriculture, Khon Kaen University
Dr. Pijika Timsuksai	Lecturer, Faculty of Agricultural Technology, Sakon Nakhon Rajabhat University

3. Research Objectives

3.1 To describe and compare the ecological structure and functions of homegardens of the Vietnamese in Central Vietnam and Northeast Thailand.

3.2 To analyze the inputs and outputs of homegardens of the Vietnamese in Northeast Thailand and to assess their productive efficiency.

4. Research Methodology

4.1 Selection of study sites

This study was designed to compare the ecological structure and function of homegardens of two groups of Vietnamese who share a common ancestry but now live in two different environments. One Thai-Vietnamese (Viet) village in Northeast Thailand and one Vietnamese (Kinh) village in Central Vietnam were selected for this study and analyse the cost and benefit of homegardens of the Vietnamese in Northeast Thailand. These two villages were the same ones where Timsuksai (2014) did her study of homegardens.

In Northeast Thailand, Baan Najok in Muang district, Nakhon Phanom province was selected, because there are many Thai-Vietnamese living there who engage in agriculture and have a long tradition of homegarden cultivation.

In Central Vietnam, Nam villages in Ha Tinh province was selected for this study, because most of the Vietnamese in Nakhon Phanom province claim that their ancestors came from Ha Tinh province more than a century ago.

4.2 Selection of study households

In a previous study by Timsuksai (2014) the homegardens of random samples of twenty Vietnamese households were studied in each study village in Northeast Thailand and Central Vietnam. For the present research, ten sample households were selected from among these 20 households. In order to be selected households must meet these criteria: 1) Live in the villages for a long time (more than 10 years); 2) Currently have a homegarden that they actively cultivate; and 3) Are willing to be interviewed and are mentally competent to answer questions. In the Central Vietnam case, Map showing the location of these 20 houses was drawn (Figure 1). Starting from the first house that has been identified in previous study by Timsuksai (2014), every house from these 20 houses (except three households that only started living in this village from 2004) that met our selection criteria was selected to interview until a sample of ten households was achieved. In Northeast Thailand, from 20 sampled households, all ten households that met the selection criteria were interviewed.

In order to analyze the inputs and outputs of Vietnamese homegardens in Northeast Thailand and assess their productive efficiency, nine out of the 10 ten sample households that were selected above were selected to keep records about

inputs and outputs of their homegardens. One household which had a fruit tree garden with a long production cycle was excluded from this study.

4.3 Data collection

** Secondary data*

Secondary data including information about geography, topography, soil series, climate, demography, socio-economic situation, etc. of the study sites was collected from appropriate local government administrative offices and the village headmen.

** Primary data*

Questionnaires, observation and measurement and informal discussion with sampled households were used to collect data about characteristics of their homegardens such as areas, species composition; functions of individual species, and household economy, etc. The structure of homegardens (horizontal, vertical) was recorded by taking photographs and making drawings.

Data on gardening inputs and outputs were gathered by having each household complete a daily record sheet for ten days. These records included the following information:

- 1) Type of activities in homegardens and who performed them for how long;
- 2) Type, amount and cash value of material inputs (e.g., manure, fertilizer, fuel) used in homegardens;
- 3) Amount and cash value of products produced for daily household consumption;
- 4) Amount and cash value of products produced for sale.

4.4 Data analysis

Data on all of the homegardens were entered into an Excel database, which was used to compile tables of characteristics for all homegardens.

a. Methodologies for describing and comparing the structure and functions of Vietnamese homegarden in Central Vietnam and Northeast Thailand

The ecological structure and functions of homegardens in both villages in Central Vietnam and Northeast Thailand were described in terms of the following dimensions:

** Horizontal dimensions include:*

- Shape of planting area or plot: Geometric form include plots or beds with square, rectangular, or circular shapes. Organic form include plating areas with irregular or curvilinear shapes
- Definition of boundaries of planting areas or plots: Boundaries can be sharp and clearly marked or indeterminate and ill-defined.
- Arrangement of individual plants within planting areas or beds: Individual plants can be planted in parallel lines (lineal) or in multiple clusters of plants, usually including representatives of two or more species (polycentric).
- Species composition within each plot: Planting areas or beds can be planted with only a single kind of plant species (mono-species) or with a mixture of two or more different species (multi-species).

** Vertical dimensions include:*

- Number of levels of vegetation: Plants of different species have different heights, which were recorded for 5 levels: Level 1 $\leq$ 1 m, Level 2 = 1.01-5 m, Level 3 = 5.01-10 m, Level 4 = 10.01-15 m, and Level 5 $>$ 15 m. All plants in the garden may be of the same height (single level) or they may have different heights (two or more levels).

- Canopy overlap: The share of the garden area in which the canopies of plants of different heights overlap each other (non-overlapping, < 50% overlapping, and >50% overlapping).

* Functions of different plant species: The functions of plant species were divided based on the primary function of the individual species in homegardens, such as food; medicinal; spices; aesthetic, construction materials, fodder, shading, and other uses.

b. Methodologies for analyzing inputs and outputs and accessing the productive efficiency of Vietnamese homegarden in Northeast Thailand.

Because this study is focused on analysis of inputs and outputs in the production of short cycle vegetable and flower crops, long production cycle crops such as fruit trees (e.g., dragon fruit, jackfruit, banana, and pomelo) and spices are not included in this analysis.

Data were entered into an Excel database and analyzed by using standard descriptive statistics. The calculation of the cash value of inputs and outputs in these homegardens was based on the following factors:

- The cost of hired labor equals 300 baht/day (8 hours).
 - The cost of irrigation was based on calculating the cost of the number of kilowatt hour of electricity used to power the pump used for watering the homegarden.

- Food produced for home consumption was assigned a cash value based on the market price of the relevant items on the recorded day.

- The cash value of products for sale was calculated based on the market price of the specific items on the recorded day.

The productive efficiency (Net input-output ratio) of homegardens was calculated using the following formulas:

$$\text{- Return on input cost} = \frac{\text{Net return}}{\text{Total variable cost}}$$

$$\text{- Return on planted area} = \frac{\text{Net return}}{\text{unit planted area of land}}$$

$$\text{- Return on labor} = \frac{\text{Net return}}{\text{Labor input}}$$

5. Research Findings

5.1 Describe and compare the ecological structure and functions of homegardens of the Vietnamese in Central Vietnam and Northeast Thailand

Species composition and density

Although the homegardens in Nam village in Central Vietnam covered a smaller area on average than those in Najok village in Northeast Thailand, they contained a larger total number of species (89) than the latter (76) (Table 1). The mean number of species per garden was 39 in Nam village compared to 26 in Najok village. The average density of species in the homegardens in Nam village was also greater, with 1.6 species per 100 m² compared to 0.9 species per 100 m² in Najok village.

Despite the fact that they are located in two different areas with quite distinct environment, 50 species were found in common in the homegardens in the two villages. However, there were also considerable differences in species composition between the gardens in the two sites: 39 species were found only in gardens in Nam

village in Central Vietnam and 26 species were found only in gardens in Najok village in Northeast Thailand. There are also important differences in the types of species found in gardens in the two sites: There were 51 perennial species (57%), and 38 annual species (43%) in Nam village whereas in Najok village there were 42 annual species (55%), and 34 perennial species (45%).

Seventy percent of the sample households in Nam village plant rice in well-watered low-lying areas in their homegardens for two crops each year. Rice is grown entirely for family consumption. In Najok village, on the other hand, only one household planted rice in their garden for a single crop in the rainy season. Most of the rice was consumed by the household with the surplus sold for cash. In Nam village every household had chickens, buffaloes and pigs in their gardens but only a few households in Najok village had buffaloes and chickens in their gardens. Fishponds were also located in all of the homegardens in Nam village but there were no fishponds in the homegardens in Najok village.

Spatial distribution of species within the homegardens

The spatial distribution of species in the homegardens was also different between the two villages (Figure 2 and Figure 3).

In Nam village, rice was grown in the lowest lying area with abundant water. Staple crops such as peanuts, beans, and maize were grown on level higher ground in front of, behind or beside the houses. Vegetables and spices were grown next to the kitchen where they can easily be accessed. Sometimes they were located next to the courtyard. Almost all of fruit and timber trees were grown behind and beside the houses, with a few species such as eggfruit (*Lucuma mammosa*), jack fruit (*Artocarpus heterophyllus*), and Bengal almond (*Terminalia catappa* L.) were grown in front of the house to provide shade to the courtyard. Aquilaria and Acacia trees were grown on the outer boundary of the gardens with neighboring house plots. The stables for livestock were located far from the well and the kitchen. Fishponds were located in low areas that can hold water.

In Najok village most of the areas in front of the houses were used to grow short cycle crops with high economic values such as vegetables, flowers and sweet corn. Fruit trees and other big trees were located behind and beside the houses.

Homegarden structure

Although they are located in two different environments the homegardens in both Najok and Nam villages have similar modal horizontal and vertical structural patterns (Table 2). Their horizontal structure is characterized by geometric shaped planting areas with clearly defined boundaries, lineal arrangement of individual plants with planting area, and mono-species composition of each planting area. Vertical structure is characterized by only a few levels of vegetation, and relatively limited canopy overlap (Timsuksai, 2014). However, several differences in the modal vertical structures of the gardens in the two sites were found. The homegardens in Nam village had 3 or 4 levels of vegetation whereas the homegardens in Najok village had only 2 levels of vegetation. The gardens in Nam village also had extensive areas with overlapping canopies, with half of the planted area having less than 50% overlap, and half having more than 50% overlap whereas the gardens in Najok village had 50% of their planting areas with only a single layer of vegetation, 45% with less than 50% overlap, and only 5% had more than 50% overlap.

Functions of plant species in the homegardens

All plant species in the gardens were categorized according to their primary

use (Table 3). In Central Vietnam a greater share of the species were used for fodder, construction materials and industrial materials whereas in Northeast Thailand a higher share of species were used for food, medicine, and other uses. The number of species used for fodder in homegardens in Central Vietnam was higher than in Northeast Thailand because every household in Nam village kept livestock in their gardens whereas only a few households in Ban Najok had livestock in their gardens.

These differences in the functions of species in large part reflect differences in the purposes of homegardens in two areas which in turn are influenced by the quite different socio-economic conditions in Central Vietnam and Northeast Thailand. In Central Vietnam, because the village is quite remote and has only very limited access to the market, the main purpose of the gardens is to supply the consumption needs of the rural households. In Northeast Thailand, however, where access to the market is easy, the main purpose of the homegardens is to produce commercial crops to generate cash.

Another difference between the functions of species in the two areas is that many of the species (33%) in the homegardens in Nam village in Central Vietnam serve multiple functions whereas in Najok village in Northeast Thailand only a few species (7%) have multiple functions. Thus, in Nam village rice, maize, and bananas are used for food and fodder; ginger, Vietnamese balm, Chinese chives, turmeric, perilla, spearmint, fishwort and mugwort are used for both food and medicine; fruit trees such as pomelo and oranges are used for food as well as having social and cultural uses, while jack fruit, egg fruit, longan, litchi, and mango are used for food, social use, shading, and firewood; and areca nut and betel leaves are used as stimulants and also have social and cultural uses. In Najok village sweet corn is used for food and fodder; jack fruit is used for shading and food; areca nut and betel leaves are used as stimulants, sold for cash income and also have cultural uses.

5.2 Analyze the inputs and outputs of homegardens of the Vietnamese in Northeast Thailand and to access their productive efficiency

Input costs

Table 4 shows the costs of all inputs used for growing vegetables and other short cycle crops. The imputed cost of family labor accounted for 85% of total input costs. Household spent on average 5.3 hours per day, ranging from 1.5 hours to 10 hours per day, working in their gardens (Table 5). Labor was expended on land preparation, planting, applying fertilizer, watering, erecting shade cloth, weeding, and harvesting. During the period of data collection, most of the vegetable crops in their homegardens were ready to harvest, and all households engaged in harvesting activities, so that this activity accounted for 43% of labor costs. Because it was the dry season, watering accounted for the second greatest amount of labor costs (35%). There were 7 households doing land preparation, applying fertilizer and planting, but only in small plots, so preparing land (5%), applying fertilizer (2%), planting (4%), and erecting shading for vegetable beds (1%) represented only small shares of total labor input costs.

Electricity used to power the pumps for irrigating the homegardens accounted for 6.8% of total input costs. Because it was the dry season, the vegetables needed to be watered every day (for an average of 1.8 hours per day). Manure represented 6.8% of input costs. Because manure was the main fertilizer used in these gardens there was almost no expenditure on chemical fertilizer. Expenditures on chemical insecticides were also small.

Expenditures on seed and fuel represented the smallest share of input costs. Most of the seeds used in these gardens were saved by the farmers from previous

crops, or bought cheaply from the local shops in their village. The fuel cost was low because almost all of the activities in the gardens were done by human labor. Farmers only used two-wheeled tractors once each year when they started preparing land for the new planting season. For subsequent crops they used hoes to cultivate the soil.

Output values

The output values of homegardens depended on the kinds of crops grown and their yields (Table 6).. On average, each household obtained gross income of 852 baht (US\$26.4) per day in the 10 days that were recorded, and according to estimates by the farmers, 125,652 baht per year. The mean cash value of outputs per square meter of planted area was 18 baht, ranging from 7 to 31 baht/m² in the 10 days that were recorded, and according to estimates by the farmers, 48 baht ranging from 31 to 72 baht/m²/year.

Because they have good yields, cover most of the planted area, and have high prices, vegetables had the highest output value, accounting for 89% of the total output value of homegardens. The output value of vegetables per square meter of planted area was also the highest, with an average value of 19 baht/m², ranging from 4 to 35 baht/m², in the 10 days recorded, and according to estimates by the farmers, average annual value of 58 baht/m², ranging from 35 to 92 baht/m². The output values of sweet corn and other crops were not very high because they were grown in a much smaller area and their prices were lower than vegetable prices.

The productive efficiency of the homegardens

Although input costs are high because of high labor costs, the net return of homegardens was also high. On average, the net return of the homegardens was 620 baht per day, with a range from 40 to 1,325 baht per day during the 10 days that were recorded (Table 7). The productive efficiency of the homegardens was also quite high in terms inputs of labor, capital, and land. The overall average net return on input cost (net benefit - cost ratio) was positive at 2.7:1. Productivity per labor hour was high with an average net return per labor hour of 117 baht. Net benefits per unit area were also quite high with an average net return of 13 baht/m² of planted area during the 10 day study period.

6. Conclusions

Although the Vietnamese in Northeast Thailand and Central Vietnam have lived in different environments for more than a century, their homegardens display great similarity in structure, and functions. The homegardens of the Vietnamese in both areas closely correspond to the temperate type of homegardens (Niñez, 1987). Their horizontal structure is characterized by having geometrically shaped planting areas with sharp boundaries, lineal arrangement of individual plants within the planting areas, and mono-species composition of each planting area. Their vertical structures are both characterized by having only a few vegetation levels and relatively limited canopy overlap, although the gardens in Central Vietnam have more vegetation levels and a larger share of their area covered by overlapping canopies. The gardens in two areas also contain many of the same species although the gardens in Central Vietnam contained more species used for fodder and as construction and industrial materials whereas in Northeast Thailand more of the species were used for food, medicine, and other uses. However, the purpose served by the homegardens in two villages are different, with those in Central Vietnam primarily used to meet household consumption needs whereas those in Northeast Thailand are used primarily for commercial production of cash crops.

That the homegardens of the Thai-Vietnamese in Northeast Thailand display similar structure and functions to the gardens of the Vietnamese in Central Vietnam is remarkable since the former group have been living for more than a century surrounded by Tai-speaking ethnic groups whose gardens have a completely different structural pattern. The gardens of these Tai-speaking groups display a common structural pattern which is characterized by having an organic shape, indeterminate boundaries of planting areas, polycentric planting patterns, multi-species composition of each planting area, multi vegetation levels, and extensive canopy overlap. This structural pattern is similar to tropical forest type of homegarden described by Nair (2001).

It can be concluded that culture is a more important determinant of the form and function of homegardens than either environmental conditions or the purposes for which gardens are used by the farmers. This finding is in keeping with a considerable body of research on homegardens of groups that have migrated to new countries elsewhere in the world. These studies of homegardens of immigrant minority group in other parts of the world have commonly found that they tend to replicate the garden models of their homeland rather than those of the countries where they settled.

This study also found that, although the Thai-Vietnamese homegardens in Najok village have high inputs, their productive efficiency was also high with an average net return on input cost (net benefit - cost ratio) of 2.7:1, which is much higher than for rainfed rice, which is the main alternative agricultural system in the area. Productivity per labor hour was high with an average net return per labor hour of 117 baht (US\$3.62). Net benefits per unit area were also quite high with an average net return of 1.3 baht/m²/day of planted area. Not surprisingly, the Thai-Vietnamese farmers have largely abandoned cultivating rainfed rice in order to concentrate on their much more productive homegardens.

Despite the high productivity of homegardens, however, the area of homegardens cultivated by these farmers is relatively small. Further expansion of this system appears to be constrained by the limited supply of household labor and the high cost of employing hired laborers. Finding ways to reduce the labor time needed to manage the homegardens might allow households to expand production and increase their incomes.

7. Tables and Figures

Table 1 Comparison of plant species diversity in homegardens in Najok village in Northeast Thailand and Nam village in Central Vietnam

Characteristics	Nam village, Central Vietnam (n = 10)	Najok village, Northeast Thailand (n = 10)
<i>Number of species</i>		
Total	89	76
Average per household	39	26
Range (min – max)	28 – 49	19 – 30
<i>Species density/100 m²</i>		
Average	1.6	0.9
Range (min – max)	0.9 – 2.2	0.3 – 1.8

Table 2 The ecological structure of Vietnamese homegarden in Central Vietnam (n=10) and Northeast Thailand (n=10)

Structural dimension		Alternatives forms	Central Vietnam		Northeast Thailand	
			%	Modal pattern	%	Modal pattern
Horizontal characteristics						
Shape of planting area		All Geometric	60	Geometric	70	Geometric
		> 50% Geometric	25		15	
		> 50% Organic	15		0	
		All Organic	0		15	
Boundary definition of planting area		All Sharp	75	Sharp boundary	95	Sharp boundary
		>50% Sharp	10		0	
		>50% Indeterminate	10		0	
		All Indeterminate	5		5	
Arrangement of individual plants within planting area		All Lineal	55	Lineal	75	Lineal
		>50% Lineal	45		5	
		>50% Polycentric	0		5	
		All Polycentric	0		15	
Species composition within planting area		All mono-species	90	Mono-species	95	Mono-species
		>50% Mono-species	10		0	
		>50% Multi-species	0		0	
		All Multi-species	0		5	
Vertical characteristics						
No. of vegetation levels		1	0	3-4	0	2
		2	0		55	
		3	45		10	
		4	45		20	
		5	10		15	
Share of planting area covered by overlapping layers		Non-overlapping	0	Non-overlapping	50	Non-overlapping
		<50% Overlap	50		45	
		>50% Overlap	50		5	

Table 3 Primary functions of plant species in homegardens in Nam village in Central Vietnam and Najok village in Northeast Thailand

Function	Central Vietnam		Northeast Thailand	
	No.	%	No.	%
Food	51	57.3	51	67.1
Aesthetic	12	13.5	9	11.8
Fodder	7	7.9	2	2.6
Construction materials and Shading	7	7.9	3	3.9
Medicinal	4	4.5	4	5.3
Stimulant	3	3.4	3	3.9
Industrial materials	2	2.2	0	0.0
Other uses	3	3.4	7	9.2
Total	89	100.0	76	100.0

Table 4 Input costs (in Thai baht) for short cycle crop production in Vietnamese homegardens in Najok village (n=9 homegardens for 10 days)

Inputs	Mean (Baht)	Minimum (Baht)	Maximum (Baht)	Total for 9 gardens (Baht)
Manure	158.3 (6.8%)	0.0	400.0	1425.0
Seed	15.6 (0.6%)	0.0	125.0	140.0
Fuel	13.9 (0.7%)	0.0	90.0	125.0
Irrigation	158.5 (6.8%)	21.7	420.0	1426.7
Labor	1986.3 (85.2%)	553.1	3768.8	17877.0
Total input cost	2332.6 (100.0%)	578.7	4267.5	19993.0
Input cost per m ² planted area	4.9	2.1	7.8	

Note: 1.00 US\$ = 32.34 Baht, April, 2014

Table 5 Labor expenditure (hour) in Vietnamese homegardens in Najok village (n=9 homegardens for 10 days)

Activities	Mean	Min	Max
Land preparation	2.8 (5%)	0.0	6.5
Fertilizer Application	0.9 (2%)	0.0	3.0
Planting	2.2 (4%)	0.0	7.5
Erecting shade cloth	0.3 (1%)	0.0	0.8
Watering	18.7 (35%)	7.8	40.0
Weeding	5.3 (10%)	0.0	16.8
Harvesting	22.8 (43%)	3.5	62.0
Total	53.0 (100%)	14.8	100.5
Labor hour per day	5.3	1.5	10

Table 6 Output values (in Thai baht) of short cycle crops in Vietnamese homegardens in Najok village (n=9 homegardens for 10 days)

Components	Mean (Baht)	Minimum (Baht)	Maximum (Baht)	Total for 9 gardens (Baht)
Output values				
Vegetables	7622.8 (89%)	1400.0	17525.0	68605.0
Sweet corn	761.1 (9%)	0.0	6400.0	6850.0
Others	137.8 (2%)	0.0	1240.0	1240.0
Total product value	8521.7 (100%)	1420.0	17525.0	76695.0
Output values/m²				
Vegetables	19.0	3.7	35.1	19.0
Sweet corn	11.7	0	18	11.7
Others	6.4	0	12.4	6.4
Whole garden	17.9	6.9	31.3	17.9

Note: 1.00 US\$ = 32.34 Baht, April, 2014

Table 7 Input-output ratios of Thai-Vietnamese homegardens in Najok village (n=9 homegardens for 10 days)

Productive efficiency	Unit	Mean value	Minimum	Maximum
Total input costs	Baht	2332.6	578.7	4267.5
Total product value	Baht	8521.7	1420.0	17525.0
Net return	Baht	6189.1	399.6	13257.5
Net return per day	Baht	618.9	40.0	1325.8
Net return per planted area	Baht/m ²	13.0	3.1	23.7
Net return per labor hour	Baht/hour	116.8	21.1	281.4
Ratio of net return/ input cost		2.7	0.4	7.2

Note: 1.00 US\$ = 32.34 baht, April 2014



Figure 1 Map showing the location of household that has been selected by Timsuksai (2014) and sample households of this study

- | | |
|---|-------------------------------------|
| ○ | Sample houses in Timsuksai 's study |
| ▲ | Sample houses of this study |



Figure 2 Homegardens of the Kinh in Central Vietnam; a) Rice was located in lowest area, staple crops was located in upper land; b) vegetables and spices were grown near kitchen; c) Most fruit trees were located behind the house; d) stables for livestock were located far from kitchen



Figure 3 Homegardens of the Vietnamese in Northeast Thailand; a, b) Vegetables and other short cycle production crops were grown in front of the house; c, d) Fruit trees and other big trees were located behind or beside the house

8. Accomplishments:

8.1 Papers (please indicate the title of paper, name of the journal and impact factor for each paper)

a. papers that have been published

Cost – benefit analysis of vegetable production in the Thai-Vietnamese homgardens in Northeast Thailand. *Khon Kaen Agriculture Journal* 44(3): 527-536

d. manuscript will be submitted to journal

A comparison of the ecological structure and functions of Vietnamese homegardens in Central Vietnam and Northeast Thailand. *Khon Kaen Agriculture Journal* or *Vietnam Journal of Agriculture Science*.

8.2 Conference / seminar / workshop attendance

1. TRF seminar series in basic research: The Agrarian transformation in Northeast Thailand. 2014. Poster presentation
2. Seminar on Scientific Research 2015. Vietnam National University of Agriculture, Hanoi, Viet Nam. 2016. Oral presentation.

8.3 Completion of an academic degree

Master of Science degree in Agriculture. Khon Kaen University, 2016.

8.4 Awards received

Award for outstanding poster presentation in TRF seminar series in basic research: The Agrarian transformation in Northeast Thailand.

1. Title of Sub-project: Factors influencing the decline of traditional cross-stream earthen weir (Thamnop) irrigation in Northeast Thailand

2. Names and Affiliations of Researchers:

Prapatsorn Wongsalee, A. Terry Rambo, Fukui Hayao and Arunee Promkhambut

3. Research Objectives:

To identify contextual factors that may influence the decline of this traditional irrigation technology (Thamnop).

4. Research Methodology

Selection of study sites

Two villages were selected for study on the basis of one having a working Thamnop whereas the other site had an abandoned Thamnop. Two districts (Amphoe) of Surin Province were judged to be appropriate based on CMH documents and the survey records of Thamnop by Fukui and Hoshikawa (n.d.). A preliminary survey confirmed the suitability of the two districts and identified Khok Mueang village in Ban Chan sub-district, Sangkha District (Existing Thamnop) and Alue village in Samrong Thap District (Abandoned Thamnop), and as suitable for in-depth study.

Data collection and analysis

There were three levels of inquiry. The first was the sub-district (*tambol*) level in which general information on the area, with particular emphasis on Thamnop, was obtained through the Tambol Administrative Organization (TAO). The second level was the village (*mu ban*) level, in which the village headman and other villagers who actually made use or used to make use of Thamnop were interviewed to understand the system of Thamnop and to help identify sample households for more in-depth investigation. The third level was the household level. Five households in Khok Mueang village and 6 households in Alue village were selected to be interviewed. All of the sample households either currently cultivated rice or used to cultivate rice in fields near to a Thamnop for a long time, actually benefitted or used to benefit from the Thamnop, knew well the history of Thamnop, and were willing and able to be interviewed at length.

Data were collected during March-April 2010 from the sample households using semi-structured questionnaires and through participation-observation during the extended period when the investigator resided in the villages in the houses of the farmers. Detailed notes of observations and conversations with informants were kept in field notebooks. The documents and secondary data, household questionnaires, and notes based on observation were compiled into a data base that was employed for qualitative analysis.

5. Research Findings

Structure and functioning of Thamnop

A Thamnop is an earthen weir constructed across a stream that blocks the downstream flow of water in order to raise the water level on the upstream side of the weir. Whenever clayey textured soil is available it is used to build the Thamnop since weirs constructed of sandy soil collapse easily. The crest of the Thamnop is made higher than the stream banks and, therefore, no water flows over the crest. If the water were ever to flow over the crest of the weir, the water would easily destroy it, since the Thamnop is made of earth and wood, and covered with neither stone nor concrete.

Instead, the raised water spills over the banks upstream of the weir, inundating the paddy fields upstream of the Thamnop first, and then flowing overland into the downstream fields next. This thin sheet of water moving slowly over paddy fields eventually returns to the original stream at some distance downstream. Since the whole flow of a stream is diverted, there is no water flowing in the section of the stream immediately downstream of the Thamnop. Although a conventional weir superficially looks the same as a Thamnop, it functions entirely differently. It blocks the stream in order to raise the upstream water level so that the water can be diverted into an irrigation channel dug on the upstream side of weir. The volume of water diverted to the channel is controlled by the height of weir and/or a sluice installed on it over which excess water flows back into the stream channel on the downstream side of the weir (Fukui and Hoshikawa, n.d.). This type of weir is used in many parts of the world, including in the intermountain basins in North Thailand where it is called “fai” (Vanpen, 1986). Hence, the main difference between the Thamnop and the weir is that, in the case of the weir, any excess water is allowed to overflow the crest but, in the case of the Thamnop, water is not allowed to overflow the crest but instead is directed so as to overflow the upstream stream banks.

The existing Thamnop in Khok Mueang village, Ban Chan Sangkha District

This still-functioning Thamnop was constructed in 1953. Built out of clayey textured soil, it is located at the mid-point between the lowlands and uplands. The earthen bund has a width of 2 meters and a height of 1.5 meters. The length of the bund is about 6 kilometers and it is further extended on both sides with long wings. Lines of trees are planted on each shoulder of the Thamnop so that their roots can strengthen the Thamnop and make it more resistant to erosion. A spirit house is located close to the Thamnop which encourages the villagers to protect the Thamnop. In its almost 60 year history, this Thamnop has never been broken.

The paddy fields above and below the Thamnop depend on irrigation water from the Thamnop during drought periods in the rainy season. On average it provides irrigation water to about 160 hectares of paddy fields and benefits around 500 households in the village for an average irrigated area of 3,200 m² per household.

Small private weirs (called *taa Thamnop*) have been constructed on channels flowing from the upstream side of the main Thamnop in order to spread its water to a wider area. In addition, farmers have installed small concrete pipes in the bund to allow water to flow to their fields. A further benefit of the Thamnop is that its bund serves as a raised roadway used by people, livestock, hand tractors, motorcycles and cars.

In the past the farmers cultivated their paddies with buffalo, did manual rice transplanting, and grew traditional varieties such as Nang-Rong and Nang-Daeng varieties. In addition, some farmers grew vegetables for their own consumption around the bund next to the stream. Since 2002, farmers have plowed using hand tractors, employed direct seeding, and abandoned traditional varieties in favor of KDML 105 and RD 15. Only a few farmers grow vegetables. Use of pesticides to destroy the golden apple snails that have infested the paddy fields has polluted the water in the Thamnop so villagers no longer use it as a source of drinking water as they did in the past.

The abandoned Thamnop in Alue village, Samrong Thap District

This Thamnop was constructed in the lowland area in 1932. It was constructed from clayey textured soil. The bund was 1.5 meters wide and 1.5 meters high. It was about 3 kilometers long and was extended on both sides with long wings. Many small concrete pipes were inserted under the earthen bund to direct water into the paddy fields. This Thamnop always had problems, both because it frequently flooded low-lying paddy fields and because it often broke when heavy rains swelled the stream. To alleviate flooding and improve water sharing from the Thamnop, the villagers, organized by the TAO, shared their labor to construct a weir called Fai Pa-Cha-R-Sa (People Volunteer Weir) in the eastern part of the Thamnop. Then, the government Land Development Department introduced a Monkey Cheeks project (Kaem Ling) to replace this Thamnop in 2010. It was designed to reduce flooding in the lower lying land by draining the water through a system of ditches and canals (or klongs) into small reservoirs (Wikipedia, 2012). However, the paddy fields around it still were subject to flooding in the rainy season because construction of the Kaem Ling was uncompleted.

In the past, when it was still functioning, this Thamnop irrigated an average area of 84 ha and benefitted around 296 households, for an average irrigated area of 2,838 m² per household. In addition, farmers used the bund of the Thamnop for transportation by walking, animals and carts.

In the past, the farmers grew rice by transplanting; human labor use, animal plowing, and planted traditional varieties such as Nang-Rong and Nang-Daeng varieties. Other crops like kenaf and cassava were grown in upland areas and vegetables were grown in low-lying areas around the stream for both sale and home consumption. Later, farmers changed to planting eucalyptus in the uplands. Vegetable growing disappeared after the Thamnop was converted into a Monkey Cheek project in 2010. Now, farmers have changed from rice transplanting to direct seeding, use hand tractors instead of buffalo for plowing, and plant KDML 105 and RD 15 rice varieties. Because of heavy use of pesticides in the paddy fields to control golden apple snail, the stream water is no longer fit to drink.

Comparison of the context of the still-functioning and abandoned Thamnop

Some key differences in the contexts of still-functioning and abandoned Thamnop have been identified (Table 1). It can be seen that both physical factors and social factors differ among the two cases. The topographical setting at the midpoint between the uplands and lowlands of the still functioning Thamnop endows it with a much larger command area and provides benefits to many more households than is the case with the abandoned Thamnop's lowland location. Moreover, because of its favorable topographical position, it does not cause extensive flooding of low-lying paddy fields as the abandoned Thamnop used to do. The existing Thamnop has also been very durable and has never broken, in part because it is reinforced by the roots of the lines of trees planted on its shoulders and because the presence of the nearby spirit house encourages the villagers to protect it. The abandoned Thamnop, on the other hand, lacked these protections and suffered frequent breaks that required the villagers to make extensive repairs. Overall, therefore, because the still-functioning Thamnop provides major benefits and causes few problems to villagers, there was no incentive to replace it with government water management projects as occurred in the case of the abandoned Thamnop.

6. Conclusions

This preliminary case study has identified several key contextual factors that appear to be associated with retention or abandonment of Thamnop including physical as well as social factors such as topography negative effects and proper case by villagers. Further research in additional sites with existing and abandoned Thamnop is needed to verify these factors. Also, more in-depth research on the benefits and costs to individual farm households of having a Thamnop is called for. This information may throw further light on the question why Thamnop have been declining in number in the Northeast in recent years and help to identify the potential of this traditional system for use on the future.

7. Tables and Figures

Table 1 Comparison between the context of the existing and abandoned Thamnop (TN).

Category	Still-functioning Thamnop	Abandoned Thamnop
	Khok Mueang Village	Alue Village
Topographical position	Midpoint between uplands and lowlands	Lowland
Average irrigated area (ha)	160	84
Texture of soil used to construct TN	Clayey	Clayey
Tree roots protect TN	Lines of trees planted on both shoulders of TN	No trees
Government water management projects	No government projects to replace TN	The Thamnop was replaced by a weir constructed by the TAO and a Monkey Cheeks flood control system constructed by the Land Development Department.
Benefits from TN	Approximately 500 households use water for paddy fields (average area of 3,200 m ² /HH)	In the past about 296 households used water for paddy fields (average area of 2,838 m ² /HH)
Negative effects of TN	None	Frequent flooding of low-lying paddy fields
Religious beliefs supporting TN	Villagers maintain a spirit house near the TN	No spirit house near TN
Taa-TN (small private TN downstream from TN)	Several small <i>taa-Thamnop</i> downstream from main TN expand area reached by irrigation water	No downstream <i>taa-Thamnop</i>

Source: information obtained from the villagers

8. Accomplishments**8.1 Conference / seminar / workshop attendance**

Poster presentation at TRF Seminar Series in Basic Research: The Agrarian Transformation in Northeast Thailand, 15 September 2014, Faculty of Agriculture, Khon Kaen University, in the title of Indigenous Soil Classification Systems in Northeast Thailand; Preliminary Study.

8.2 Completion of an academic degree

Master's thesis was successfully defended on the 14th November 2014, and completed revision has been accepted by the Graduate School of Khon Kaen University.

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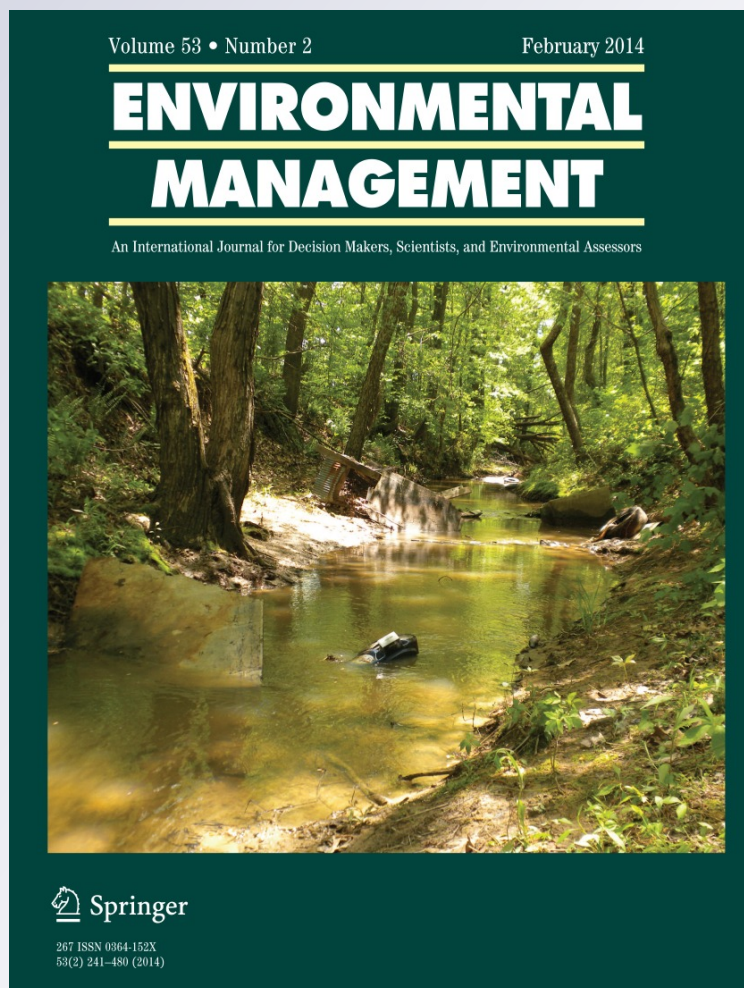
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Can't See the Forest for the Rice: Factors Influencing Spatial Variations in the Density of Trees in Paddy Fields in Northeast Thailand

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Abstract The widespread presence of trees in paddy fields is a unique feature of Northeast Thailand's agricultural landscape. A survey of spatial variability in the density of trees in paddy fields in the Northeast Region was conducted utilizing high resolution satellite images and found that the mean density in the whole region was 12.1 trees/ha (varying from a high of 44.6 trees/ha to a low of 0.8 trees/ha). In general, tree densities are higher in the southeastern part of the region and much lower in the northern central part. Tree density was influenced by multiple factors including: (1) the history of land development, with more recently developed paddy fields having higher densities, (2) topography, with fields located at higher topographical positions having a higher mean density of trees, (3) access to natural forest resources, with fields in areas located close to natural forests having higher densities, (4) amount of annual rainfall, with fields in areas with higher average annual rainfall having higher tree densities, and (5) landholding size, with fields in areas with larger-sized landholdings having more trees. However, there is a considerable extent of co-variation among these factors. Although trees remain an important element of the paddy field landscape in the Northeast, it appears that their density has been declining in recent years. If this trend continues, then the vast "invisible forest" represented by trees in paddy fields may truly disappear, with negative

consequences for the villagers' livelihoods, biodiversity conservation, and carbon sequestration in the rural ecosystem.

Keywords Agroforestry · GIS methodology · Indigenous knowledge · Landscape ecology · Anthropogenic forest

Introduction

During the twentieth century, Northeast Thailand (often referred to by its Thai name, *Isan*) was an agricultural frontier that suffered extensive deforestation, with forest coverage declining from over 90 % in the 1930s to 14 % by the end of the 1980s (Pendleton 1943; Vityakon et al. 2004). However, despite extensive conversion of forest land to agricultural uses, trees have remained a prominent part of the rural landscape, especially in the paddy fields that cover most of the lowland areas in the region. Some of these paddy field trees occupy the tops of the earthen bunds, while others are scattered around on the surface of the fields themselves. When seen from the air, the landscape resembles a wooded savannah; indeed, there are so many trees in the paddy fields that Takaya and Tomosugi (1972) aptly labeled them as "rice-producing forests." Although the trees growing in paddy fields are not officially recognized as part of Thailand's forest resources, constituting what Hecht (2004) has called an "invisible forest," they represent a very important livelihood resource for rural villagers, help to maintain regional biodiversity, and serve as an important, albeit unmeasured sink for carbon. However, unlike the anthropogenic peasant forests in frontier zones in Latin America, which have only recently developed in response to social and economic

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changes linked to globalization (Hecht 2010; Hecht and Saatchi 2007), the trees in paddy fields in Northeast Thailand represent an adaptation made by subsistence-oriented rice farmers to the specific agroecological conditions of Isan long before the region became integrated into the wider world (Pendleton 1943). Indeed, our research suggests that on-going changes in agricultural practices resulting from increased integration into the global market are associated with a continuing decline in tree density in the agricultural landscape.

Although the presence of trees in paddy fields in the Northeast has been discussed in many earlier papers (e.g., Grandstaff et al. 1986; Vityakon 2001), and a few researchers have reported on the density of these trees in limited local areas (e.g., Watcharakitti 1979; Watanabe et al. 1990; Prachaiyo 1993), no previous study has been made of regional variations in densities. Our objectives in this paper are to describe spatial variations in the density of trees in paddy fields in the whole Northeastern Region, to investigate the influence of several factors including history of land development, topography, the availability of natural forest resources, rainfall and landholding size on such spatial variation, and to briefly consider the implications of recent declines in density for the Isan rural ecosystem.

Background

While the presence of trees in paddy fields has been reported in a few other places in Asia, including Madhya Pradesh (Viswanath et al. 2000), Tamil Nadu (Jambulingam and Fernandes (1988), and Nagaland (Cairns 2007) in India, as well as in some districts in Bangladesh (Hocking and Islam 1995), it is in Northeast Thailand (as well as neighboring parts of Northern Thailand and Laos) where this unique type of agroforestry system has its widest extent. It is generally believed that the Isan farmers retain the trees in their paddy fields as an adaptation to the sandy infertile soils that characterize the Northeastern Region (Pendleton 1943). The leaf litter from the trees has been found to increase the amount of soil organic matter in the paddy fields and provide needed nutrients to the rice plants (Vityakon 1993; Vityakon et al. 1993). In addition, the trees also provide many valuable resources, such as timber, food, medicine, fuelwood, and livestock feed, that make an important contribution to rural livelihoods (Grandstaff et al. 1986; Vityakon 2001).

Spatial Variation in Density of Trees in Paddy Fields

Although trees are found growing in paddy fields everywhere in the Northeastern Region, there are very noticeable

differences in their density from area to area. However, only a few limited surveys have been made of the density of trees in paddy fields in a few local areas in the region. Watcharakitti (1979) reported the average density of trees in paddy fields in the Nam Pong River basin in Khon Kaen province was 51 trees/ha, with a maximum density of 150 trees/ha, compared to 468 trees/ha in an undisturbed Dry Dipterocarp Forest. A survey in four sites in Khon Kaen province by Watanabe et al. (1990) showed that the density of trees varied greatly from site to site ranging from 30 to 149 trees/ha. Prachaiyo (1993) found that the density of trees in the paddy fields in 16 villages located in the Phu Wiang District, Khon Kaen Province, varied between 0 and 13 trees/ha. Prachaiyo (2000) subsequently surveyed a total of 31 plots in 12 provinces in the Northeast and found that the density of trees in paddy fields ranged from 4 to 24 trees/ha with an average density of 15 trees/ha. Thus, although past surveys have reported widely varying densities of trees in paddy fields in different parts of Northeast Thailand (ranging from 0 to 150 trees/ha), it is difficult to make any general conclusions about the region as a whole, because of the different locations where studies were conducted, the quite differing conditions of the study plots, and, especially, differences in the times when they were done. It is well known that the density of trees generally declines over time (Grandstaff et al. 1986) so that it can be expected that surveys done at earlier dates will have found higher densities than are to be expected at present. In addition, the geographical coverage of these surveys is very limited so that it is impossible to draw conclusions about variation in the density of trees in paddy fields in different parts of the Northeastern Region.

Factors Influencing Spatial Variations in the Density of Trees in Paddy Fields

Systematic analyses of the reasons for spatial variations in tree densities among different localities within the region are also lacking, although previous studies have identified a number of probable factors including: (1) history of land development, (2) topography, (3) the availability of natural forest resources, (4) rainfall, and (5) landholding size.

- (1) *The history of land development:* Newly cleared paddy fields tend to have higher tree densities than long established fields (Grandstaff et al. 1986; Vityakon 1993, 2001). These differences in density may reflect both differences in the length of time that trees in the two types of fields have been exploited and differences in the growing conditions for trees in the older and newer fields. In older fields, the farmers have had a longer period of time to cut down trees for their own use, while some of the remnant forest trees

may have died because of the poor growing conditions in lower paddies and also have suffered natural mortality due to senescence (Vityakon 1993).

- (2) *Topography*: The Northeastern landscape is characterized by gently undulating terrain that is divided into many small mini-watersheds (KKU-Ford 1982). Within each of these units the lowest-lying parts in the valley bottom are used for lower paddy fields while the lower slopes are devoted to upper paddy fields. The highest slopes are covered with dryland cash crop fields and remnant patches of forest (Grandstaff et al. 1986). It has been observed that tree density is higher in the upper paddy fields than in the lower paddy fields. This may be because the lower paddy fields are cultivated more intensively than the upper paddies, which can damage the roots of surviving forest trees, and are also more frequently flooded so that waterlogging of their roots ultimately causes the death of any forest trees that have not already been cut down by the farmers to obtain timber and firewood (Vityakon 1993).
- (3) *The availability of natural forest resources*: There are two competing hypotheses about the relationship between the availability of natural forest resources and the density of trees in fields. Vityakon et al. (1996) reported that villages which have easy access to nearby forests retained more trees in paddy fields than villages located farther away from forests. This is presumably because the villagers can easily collect timber and firewood from the forest, so do not need to exploit the trees in their paddy fields as heavily as they would if the forest was less accessible to them. However, Kosaka et al. (2006) reported the opposite finding from Central Laos where tree density was much higher in a village without a nearby forest than in a village with an easily accessible adjacent forest, presumably because the villagers with access to abundant forest resources felt no need to conserve trees in their own fields.
- (4) *Rainfall*: Rice yields in the rainfed paddy fields of Northeastern Thailand are wholly dependent on the amount and timing of rainfall. The amount of rainfall tends to be higher in the provinces along the Mekong River and lower in the southwestern parts of the region (KKU-Ford 1982). There is also considerable variability in the amount and timing of rainfall from year to year and place to place with droughts occurring more often in some parts of the region than others. It has been suggested that trees in paddy fields may represent an adaptation by the farmers to drought risk. Although trees usually depress the yield of rice plants growing under their canopies due to the impact of shading (Vityakon et al. 1993) and the

competition for water and nutrients between the roots of the rice plants and the trees, some farmers also claim that in dry years rice yields close to trees were higher than that in other parts of their paddy fields (Vityakon 1993).

- (5) *Landholding size*: Vityakon et al. (1996) reported that the size of individual farms was associated with the density of trees. Larger farms usually had more trees/ha than smaller ones. It has been suggested that farmers with only a small area of paddy fields cannot afford the loss in rice yields in the area immediately around the trees that is caused by shading (Vityakon et al. 1993) and root competition. Farmers with larger landholdings can afford to lose some rice production from fields with a lot of trees because they can compensate for this loss with production from other fields that are more open (Vityakon 2001).

Methodology

This study was designed (1) to measure differences in the density of trees in paddy fields in the whole Northeastern Region and (2) to test several hypotheses about factors influencing variations in density. Satellite images and GIS data from several different sources were used in conducting this analysis as summarized in Table 1.

Measuring Spatial Variations in Density of Trees in Paddy Fields in Different Parts of the Region

Northeast Thailand covers an area of 168,854 square kilometers (Fig. 1). We surveyed the density of trees in various parts of the region using IKONOS satellite images available through Point Asia. Point Asia contains a collection of high resolution satellite imagery (IKONOS). IKONOS collects black and white (panchromatic) images with 0.82 m resolution and multispectral imagery with 4 m resolution. Imagery from the panchromatic and multispectral sensors can be merged to create 0.82 m color imagery (pan-sharpened) (Geo-Eye website 2012). It is well known that one can recognize and identify individual tree crowns (i.e., all of the above-ground parts, including lateral stems, leaves and reproductive structures that extend from the plant's trunk or main stem) in IKONOS satellite images (Gougeon and Leckie 2006; Kubo and Muramoto 2008; Grish Kumar and Padmaja 2012). The resolution is sufficiently high to allow the identification of the boundaries of paddy fields and the location of trees within these fields using the naked eye. At the time the study was undertaken, Point Asia included high resolution coverage of most of Thailand, whereas Google Earth only covered

Table 1 Data sources used in this study

Factor	Grouping	Source	Years
Density of trees in paddy fields	–	Point Asia IKONOS images	2003–2007
History of land development	1: Newer paddy field group 2: Older paddy field group	A set of US Army Map Service maps, 'INDOCHINA and THAILAND 1:250,000 Series L509' compiled between 1954 and 1962 based on 1:50,000 maps showing land uses such as woodland and rice paddies compiled by the Thai Royal Survey Department before the 1950s	Before 1950
Topographic position	1: Flood plain and low terrace 2: Middle terrace 3: High terrace and hill	GIS data from the Land Development Department of Thailand	Unknown
The availability of natural forest resources	1: Forest group 2: Non-forest group	GIS data from the Royal Forest Department of Thailand based on Landsat 5 images of year 2000	2000
Rainfall	1: <1,200 mm 2: 1,201–1,400 mm 3: 1,401–1,600 mm 4: >1,601 mm	GIS data from the Ministry of Transportation of Thailand	1981–2001
Landholding size	1: Smaller-sized landholding group 2: Larger-sized landholding group	Basic village-level information database of the Community Development Department, Thailand	2005

about 20 % of the country (Udompitissap and Duangvichitkun 2006). A limitation of Point Asia images is that they are not date stamped making it difficult to know the exact year and season when the images were taken but, according to Point Asia Dot Com Co., Ltd., all of the images were taken in 2003–2007. The images employed in this study were accessed from Point Asia (<http://www.pointasia.com>) between 1 April and 31 August 2011.

The survey was conducted in the following steps:

Sampling

A grid composed of 1×1 km cells was overlaid on an image of Northeast Thailand for the area from $14^{\circ}00'N$ – $100^{\circ}50'E$ to $18^{\circ}30'N$ – $105^{\circ}40'E$. This grid covers all of Northeast Thailand with a total of 176,669 grid cells (there are 501 cells on the north–south axis and 521 cells on the east–west axis). Initially, 350 of these grid cells were randomly selected but, after checking the Point Asia images, 147 cells had to be excluded from the survey because they were found to be unsuitable for analysis. Of these, 88 grid cells had no satellite images or the images could not be utilized because of too much cloud cover (25.1 % of the initial sample of grid cells); 59 grid cells (16.9 % of the initial sample) had satellite images but contained either no paddy fields or such a small area of paddy fields as to be unusable. The images for the 203 remaining grid

**Fig. 1** Location of Northeast Thailand

Fig. 2 Location of the 203 grid cells included in this survey

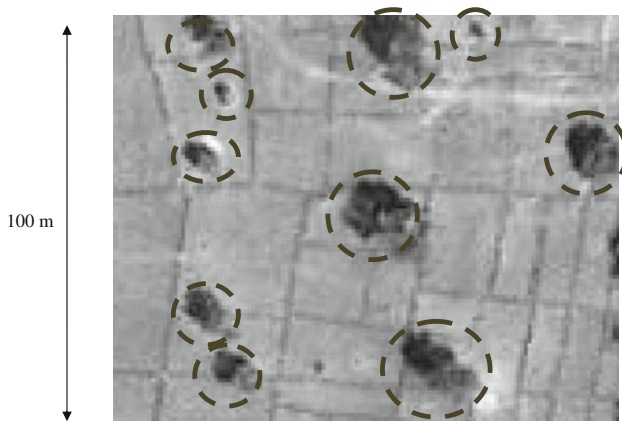
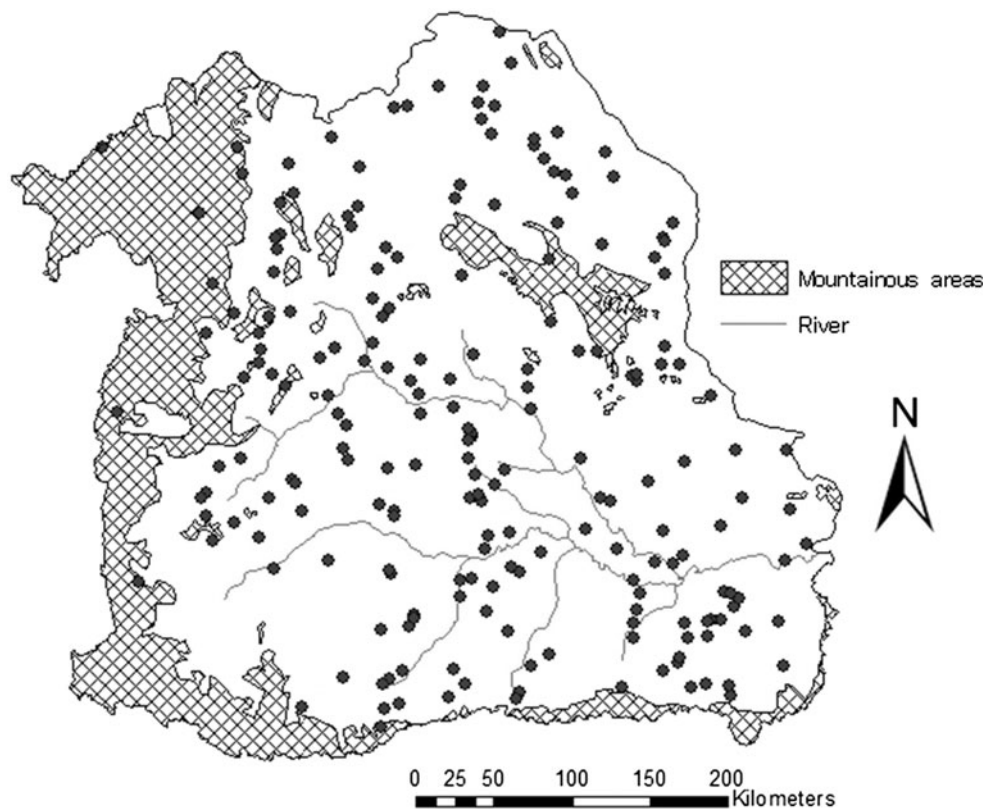


Fig. 3 Example of counting of trees in paddy fields (Dashed circles indicate individual trees)

cells (0.1 % of the total number of grid cells) were analyzed in this survey (Fig. 2).

Identifying Paddy Fields in the Grid Cells

Within each of the sample grid cells (1×1 km), the boundaries of paddy fields were identified by the naked eye of the analyst and the area of the paddy fields was calculated using Arc View version 9.1 (ESRI) geographical information software.

Calculating the Density of Trees in Paddy Fields

All of the tree canopies inside the boundaries of the paddy fields within each grid cell were counted using the naked eye of the analyst. In those cases, when there were several trees forming a single cluster, and it was not possible to count each tree individually due to insufficient resolution, the whole cluster was counted as one tree. In many cases, these clusters are clumps of bamboo while, in other cases, they are composed of several small trees growing closely together on top of a termite mound, so are functionally equivalent to a single tree. An example of counting trees in paddy fields is shown in Fig. 3. Once the total number of trees in all of the paddy fields within a grid cell was established, then the density of trees was calculated with the following formula using Arc View:

$$\begin{aligned} \text{The mean density of trees in paddy fields (number/ha)} \\ = \text{total number of trees in paddy fields/area} \\ \text{of paddy fields (ha).} \end{aligned}$$

Based on the calculated mean density of trees in paddy fields in the selected grid cells, a map of the mean density zones of trees in paddy fields was made by using the kriging method.

Testing Hypotheses About Factors Influencing Variation in Density of Trees in Different Localities

Five hypotheses about factors influencing spatial variability in tree densities were formulated based on publications of earlier research and subject to testing. In all cases, a difference of $|p| < 0.05$ was considered significant.

Hypothesis 1 More recently developed paddy fields have higher density than older fields.

In order to examine if the density of trees in paddy fields is related to the history of land development, a set of maps showing land use, “INDOCHINA and Thailand 1:250,000 Series L509,” was obtained from the University of Texas Libraries’ website (<http://www.lib.utexas.edu/maps/ams/indochinaandthailand>) on 1 April, 2011. These 1:250,000 scale maps were compiled by US Army Map Service based on 1:50,000 maps showing land uses such as woodland and rice paddies that had been compiled by the Thai Royal Survey Department before the 1950s (Table 1). Eighteen sheets covering Northeast Thailand were utilized in this survey of which five sheets were compiled in 1954, three in 1955, nine in 1958, and one in 1962. Because we cannot assign precise dates to the land use data, we can only be certain that it represents land use sometime before the 1950s. Using GIS, the map of tree densities compiled from the IKONOS images was overlaid on these maps of past land use. Based on the land use categories displayed on the maps, grid cells were classified into the newer paddy field group, for which all cell areas were categorized as woodland (69 grid cells), and the older paddy field group, for which parts of cell areas were categorized as rice paddy (116 grid cells). Eighteen grid cells including non-classified land were excluded from the analysis. Any paddy fields now found in cells in the newer paddy field group would have been developed after the maps were made so can be considered as new fields. Since cells in the older paddy field group already contained paddy fields by the early 1950s, any fields we found inside these cells can be considered as old paddies. The statistical significance of differences among the groups was tested with the two-sided Mann–Whitney U test.

Hypothesis 2 Paddy fields located at higher topographic positions have higher tree densities than lower-lying fields.

In order to examine if the density of trees in paddy fields is related to topographical position, GIS data on the spatial distribution of all of the soil series in the region was obtained from the Land Development Department of Thailand (Table 1). Because each soil series in Northeast Thailand only occurs in a specific physiographic position it is possible to assign a topographic position to each paddy field based on its particular soil series. Because the number

Table 2 Soil series and their associated physiographic positions in Northeast Thailand

Physiographic position	Soil series
Flood plain	Chiang Mai (Cm), Sanphaya (Sa), Chaiphaphum (Cy), Phimai (Pm), Ratchaburi (Rb), Si Songkhram (Ss), Si Thon (St)
Low terrace	Chiang Rai (Cr), Kula Ronghai (Ki), Lom Kao (LK), Nakhon Phanom (Nn), On (On), Phen (Pn), Reun (Rt), Roi-Et (Re), Tha Tum (Tt), Tha Uthen (Tu), Ubon (Ub)
Middle terrace	Korat (Kt), Nam Phong (Ng), Phon Phisai (Pp), Sakon (Sk), Satuk (Suk), Sakhu (Sk), Warin (Wn)
High terrace/hill	Yasothon (Yt), Borubau (Bb), Buriram (Br), Chaturat (Ct), Khao Yai (Ky), Loei (Lo), Lop Buri (Lb), Tha Li (Tl), Tha Yang (Ty)

Source Keerati-Kasikorn (1984), table on pp. 181–204

of soil series was too large to permit examination of the relationship of each individual series with the density of trees in paddy fields, they were grouped together into soil series associated with three land form categories: (1) flood plains and low terraces, (2) middle terraces, and (3) high terraces and hills. Each type of land form is associated with certain specific soil series (Table 2). In doing this analysis, the various soil series occurring in each grid cell were identified in order to determine the landforms occurring within the cell. In those cases, where sample grid cells included two or more different physiographic units, the cell was assigned to the dominant land form within it. We found that 66 cells contained only one type of topography (32.5 %), 85 cells (41.9 %) contained more than one type of topography but with more than 70 % of the area occupied by the representative topography, and only 52 cells (25.6 %) contained more than one type of topography with <70 % of the area occupied by the representative topography. The 203 grid cells were categorized into 73 cells of flood plain and low terraces, 101 cells of middle terraces, and 15 cells of high terraces and hills. Fourteen grid cells were excluded from the analysis because they could not be assigned to any land form category. The statistical significance of differences in tree density among different landforms was tested with the Kruskal–Wallis test.

Hypothesis 3 Paddy fields in areas with nearby forests have higher densities than fields in areas without easy access to forests.

In order to examine if the density of trees in paddy fields is related to the availability of natural forest resources, GIS data of land use and forest cover in 2000 were obtained on 1 August, 2011 from an online website (<http://www.rsgis.ait.ac.th/souris/thailand.htm#THAIDEM300>). The map,

which is for the most recent year for which data are available, was originally drawn by the Royal Forest Department based on Landsat 5 remote sensing images of Thailand (Table 1). Based on the GIS map, all of the sample grid cells were categorized into a forest group, which in 2000 had some area of forest within each cell (54 grid cells), and a non-forest group, which had no forest area within each cells (149 grid cells). Natural forest resources can be assumed to be easily available to villagers in the forest group because of their proximity to the forest. On the other hand, it would be more difficult for villagers in the non-forest group to gain access to forest resources because of the greater distances involved. The statistical significance of density differences between the groups was tested with the two-sided Mann–Whitney *U* test.

Hypothesis 4 Paddy fields in areas with lower mean annual rainfall have higher densities than fields in higher rainfall areas.

In order to examine if the density of trees in paddy fields is related to annual rainfall, GIS data of rainfall collected by the Ministry of Transportation of Thailand were obtained from a website (<http://www.rsgis.ait.ac.th/Thailand.htm>) on 1 August, 2011 (Table 1). Monthly rainfall from 1981 to 2001 was compiled only for the 244 stations located in the Northeastern Region that have complete rainfall data for more than 10 years with no missing monthly data. Mean annual rainfall was calculated for each selected station. Isohyets for mean annual rainfall were drawn using the Inverse Distance Weighting interpolation (IDW) method. The mean annual rainfall of each of the sample grid cells was assigned based on its location on the isohyets map and the grid cells were categorized into four groups based on the total amount of annual rainfall: (1) 1,200 mm or less (71 grid cells), (2) 1,201–1,400 mm (57 grid cells), (3) 1,401–1,600 mm (48 grid cells), and (4) more than 1,600 mm (27 grid cells). The statistical significance of differences among different rainfall groups was tested with the Kruskal–Wallis test.

Hypothesis 5 Tree densities in paddy fields are higher in areas with larger-sized landholdings than in areas with smaller-sized landholdings.

In order to examine if the density of trees in paddy fields is related to size of landholdings, the basic village-level information database of the Community Development Department (Table 1) was utilized. Mean agricultural land holding size in the sub-district (*tambol*) level was calculated from the database. Based on the mean agricultural landholding size of the largest share of the area within the cell, all of the sample grid cells were categorized into a smaller-sized landholding group with an area of 2.0 ha or less (62 grid cells), with a mean area of 1.5 ha, and a

Table 3 Range of variation in the density of trees in paddy fields in Northeast Thailand

Density of trees in paddy fields (per hectare)	Number of grid cells	%
0.0–5.0	29	13.3
5.1–10.0	54	26.6
10.1–15.0	56	27.6
15.1–20.0	33	16.8
≥20.1	31	15.8
Total	203	100.0

larger-sized landholding group with an area of 2.1 ha or more (136 grid cells), with a mean area of 3.2 ha. Five grid cells were excluded from this analysis because of lack of data. The majority of the cells (70 %) contain an area with only a single mean landholding size or have more than 70 % of their area in the same size category (22 %), while only 8 % of the cells have <70 % of their area in the same size category. The statistical significance of density differences between the larger-sized land holding group and the smaller-sized landholding group was tested with the two-sided Mann–Whitney *U* test.

Results and Discussion

Spatial Variations in the Density of Trees in Paddy Fields in the Northeastern Region

Although the paddy fields in almost all of the grid cells in the sample contained at least some trees, there are major variations in the density of trees per hectare in paddy fields among the sample grid cells with a range from 0.8 to 44.6 trees/ha (Table 3). The bottom quartile (25 %) has 6.6 trees/ha, the median (50 %) is 11.6 trees/ha, and the top quartile (75 %) has 16.7 trees/ha. The density of trees found in this survey is considerably lower than was reported in earlier surveys (Watcharakitti 1979; Watanabe et al. 1990; Prachaiyo 1993, 2000). Although this difference may be partly accounted for by use of different methods in our survey and earlier studies (e.g., the total number of trees in our survey may be somewhat undercounted because clumps or clusters that may include several trees were counted as single trees), the differences are so great as to suggest that there has been a real decline in tree densities over time. The fact that a recent survey in two villages in nearby central Laos found densities similar to ours, with an average just under 20 trees/ha in a newly established village with an abundance of adjacent forest and 15 trees/ha in an old village without any adjacent forest (Kosaka et al. 2006) offers support for this conclusion.

Fig. 4 Spatial distribution of density of trees in paddy fields in all sample grid cells

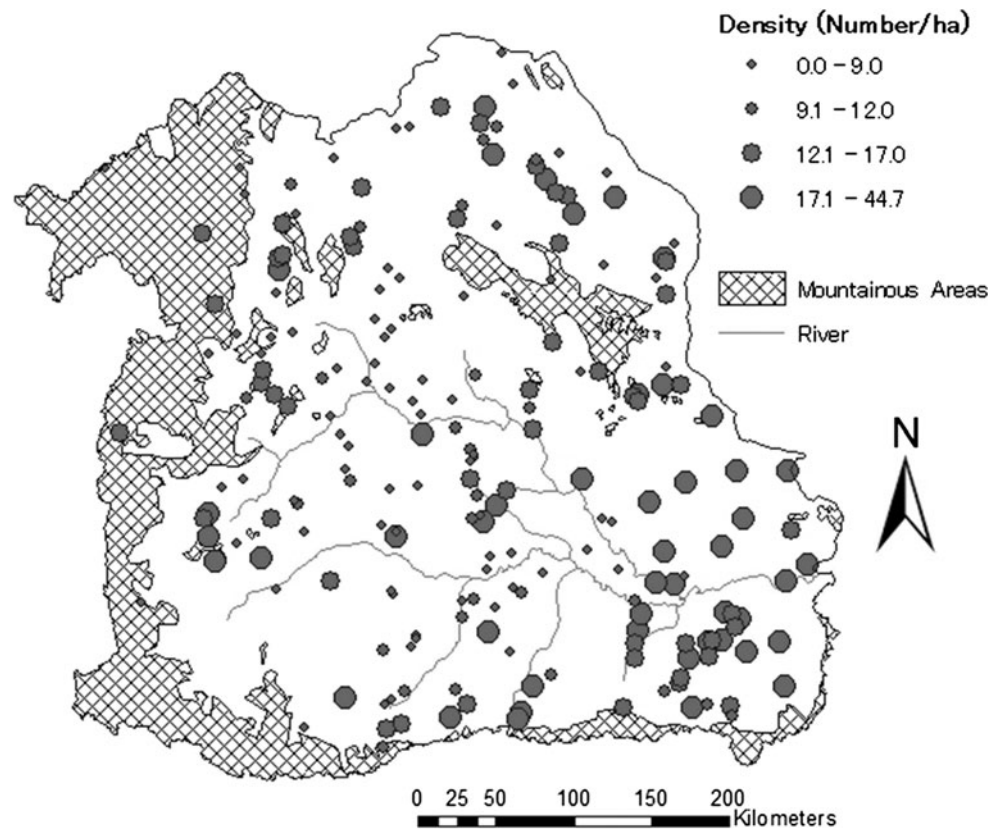


Fig. 5 Map of zones of mean density of trees in paddy fields in Northeast Thailand

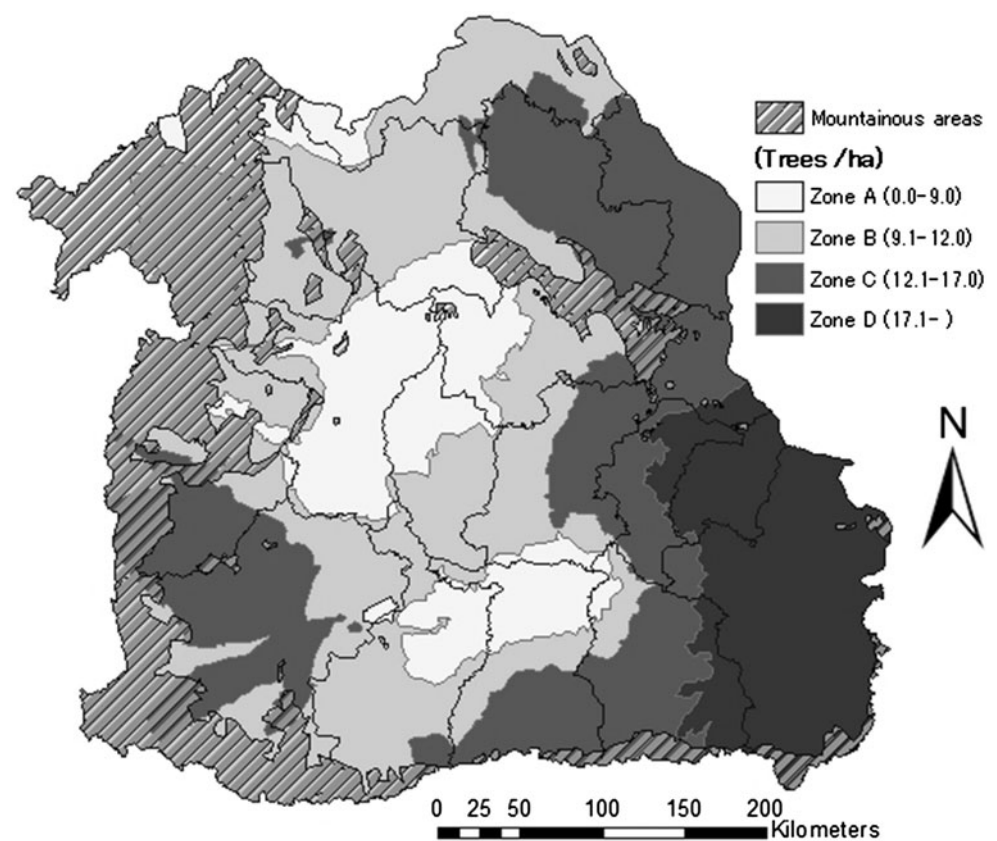


Table 4 Variations in the density of trees in paddy fields in relations to hypothesized factors

Factor	Group	Number of grid cells	Density of trees (number per hectare)				Result of Statistical test
			Mean	Bottom quartile (25 %)	Median (50 %)	Top quartile (75%)	
History of land development ($n = 185$)	Newer paddy field group (in areas wholly categorized as 'wood land' before ca 1950)	69	15.9	11.5	13.7	19.4	Significant with two-sided Mann–Whitney U test ($lpl \leq 0.01$)
	Older paddy field group (in areas all or partly categorized as 'rice paddy' before ca 1950)	116	10.7	5.6	9.0	14.9	
Topography ($n = 189$)	Flood plain and low terrace	73	9.4	5.1	7.6	12.3	Significant with Kruskal–Wallis t test ($lpl \leq 0.01$)
	Middle terrace	101	14.0	8.0	12.8	18.8	
	High terrace and hill	15	17.3	12.2	14.9	25.0	
Availability of natural forest resources ($n = 203$)	Forest group (grid cells that include forest in 2000)	54	14.3	10.4	13.1	18.9	Significant with two-sided Mann–Whitney U test ($lpl \leq 0.01$)
	Non-forest group (grid cells that do not include forest in 2000)	149	11.9	6.0	10.4	16.0	
Rainfall ($n = 203$)	<1,200	71	9.9	5.3	7.8	13.9	Significant with Kruskal–Wallis t test ($lpl \leq 0.01$)
	1,201–1,400	57	11.1	6.0	10.4	14.8	
	1,401–1,600	48	16.0	10.7	15.0	20.5	
	>1,601	27	16.1	8.9	15.3	22.7	
Landholding size ($n = 198$)	Smaller-sized landholding group (mean landholding size = <2.0 ha)	62	10.9	5.9	10.4	14.7	Significant with the two-sided Mann–Whitney U test ($lpl \leq 0.05$)
	Larger-sized landholding group (mean landholding size ≥ 2.1 ha)	136	13.1	6.8	12.2	18.3	

The spatial distribution of density of trees in paddy fields in all the sample grid cells in Northeast Thailand is shown in Fig. 4. It is evident that there are large variations in tree densities among different areas within the region. Figure 5 is a map showing the zones with different mean densities of trees in paddy fields in the region. It can be seen that the southeastern part of the region tends to have higher densities of trees, while the northern central part has much lower densities. In particular, most of the area in Amnat Charoen and Ubon Ratchathani provinces belongs to the very high density zone (more than 17.1 trees/h) whereas most of the area in Khon Kaen province belongs to the very low density zone (<9.0 trees/ha).

Factors Influencing the Density of Trees in Paddy Fields

A number of factors that may influence the density of trees in paddy fields, including (1) history of land development, (2) topographical position, (3) the availability of natural forest resources, (4) rainfall, and (5) landholding size, were discussed in the introduction to this paper and the methods to test each of these hypotheses were described in the “[Methodology](#)” section. Each of these hypothesized factors influencing density variations will next be examined in turn:

History of Land Development

A clear association between the length of time that has passed since the initial construction of paddy fields and the density of trees remaining in the fields was found (Table 4). The mean density of trees in paddy fields of the newer paddy field group (15.9 trees/ha) is higher than that of older paddy field group (10.7 trees/ha). The difference is highly significant ($lpl \leq 0.01$) according to the Mann–Whitney U test so the result clearly supports the hypothesis that density is influenced by the history of land development in each area. This finding is in accord with the observations about the relationship between time of land clearance and density of trees in paddy fields made by earlier researchers including Grandstaff et al. (1986), Viyakon (1993, 2001), and Prachaiyo (2000).

Topographical Position

It was found that paddy fields located at higher topographical positions (middle terraces, high terraces, and hills) in the landscape have a higher mean density of trees (14 and 17.3 trees/ha, respectively) than those located at lower positions (flood plain and low terraces) (9.4 trees/ha)

(Table 4). The differences are highly significant ($p \leq 0.01$). This result supports the hypothesis and is in keeping with the findings of previous studies (Grandstaff et al. 1986; Vityakon 1993, 2001; Prachaiyo 2000).

Availability of Natural Forest Resources

It was found that the mean density of trees in paddy fields is higher (14.3 trees/ha) in areas located close to natural forests than in areas located far from forests (11.9 trees/ha) (Table 4). The difference is highly significant ($p \leq 0.01$) according to the Mann–Whitney U test. This difference may, at least in part, reflect the fact that villagers living close to a forest can easily collect timber and firewood there so have less need to exploit the trees in their paddy fields, as was suggested by Vityakon et al. (1996). However, the contrary observations by Kosaka et al. (2006) that tree density in paddy fields in Laos was much higher in a village without a nearby forest than it was in a village with an adjacent forest suggest that other factors in addition to mere physical proximity may be at work in specific cases. In particular, the character of the forest management regime and rules regulating exploitation of forest resources might be expected to affect the extent to which villagers are able to rely on forest trees as substitutes for their own on-farm trees. For example, a detailed study in Bolivia found that a strong package of common property forest management practices provided the strongest incentives for on-farm tree planting (Bluffstone et al. 2008). If laws protecting natural forests are only weakly enforced, as tends to be the case in Northeastern Thailand, then villagers with ready access to them are likely to exploit these common property resources instead of cutting the trees on their own land. On the other hand, in areas with more effective forest protection systems, villagers will be forced to rely more heavily on the trees growing on their own land. This can lead either to a decrease in tree density if farmers over-exploit their tree resources or to an increase in tree density if they begin to plant more trees in their paddy fields to provide needed resources that they can no longer obtain from natural forests.

Rainfall

There is a general descending trend in the total annual amount of rainfall from the northeastern part of the region along the Mekong River, with more than 2,000 mm/year, to the southwestern part of the region, with <1,000 mm/year, but in the southeastern part the annual rainfall is also high (Fig. 6). The general spatial pattern is similar to that described in previous surveys (KKU-Ford 1982; Nawata et al. 2005).

It was found that the density of trees was higher in areas with higher average annual rainfall than it was in areas with lower rainfall and that mean densities increased progressively

as the amount of rainfall increased (Table 4). The differences among the groups are highly significant ($p \leq 0.01$) according to the Kruskal–Wallis test. The finding that higher annual rainfall areas have more trees in paddy fields is clearly contrary to the hypothesis that trees represent a farmer adaptation to drought risk (Vityakon 1993). Of course it is also possible that the density of trees in the natural forest in areas with more rainfall was higher than in the forest in drier areas, so that more trees were left standing when farmers first cleared paddy fields in these areas. Unfortunately, however, systematic information on the tree density of natural forest in different parts of the Northeast is unavailable so we cannot verify this supposition. However, our finding is in accord with a recent global survey of tree cover on agricultural land that found a strong positive association between higher precipitation and the extent of tree cover (Zomer et al. 2009).

Landholding Size

It was found that areas with larger-sized landholdings have more trees/ha (13.1 trees/ha) than areas with smaller-size ones (10.9 trees/ha) (Table 4), which is a significant difference ($p \leq 0.05$) according to Mann–Whitney U test. Although the association between landholding size and tree density is relatively weak, the mean number of trees/ha is modestly higher in cells having large-sized landholdings and somewhat lower in cells with small-sized holdings (Table 4). It was also found that only one-third of all cells with small-sized holdings have high mean tree densities, whereas one-half of cells with large-sized holdings have high densities (Table 5). This finding is in keeping with an earlier study in Northeast Thailand by Vityakon et al. (1996) which found that tree densities were higher on larger-sized farms. This appears to be a common pattern in agroforestry systems on a global basis. Thus, a meta-analysis of 32 empirical studies of factors influencing adoption of agroforestry in the tropics, found that almost twice as many studies reported a positive association between plot size and tree planting than reported a negative association (Pattanayak et al. 2003). The positive association between farm size and tree planting may reflect the fact that farmers with larger plots simply have more space available for trees and may also have a greater capability to absorb the risks associated with growing trees (Sood and Mitchell 2009). However, in central India it was found that smaller farms had much higher tree densities in paddy fields than larger farms, reflecting the fact that a great deal of labor was required to prune the canopies and roots of the *Acacia nilotica* trees, making it difficult for farmers with larger farms to maintain high densities (Viswanath et al. 2000). In Northeast Thailand, however, farmers expend little time or effort in managing trees in their paddies.

Fig. 6 Isohyets for mean annual rainfall in Northeast Thailand

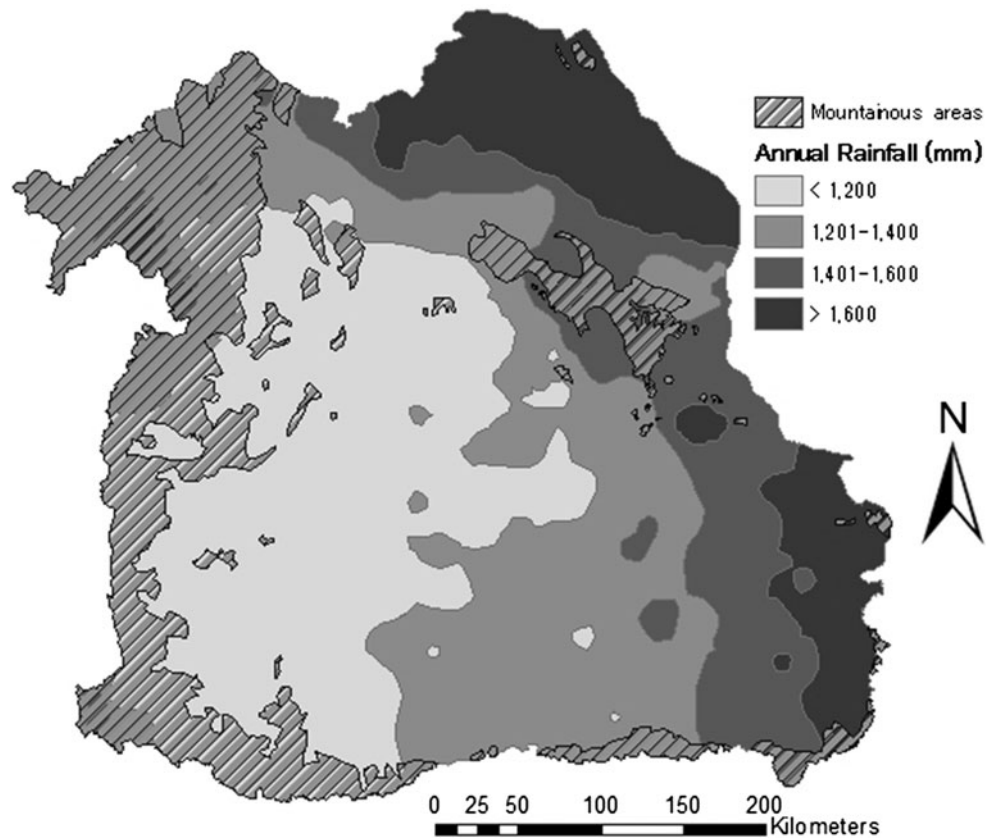


Table 5 Co-variation among hypothesized factors determining variations in the density of trees in paddy fields showing number of grid cells and percentage (%) of total number of cells for each factor

Mean density of trees	Age of paddy fields (<i>n</i> = 185)		Topography (<i>n</i> = 189)			Forest access (<i>n</i> = 203)		Rainfall (<i>n</i> = 203)		Landholding size (<i>n</i> = 198)	
	Newer	Older	Flood plain/low terrace	Middle terrace	High terrace	Forest	No forest	Low (1,400 mm or less)	High (>1,400 mm)	Small (2 ha or less)	Large (>2 ha)
Low (0–12)	26 (25.2)	77 (74.8)	49 (46.7)	50 (47.6)	6 (5.7)	18 (16.1)	94 (83.9)	102 (91.1)	10 (8.9)	41 (37.6)	68 (62.4)
High (>12)	43 (52.4)	39 (47.6)	24 (28.6)	51 (60.7)	9 (10.7)	36 (39.6)	55 (60.4)	26 (28.6)	65 (71.4)	21 (23.6)	68 (76.4)
Total	69	116	73	101	15	54	149	128	75	62	136

Co-variation Among Factors Influencing the Density of Trees in Paddy Fields

As Table 5 shows, paddy fields with lower tree densities tend to occur in areas with older paddy fields, flood plain or lower terrace topographical positions, no natural forest, low rainfall, and, to some extent, smaller-sized landholdings, whereas paddy fields with higher tree densities are more likely to be found in areas with newer paddy fields, middle or high terrace topographical positions, forest, high rainfall, and larger-sized landholdings. The association

between lower tree densities and older paddy fields, no forest, and low rainfall is quite strong with more than 70 % of low density cells falling in these categories. The association of higher densities with high rainfall and large landholding size is also quite strong with more than 70 % of high density cells belonging to these categories.

It is likely that a number of the factors influencing tree density may co-vary in ways that confound their effects, making it difficult to determine how strong an influence each factor exerts independently. For example, it is difficult to separate the effects of topographical position on tree

density from the effects of the history of land development. That is because upper paddy fields, which tend to have more trees than lower fields, not only offer more favorable conditions for tree survival but also were usually cleared much more recently than the lower paddy fields, whereas older fields are usually located in the lowest elevation land in the mini-watersheds, which have the most favorable soil and moisture conditions for rice growing but are an unfavorable habitat for trees (Prachaiyo 2000). Because the pioneering farmers preferred to first clear the forest from lower-lying fields, and only later expanded rice cultivation onto less desirable higher areas (Takaya and Tomosugi 1972; Vityakon 1993, 2001), the older lower paddies have been cultivated for a longer period of time than the newly reclaimed upper paddy fields and also provide a less favorable habitat for forest trees.

In order to determine the relative importance of the history of land development and topographical position we compared the density of trees in all of the cells with older paddy fields with that of more recently developed cells occupying a lower lying topographical position within the landscape. Out of 73 cells assigned to the flood plain/low terrace landform groups, 56 were categorized as older paddy fields and only five were categorized as newer paddy fields (12 cells could not be assigned to either category). The mean density of the 56 older paddy field grid cells was 9.4 trees/ha and that of five newer paddy field grid cells was 15.9 trees/ha. Although the difference in density is not statistically significant ($|p| \leq 0.1$) because of the small sample size of newer paddy fields, the fact that newly cleared fields have higher tree densities than older fields within the same land form suggests that the history of land development may be a more important factor than topographical position in determining tree density. However, the retention of more trees in higher level fields than in lower level fields may also be a reflection of their relative benefits and costs to the farmers. The upper paddies generally have much lower rice yields than the lower paddies because their soils are less fertile and have lower clay content, less organic matter, and poorer water retention capabilities (Craig 1988). The farmers are well aware that addition of tree litter can help improve infertile soil (Pendleton 1943), so may recognize that retaining trees in the upper paddies is more essential than it is in the case of the better endowed lower paddies. It is also the case that the upper paddies have much less stable yields than the lower paddies, indeed fail to produce a harvest at all in 2 out of 3 years (Rigg 1985). Keeping trees in the upper paddy fields may to some extent help to stabilize fluctuations in rice yields because, in years with abundant rainfall, yields will be relatively high, despite the lower productivity of the shaded rice plants growing close to the trees, whereas in drought years, when the unshaded rice plants perform poorly, the rice plants growing in the shade of the trees will still have some yield (Craig 1988; Vityakon 1993). Moreover, since, in any

case, the upper level paddy fields are much less productive than the lower ones, it is possible that the value of the goods and services that the trees provide to the farmers may to some extent offset whatever reduction they may cause in rice yields.

Availability of natural forest resources also tends to co-vary together with history of land development and topographical position. Old paddies (48.2 % of all the cells containing old paddy fields in our sample) are usually located in flat bottoms or lower terraces in villages which are also located far from natural forests. On the other hand, newly developed paddies are usually located on middle or high terraces (88.4 % of all the cells containing new paddy fields in our sample) in villages that are located closer to the mountainous areas where most of remaining natural forests in Northeast Thailand are found. Consequently, differences in the availability of natural forest resources may to a considerable degree simply be a reflection of differences in topographical position rather than being an important determinant of variations in tree density in its own right.

Summary and Conclusions

Although the mean density of trees in paddy fields in Northeast Thailand is 12.1 trees/ha, there are very pronounced spatial variations in densities in different parts of the region. In general, the upper central part of the region has the lowest tree densities while southeastern part has the highest densities.

Several factors, including differences in the history of land development, topography, the availability of natural forest resources, annual rainfall, and land holding size have been shown to be associated with variations in the density of trees in paddy fields in the Northeastern Region. However, there is considerable co-variation among these factors, especially the history of land development, topography, and the availability of natural forest resources, making it difficult to determine their relative importance. Higher paddies generally have higher densities because they were cleared more recently than lower-lying fields and also because they are likely to be located closer to natural forests, which the farmers prefer to exploit in place of cutting trees in their own fields. At the same time, the benefits to the farmers of keeping trees in upper paddies are greater, and the costs lower, than is the case in lower paddies.

Finally, although historical data on the density of trees in paddy fields in earlier periods are very sparse, it appears that the density of trees in paddy fields has been gradually declining over the past 50 years. For example, Khon Kaen Province, which now has the lowest mean tree density (6.8 trees/ha) of any province in the Northeast, reportedly had considerably higher densities (30–150 trees/ha) in the 1970s and 1980s (Watcharakitti 1979; Watanabe et al. 1990).

Vityakon (2001) has concluded, based on her own long-term observations, that the number of trees in fields in farming systems in Northeast Thailand has been declining over time as farmers cut down more trees to meet their needs for timber and firewood and as some remnant forest trees, especially those located in lower paddy fields, die naturally as a consequence of the transformation of their natural habitats or senescence. Cutting of trees has been accelerated by the recent increase in the use of four-wheel tractors and combine harvesters, which have difficulty in working efficiently in fields with many trees (Praweenwongwuthi 2009) as well as by the planting of sugarcane in many paddy fields, especially upper paddies. Sugarcane is vastly more profitable for the farmers, but also much less shade tolerant than rice, leading to cutting down of more trees (field observations of authors). If this trend continues, then the vast “invisible forest” represented by trees in paddy fields may truly disappear, with negative consequences for the livelihoods of the villagers, loss of biodiversity, and reduced ability of the rural ecosystem to sequester carbon. Finding ways to help reverse this decline is an important priority if land degradation, which is widespread in the Northeast, is to be countered and the sustainability of agricultural production enhanced.

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A Burning Issue

Rethinking the Transition from Hunter-Gatherer to Industrial Sociometabolic Regimes

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Summary

Hunter-gatherers are commonly seen as having a fundamentally different sociometabolic regime from agrarian and industrial societies because they are thought to directly appropriate the products of natural ecosystems without modifying those systems in order to enhance their productivity. However, ethnographic and archeological evidence reveals that many hunter-gatherers extensively employed fire to manage their ecosystems so as to increase production of desirable wild resources, thus engaging in "colonization of nature" that is not qualitatively different from that practiced by other types of society. They systematically burned wild vegetation in order to increase populations of edible wild plants consumed by humans and promote growth of forage for game animals. Deliberate ecosystem burning by Australian Aborigines represented an energy expenditure of 1,512 gigajoules per capita per year (GJ/capita/yr), a level of energy use that is more than three times higher than the United States (445 GJ/capita/yr). It is their profligate consumption of biomass energy that explains why the quality of life of many hunter-gatherers was often better than that of traditional settled peasant farmers. Hence, the extent to which hunter-gatherers have a distinct type of sociometabolic regime is called into question. It can be argued that in the course of social evolution, there have been only two sociometabolic regimes. In one type, which includes hunter-gatherers, swidden agriculturalists, and industrial societies, extrasomatic energy does most of the productive work, whereas in the other type, that of premodern settled agriculturalists, production is largely dependent on human muscle power.

Introduction

The idea that the evolution of more complex human societies is driven by increases in per capita energy consumption is an old one in the social sciences (Ross and Machlis 1983). This belief is founded on the recognition that social systems, just like living organisms and ecosystems, require a continuous supply of energy in order to function (Smil 2004). Energy is required by social systems to coordinate activities of their members, produce food and other necessities, build physical infrastructure, preserve social order within the system, and defend against hostile neighboring social systems. Consequently, it is assumed that

as the consumption of energy increases, social systems become larger and more complex (Cook 1971; Cottrell 2009; Debeir et al. 1991; Rambo 1991; Smil 1994, 2004; White 1943, 1959). The anthropologist Leslie White (1943, 1959) even proposed a formula to express the relationship between energy and cultural evolution:

$$E \times T \rightarrow C$$

(in which E is the amount of energy harnessed per capita per year, T is the efficiency with which available technology employs that energy to perform work, and C is the resulting degree of cultural development).

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White asserted that culture had evolved through three increasingly complex stages as the amount of energy used per capita had increased. Very small and simple hunter-gatherer societies represented the first stage, larger and more complex agrarian societies based on domesticated plants and animals represented the second stage, and modern industrial societies using fossil fuel (FF) energy represented the third stage. In a widely reproduced graph, Earl Cook (1971) plotted energy consumption of societies at various evolutionary stages. According to his graph, per capita energy consumption increased from 8.4 megajoules per day (MJ/day) for “primitive man” (hunters and gatherers) 1 million years ago, to 50 MJ/day for early agriculturalists (swidden farmers), to 109 MJ/day for advanced agriculturalists (peasant farmers), to 962 MJ/day for “technological man” in the United States of 1970. Cook did not list any sources for the energy consumption figures assigned to premodern societies and it appears that he simply made “common sense” estimates.

Although the belief that increasing per capita use of energy is the main driving force of social evolution has become part of the conventional wisdom of the social sciences, it had never actually been empirically tested until quite recently when scholars associated with the Institute of Social Ecology in Austria, employing what has been labeled as “the Viennese sociometabolic transition approach” (Fischer-Kowalski and Rotmans 2009), published some well-documented analyses of energy use by societies representing different evolutionary stages (Fischer-Kowalski et al. 2011; Haberl 2002; Krausmann et al. 2008). These analyses show the same trends as Cook’s earlier rough estimates. Thus, Haberl’s (2002) comparative analysis of the energetic metabolism of three societies representing the hunter-gatherer, agricultural, and industrial evolutionary stages shows that daily per capita energy expenditure for hunters and gatherers (Nicobar Islands, India) was 22 MJ, increasing to 208 MJ for an advanced peasant agricultural society still largely reliant on animal draft power (a rice growing village in Northeast Thailand), and climbing to 688 MJ for a modern industrial society (Austria).

In the Viennese approach, the concept of the “sociometabolic regime” (Sieferle 2001) is used to distinguish different socioecological systems and their associated energy systems. It is assumed that the character of the socioecological system is determined by the energy system so that, following the functionalist logic that underlies this conceptual approach, those systems depending on the same source of energy and employing similar kinds of energy conversion technology are expected to display many other similar characteristics as well, including patterns and levels of resource use, demography, settlement pattern, human labor allocation patterns, institutional arrangements, and communications (Krausmann et al. 2008). Three main sociometabolic regimes have been delineated to represent successive stages in the evolutionary history of human society. These are the hunter-gatherer regime, the agrarian regime, and the industrial regime. Each of these “ideal type” regimes is said to be characterized by a distinctive energy system: Hunter-gatherers are said to have an “uncontrolled solar energy system” (Sieferle [1997] as cited in Haberl [2002]), in

which humans appropriate the products of photosynthesis of natural ecosystems without attempting to modify those systems in order to enhance their productivity; agrarian regimes rely on a controlled solar energy system, in which they purposively modify ecosystems in order to increase net primary productivity, and industrial regimes have an FF-based energy system which, for at least a short period of time, liberates them from the energetic limits of their ecosystems (Krausmann et al. 2008; Fischer-Kowalski and Haberl 2007; Sieferle 2001). This characterization of the three sociometabolic regimes is essentially a restatement, using the vocabulary of energy systems analysis, of the conventional typology of social evolutionary stages long employed by students of cultural evolution (e.g., White 1943, 1959). The stages in this typology represent a lineal progression from small, simple, and technologically primitive social systems to ever larger, more complex, and technologically advanced systems. Similarly, the identification of the sources of energy and energy conversion technology employed by each regime are basically identical to those earlier suggested by White and other cultural evolutionists. But it is precisely this aspect of their analysis, in particular the assertion that hunters and gatherers employ an uncontrolled solar energy system, in which they simply appropriate the products of natural ecosystems without attempting to increase ecosystem productivity (Fischer-Kowalski and Haberl 1997, 2007; Haberl 2002; Sieferle 2001), that deserves to be challenged in light of the accumulated evidence of ethnographic and archeological research that reveals that many hunting and gathering societies in different parts of the world have systematically modified their ecosystems to serve their needs.

The Sociometabolic Regime of Hunter-Gatherers

That hunter-gatherers have engaged in a deliberate process of ecosystem management, which Bruce D. Smith (2011) (employing a concept proposed earlier by Laland et al. [2000]) refers to as “niche construction,” is widely recognized by anthropologists. Certainly, the once widely held belief that hunting and gathering people always live in harmony with nature and have minimal impacts on nature has now been largely discredited (Rambo 1985). It is now evident that they alter their ecosystems in many ways, both deliberately and as the unintended consequences of their daily activities. In an article reviewing deliberate efforts to manage wild plant and animal resources by small-scale societies, Smith identified six general categories of niche construction:

1. General modification of vegetation communities
2. Broadcast sowing of wild annuals
3. Transplantation of perennial fruit-bearing species
4. In-place encouragement of perennial fruit and nut-bearing species
5. Transplantation and in-place encouragement of perennial root crops, and

6. Landscape modification to increase prey abundance in specific locations (Smith 2011).

All of these actions involve modification of the natural ecosystem in ways intended to increase productivity of resources needed by humans and therefore represent efforts to colonize nature. In particular, many groups of hunters and gatherers have employed fire (and, less frequently, water¹) to manage their ecosystems in ways intended to increase production of desirable wild plant and animal resources (Goudsblom 1992; Pyne 2005). Fire was used to increase production of forage for game animals, increase populations of wild plants consumed as food by humans, and increase the mobility and exploitative efficiency of human hunters and foragers by clearing low-growing vegetation that slowed their travel and made it difficult to see prey animals (Mellars 1976).

It is not known with any certainty when humans first began using fire to manage natural ecosystems, but there is some evidence that it occurred during the Mesolithic period in Europe (Mellars 1976). Certainly, the practice was very widespread among hunter-gatherers in many parts of the world at the time of first contact with European explorers. Fire was used by aboriginal hunters and gatherers to manage “natural” ecosystems in Australia (Bird et al. 2008; Gould 1971; Hallam 1985; Jones 1969; Lewis 1985; Vigilante et al. 2009), North America (Anderson 1994; Blackburn and Anderson 1993; Hough 1926; Lewis 1982; Lewis and Ferguson 1988; Stewart et al. 2002; Williams 2005), South America (Mistry et al. 2005; Pivello 2011), Africa (Shaffer 2010; Sheuyange et al. 2005), and Asia (Zong et al. 2007). Use of fire to increase ecosystem productivity seems to have been most common among hunters and gatherers residing in deserts, savannas, and seasonally dry forests, but has also been reported for the Canadian boreal forest (Lewis and Ferguson 1988) and even the humid Malaysian rainforest (Rambo 1985). A cross-cultural study of 96 hunting and gathering groups found that 16 burned for hunting, 29 burned to encourage growth of plants, and 51, mostly in areas with high rainfall or at high latitudes, did not burn (Keeley 1995, 256, Table 9.4).²

Although burning by hunters and gatherers has often been attributed to their use of fire in hunting, it is their systematic use of deliberately set fires to “clean up” the landscape, as the Australian Aborigines refer to their practice of periodically burning areas covered by mature climax vegetation cover in order to set back the successional clock, and thus increase the productivity of the ecosystem, that would seem to represent deliberate colonization of nature (Bird et al. 2008; Murphy and Bowman 2007; Russell-Smith et al. 1997). By choosing the time of the year and the frequency with which they burn an area, they are able to increase the yield of wild plants that they consume directly, or that are eaten by the wild game animals that they hunt for meat, above the natural level of an unmanaged ecosystem that is burned only when irregularly occurring lightning strikes ignite wild fires. For example, the Cocopa Indians of the American Southwest collected wild grass seed as an important source of food. According to Hough (1926, 66):

After harvest, the Indians burn off the dry grass to clear the land of rubbish, so that when the new grass springs up the harvest may be facilitated. The Indians believe that the grass is benefitted by burning and their idea appears to be good. This is a case of unintentional fertilization. It also may be seen that a continuation of this process may work a change in the habits of the grass, leading in some respects to its domestication.

Regular burning of savanna vegetation is also widely practiced by hunter-gatherers in order to increase the quantity and nutritive quality of tender shoots and leaves of forage plants that regenerate after the fire. Experiments in North America and Europe have shown that careful use of fire can increase the carrying capacity of the environment for grazing animals by 300% to 700% over that of an unmanaged ecosystem (Mellars 1976). Studies of areas burned by Aboriginal Australians have also found increases in the populations of desired game species and edible wild plants (Bird et al. 2008; Murphy and Bowman 2007; Vigilante et al. 2009).

Periodic burning by hunters and gatherers also serves to limit the natural occurrence of huge lightning-ignited wild fires, which are likely to occur after an area has accumulated an excessive fuel load, and may destroy useful species and retard the regeneration of the vegetation communities on which the hunters and gatherers depend for their food (Pyne 2005). By burning different patches within the landscape at different intervals, they also create and maintain a fine-grained mosaic environment with greatly increased edge length that enhances biodiversity (Bird et al. 2008; Lewis and Ferguson 1988).

Although many studies have shown that deliberate burning of natural vegetation by hunters and gatherers increases ecosystem productivity, and it would therefore seem logical to include the biomass energy used in fires in analyses of their sociometabolic regimes, this form of energy use has been largely omitted (with the notable exception of Sieferle et al. [2006]) in analyses employing the Viennese sociometabolic transition approach.³ Although Sieferle (2011) does acknowledge that hunters and gatherers used fire for hunting⁴ and, in the process, changed the character of the natural vegetation so as to create open grasslands that served as pasture for the large herbivores that were their favored prey, he denies that this represented “systematic colonization of nature.”⁵ Those areas where the ecosystem has been manipulated by hunter-gatherers by burning biomass are referred to as “affected areas,” although the land-use structure of these areas is said to be “100% natural vegetation” (Sieferle et al. 2006, Table 2.2), which would seem to imply that the ecosystem has not been significantly modified by human actions. Haberl (2002) also recognizes that hunters and gatherers do use a small amount of final energy (ca. 3.5 gigajoules per capita per year [GJ/capita/yr]) in the camp fires they use for cooking and warmth and that this value would be “several orders of magnitude higher in cases where hunter-gatherers burn down forests during hunting, thus promoting herbaceous vegetation,” but he does not include this extrasomatic energy in his analysis of their sociometabolic regime. Others employing the Viennese approach (e.g., Fischer-Kowalski

and Haberl 1997; Fischer-Kowalski et al. 2010; Sieferle 2001) also acknowledge that hunters and gatherers use fire for a variety of purposes, but nevertheless omit it from their sociometabolic analyses on the grounds that “hunter-gatherers do not colonize nature in the sense that they deliberately modify natural systems to make them more productive or convenient for their needs” (Fischer-Kowalski and Haberl 1997). There is a circularity in this logic (hunter-gatherers have a fundamentally different sociometabolic regime because they do not colonize nature → therefore their use of biomass energy to modify their ecosystems is not included into the analysis of their sociometabolic regime → therefore they have a fundamentally different sociometabolic regime) that obscures perception of the actual utilization of energy by hunter-gatherers.

Rethinking the Role of Biomass Energy in Hunter-Gatherer Sociometabolism

The omission of fire energy from analyses of the sociometabolic regime of hunters and gatherers is hardly a minor issue. Although detailed and reliable empirical data are difficult to obtain, the limited available evidence suggests that inclusion of the energy consumed in fires intended to manage their ecosystems would dramatically alter our view of the sociometabolism of hunters and gatherers. The only reasonably comprehensive and reliable data on hunter and gatherer use of fire to manage their ecosystems come from ethnographic studies of the Aborigines who inhabit the savanna ecosystems of Northern Australia.⁶ Until recently, these nomadic hunters and gatherers lived in small bands numbering from 20 to 50 people, with a mean population density of 1 person per two square kilometers (1 person/2 km²) (Jones 1980). Net primary production of the savanna ecosystem is quite low, with estimates of average annual accumulation of biomass in the form of easily burnable leaf litter and understory grasses and shrubs ranging from 140 grams per square meter (g/m²) (1.4 metric tons per hectare [t/ha]) (Chen et al. 2003, 409, Table 3) to as much as 1,000 g/m² (Lacey et al. 1982). Dry plant litter has an average energy content of 4.3 kilocalories per gram (kcal/g) (0.018 MJ/g) (Golley 1961, so if the average fuel load is 140 g/m², it would contain 2.52 MJ of energy. According to Lewis (1985), the Aborigines in this area burned between 30% and 50% of their whole territory each year. If they burn just 30% of their territory each year, or 600,000 m²/person, this would represent a minimum estimate of per capita energy expenditure in the form of biomass burning of 1,512 GJ/capita/yr. This is a level of energy use that is more than three times higher than the United States (445 GJ/per capita/yr) and seven times greater than the European Union (EU) (210 GJ/capita/yr) in 2000 (Haberl et al. 2006, 156). One can, of course, question the accuracy of the ecological values employed in making this estimate, but, even if they were several times lower than the numbers used here (e.g., the area burned per person is smaller or the fuel load lower than the already minimum values employed in this calculation), the total amount of energy used in burning would still be immense.

It is important to include biomass energy used in burning into analysis of the hunter-gatherer sociometabolic regime because it helps to explain the otherwise anomalous finding that the quality of life of hunters and gatherers was generally much better than that of peasant farmers in traditional agrarian states. Although citizens of modern states, who enjoy a high quality of life because they are able to exploit vast quantities of FF energy, commonly perceive hunters and gatherers as having led lives that, in Thomas Hobbes' terms were “poor, nasty, brutish and short,” modern ethnographic research does not support this stereotypical view. Indeed, there is considerable evidence that hunters and gatherers were able to adequately feed themselves with a minimum amount of work and also were generally healthier and lived longer than traditional agriculturalists (Cordain et al. 2000; Gurven and Kaplan 2006; Milton 2000).⁷ It was their enjoyment of such a high quality of life, despite working only a few hours per day, that led the anthropologist Marshall Sahlins (1974) to refer to hunters and gatherers as “the original affluent society.” A recent review of studies of eight contemporary hunting and gathering societies found that individuals spent an average of only 3.7 hours per day in procuring food (Waguespack 2005). This is a reflection of the generally high returns of food calories that they achieve per hour worked. According to a recent review of energy yields for several contemporary hunting and gathering groups (Kuhn and Stiner 2001, 102, Table 5.1), hunting of large game yielded an average of 265.4 MJ per hour (MJ/hr), small game 67.2 MJ/hr, digging of roots and tubers between 25.6 and 43.6 MJ/hr, and collecting seeds and nuts between 14.7 and 27.3 MJ/hr. Another compilation of return rates for hunter-gatherers in Australia, the Great Basin of the United States, the Canadian boreal forest, and the Malaysian rainforest shows a very wide range from 1.1 MJ/hr for grass seed in Australia to 2,991.1 MJ/hr for grasshoppers in the Great Basin (Kelly 1995, 81–82, Table 3-3). Although these figures suggest that procurement of some types of food by hunter-gatherers could be very efficient, it is not possible to extrapolate from these data to an overall estimate of average return rate for any hunter-gatherer society. There have been only a few comprehensive studies of time expended in food procurement by contemporary hunters and gatherers. It is particularly unfortunate that no studies on the productive efficiency of Australian Aborigines were made until after they had been partly resettled on government stations, where they had access to store-bought foods, and also after the government had prohibited regular burning of the environment, so the extent to which the available figures on caloric returns per hour spent in food procurement are representative of the precontact situation is open to serious question.⁸ Richard Lee's detailed study of the Kung San of Botswana in southern Africa, who used fire to manage their ecosystem in much the same way as the Australian Aborigines (Sheuyange et al. 2005), is probably the most reliable available study of labor productivity of hunting and gathering in a savanna ecosystem. He found that adults spent, on average, 3.5 hours per day in hunting and foraging and obtained 17.2 MJ for each hour spent in food procurement, so required only 29 minutes of work to procure sufficient food

Table 1 Human labor time needed to produce food in subsistence systems employing different energy sources

	Hunting and gathering (Kung San, Botswana, Africa)	Swiddening hill-rice (Iban, Sarawak)	Traditional peasant wet rice farming (colonial era Vietnam)	Traditional peasant wet rice farming (colonial era Java)	Traditional peasant maize farming (Mexico)	Semimodernized peasant wet rice farming (Northeast Thailand)	Mechanized wet rice farming (Japan)	Mechanized wet rice farming (USA)
	Human labor + fire	Human labor + fire	Human labor only	Human labor only	Human labor + oxen	Human labor + buffalo + machine power	Human labor + machine power	Human labor + machine power
Time period	28 days	1 annual crop	1 wet season crop	1 wet season crop	1 annual crop	1 wet season crop	1 annual crop	1 annual crop
Yield/t/ha	n.a.	1.1	1.5	1.1	0.94	2.0	6.3	7.37
Yield/MJ	8,373.6	16,837.6	15,383.5	11,383.8	13,986.2	20,205.2	96,203.9	111,043.1
Human labor hours	486	936	2,336	1,680	383	570.2	640	24
MJ/human labor hour	17.2	18	6.6	6.8	36.5	35.4	150.3	4,627.2
Human labor time to feed 1 person/1 day	29 minutes	31 minutes	76 minutes	74 minutes	14 minutes	14 minutes	3 minutes	<1 second
Source of data	Lee (1979) <i>en passim</i>	Nielsen and colleagues (2006), Table II	Dumont 1935 <i>en passim</i>	Van der Eng 2004, Table 3	Pimentel and Pimentel 2008, Table 10.4	Grünbühel and colleagues (2003), Table II	Pimentel and Pimentel 2008, Table 10.12	Pimentel and Pimentel 2008, Table 10.14

Note: t/ha = tons per hectare; Ml = megajoules; n.a. = not applicable.

for 1 person for 1 day (Lee 1979).⁹ Thus, it does not appear that hunters and gatherers are necessarily less productive than traditional peasant agriculturalists (table 1). Indeed, colonial-era peasants in the densely populated Red River Delta in Vietnam (Dumont 1935) and in Java in Indonesia (Van der Eng 2004), who had to entirely rely on human muscle power to cultivate their paddy fields, had to work more than twice as long as the Kung San to produce sufficient food calories to feed 1 person for 1 day, whereas swidden agriculturalists, such as the Iban of Borneo (Nielsen et al. 2006) or the Tsembaga of Papua New Guinea (Rappaport 1971), who, like all slash-and-burn cultivators, used fire energy to do much of the work of cultivating their fields (McGrath 1987; Rambo 1980), achieved approximately the same output per hour as the Kung San hunters and gatherers.¹⁰ It is only modern industrial farmers who cultivate their fields using FF-powered machinery who achieve a level of labor productivity that greatly exceeds that of hunters and gatherers using fire to manage their ecosystems¹¹ (Pimentel and Pimentel 2008).

Although their labor productivity was very high, the efficiency with which hunter-gatherers used biomass energy to increase the productivity of their ecosystems by landscape burning was extremely low. The Australian Aborigines had a strongly negative energy output-input ratio for food of 0.0023:1,¹² which is even lower than the output-input ratio of 0.11:1 achieved by the Tsembaga swidden agriculturalists in Papua New Guinea (Rambo 1984). In contrast to the very low efficiencies of these fire-using groups, the traditional wet rice-growing peasants in the Red River Delta of Vietnam, who used only their own muscle power to cultivate their crops, had a strongly positive food energy output/work energy input of approximately 11.9:1 (calculated from data in Dumont [1935]). Even FF-using mechanized American agriculture, which has often been criticized for its inefficient use of energy (e.g., Steinhart and Steinhart 1974), has a positive output-input ratio for maize production of from 4.11:1 (Pimentel 2009) to 10:1 (Gelfand et al. 2010).

The very inefficient use of almost all of the available energy in their environment by hunter-gatherers is reflected in the very low population densities that are characteristic of this sociometabolic regime. For example, the Australian Aborigines, who used 1,535 MJ/capita/yr of energy, had a population density of only 1 person/2 km². Swidden agriculturalists, who achieved somewhat greater efficiency in their use of biomass energy for food production, were able to support considerably higher densities. Thus, the Tsembaga tribal swidden farmers in Papua New Guinea, who used 20 times less energy per capita (71 GJ/capita/yr) than the Aboriginal hunter-gatherers, but used it to produce food 48 times more efficiently, had a mean population density of 14 people/km². Traditional peasant farmers, who used only their own muscle power to grow their crops, could achieve very high population densities. For example, the wet rice-growing peasants of Vietnam's Red River Delta, who used only 4.24 GJ/capita/yr of energy, had a mean population density exceeding 300 persons/km² and reaching as high as 1,500 persons/km² (Rambo 1991; Le and Rambo 1993).

Thus, the growth of hunter-gatherer societies and, to a somewhat lesser degree, swidden agriculturalists, was very tightly constrained by the total amount of biomass energy available per square kilometer in their territories. If population density should come to exceed the very low carrying capacity of these modes of production, they could no longer maintain the prolific expenditures of energy that gave them high labor productivity. They were forced to shift from a space-based energy system to one based on labor, with a consequent decrease in their quality of life.

Conclusions

Contrary to the conventional belief, hunter-gatherers do not all rely on an "uncontrolled solar energy system," in which they merely appropriate the products of photosynthesis of natural ecosystems without modifying those systems in ways that increase their productivity. Instead, many hunter-gather societies make extensive use of fire to reshape natural ecosystems to serve human needs, thus engaging in "colonization of nature" that is not qualitatively different from that practiced by agricultural societies. Hence, the extent to which hunter-gatherers have a distinct type of sociometabolic regime is called into question. Indeed, it might even be argued that, in the course of social evolution, there have been only two sociometabolic regimes. In one type, which includes those hunter-gatherer societies that used fire to modify their ecosystems, swidden agriculturalists, and industrial societies, extrasomatic energy does most of the productive work, whereas in the second type, that of hunter-gatherers who do not burn their ecosystems and premodern settled agriculturalists, production is largely dependent on human muscle power, supplemented, in some cases, by draft animals. Members of the first type of regime, because they are able to tap vast resources of biomass energy, either in the form of living vegetation in the case of hunter-gatherers and swidden farmers, or of FFs (i.e., the "subterranean forest" as Siefert [2001] has memorably called it) in the case of industrial societies, are liberated from total reliance on their own muscle power to produce their food needs.¹³

In any case, I would argue that it is not differences in the amounts of extrasomatic energy that individual hunters and gatherers consume that distinguishes the sociometabolic regime of their societies from the regimes of agricultural or industrial societies.¹⁴ Instead, what differentiates hunter-gatherer societies (regardless of whether or not they engage in large-scale modification or their ecosystems by burning) from advanced agrarian and industrial societies is the very small amount of energy that these small and simple social systems expend on integrative activities (Rambo 1991). As Elman Service (1971) has pointed out, the social organization of hunting and gathering bands is characterized by its rudimentariness, with bands lacking any other integrative means than kinship and religious rituals. Because a typical band is composed of fewer than 50 members, who are usually related by descent or marriage, and are in continual face-to-face contact in the course of their

normal daily activities, there is minimal need for special integrative institutions to maintain social cohesion. In such small groups, informal interactions among kinspeople who are coresident within the same band are the primary mechanism for maintaining social cohesion. Interactions among members occur as a matter of course during the ordinary activities of daily life, rather than requiring extra expenditure of time or effort. Consequently, a band does not expend much energy on coordinating the actions of its members or ensuring the maintenance of internal social cohesion. Integration is achieved simply by members spending a few minutes in conversation around the evening campfire to plan the next day's activities, and perhaps devoting a few hours every so often to participating in periodic ritual gatherings. No detailed quantitative studies have been made of the amount of energy expended on social integrative activities by hunting and gathering bands, but, if we assume that each member spends an average of 1 hour a day on such activities, the total amount of energy employed for societal purposes would hardly exceed a few megajoules per day (1991).

In contrast to band societies, where integration is essentially an incidental by-product of the daily routine of life, traditional agrarian states, such as the Chinese or Roman empires, required special purpose-built institutions to create and maintain social cohesion. Such states were composed of millions of members, mostly poor peasants, workers, and slaves. Despite the poverty of most of their subjects, these states themselves had immense administrative and military power. Their ruling elites employed the coercive power of the state to extract heavy taxes (usually paid in grain or forced labor service) from the peasantry. The amount of grain contributed by each peasant household was small, perhaps only a few hundred kilograms (kg) each year, but when combined with the grain contributed by millions of other households, represented a huge stock of energy that could be used to support the functioning of diverse specialized integrative institutions. These institutions included the civil and religious bureaucracies that were responsible for public administration, defense, and the performance of rites and rituals that functioned to maintain societal cohesion. These states also commonly used taxes to support construction of large-scale irrigation and flood control projects designed to improve agricultural yields, which led to what Goudsblom (1992, 54) refers to as the increase in "collective productivity" displayed by advanced agrarian societies. Again, no studies are available of energy expenditure on social integration by agrarian states, but it would certainly have been thousands, even tens of thousands, of GJ/day.¹⁵

Modern industrial societies are much larger and structurally more complex than traditional agrarian states and require correspondingly greater energy expenditures on their integrative institutions. In addition to a multitude of government agencies that attempt to maintain order and regulate the functioning of these societies, they typically have a vast interlocking array of private corporations, nongovernmental organizations, and voluntary associations that contribute to creation of social solidarity. The operation of these institutions must consume a

very large quantity of energy, but, unfortunately, I have been unable to locate any estimates of the total amount of energy used for integrative purposes by any modern industrial society. However, one can gain a sense of the magnitude of these expenditures on social integration by examining the amount of energy expended on communications. Transmission of information among millions of members by means of telephones, the Internet, and the mass media plays a critical role in the integration of modern industrial societies. Complete data are unavailable, but the United States probably expends at least 1,000 terajoules per day (TJ/day) on communications, with much, probably most, of this energy contributing to societal integration.¹⁶

The admittedly crude estimates of the amount of energy used for integrative purposes by social systems at different evolutionary stages that I have presented can certainly be questioned, but I doubt that any possible revisions will overturn the relative ranking of these different types of societies. That agricultural societies use vastly more energy for societal integration than hunting and gathering bands, and that industrial societies use even greater amounts of energy than agricultural ones, does not seem to be open to question.

It is also evident that the relationship between per capita energy consumption rates and the evolution of more complex social systems is much more problematic than has been commonly assumed. Indeed, if we were to draw a graph showing changes in per capita energy use in the course of social evolution, it would display a U-shaped curve, with the line dipping down from the very high per capita energy consumption level in many hunter-gatherer bands, to a moderately high consumption level by slash-and-burn farmers living in tribal societies, and then falling steeply to a very low per capita consumption level by peasants in traditional agrarian states, before climbing steeply to the very high per capita level of consumption by citizens of modern industrial states (Rambo 1991). It appears therefore that it is time for serious rethinking about the role played by transitions in sociometabolic regimes in the process of cultural evolution.

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Notes

1. Management of water by hunter-gatherers to manipulate ecosystem productivity is much less commonly reported than their use of fire, but some Native American hunters and gatherers are known to have constructed quite extensive systems of canals to irrigate plots of edible wild plants, thereby increasing their productivity. The Owens Valley Paiute, in what is now the American state of California, built earthen dams to divert water from streams into canals that extended for as long as 4 miles to irrigate the wild tubers and grasses that provided carbohydrates consumed by the Indians (Steward 1930). Australian Aborigines, in what is now the state of Victoria, dug extensive canal systems to regulate water levels in wetlands in order to increase the population of wild eels, a major source of protein in their diet (Lourandos 1980). Another group of Aborigines living near the Roper River in the Northern Territories constructed check dams across small streams that helped to maintain the level of water in jungle swamps during the dry season. They did this in order to maintain the habitat for wild birds and promote the growth of the wild food that lived in the swamps (Campbell 1965). More than 7000 yr BP, Mesolithic hunters and gatherers in the Lower Yangtze River basin in China intensively managed wild rice growing in coastal swamps and may have constructed bunds to retain nutrient-rich flood waters in their rice fields while blocking inundation by brackish water (Zong et al. 2007).
2. The use of fire by hunter-gathering societies to colonize ecosystems is almost certainly seriously under-reported in the ethnographic literature. It was only in the 1970s that anthropologists began to pay serious attention to this practice, by which time landscape burning had already been suppressed by governments in many parts of the world. In earlier times, most of the vast terrestrial surface area occupied by hunter-gatherers would have been amenable to modification with fire, and I suspect that landscape burning was much more commonly employed by them then.
3. In a book published in German in 2006 (which regrettably I am unable to read), Sieferle and colleagues state that total per capita energy use by hunter-gatherers is much higher (3,810 MJ/capita/yr) than it is for slash-and-burn farmers (950 MJ), settled agriculturalists (73 MJ), and industrial societies (156 MJ) (Sieferle et al. 2006, Table 2.2). Although the amounts of energy used by societies at each social evolutionary stage are different from those in the analysis presented in the present article, the general trend is the same. Curiously, this finding does not seem to have influenced subsequent analyses using the Viennese approach, including Sieferle's (2011) own discussion of the relationship between energy and cultural evolution, in which he states that hunter-gatherers had a total energy use of approximately 10 GJ/capita/yr. I am grateful to an anonymous referee for calling this important work to my attention and sending me a copy of Table 2.2.
4. Sieferle (2011) associates the use of fire by hunter-gatherers to burn the landscape exclusively with its use as a hunting technique. He states that "Fire was also an important instrument for hunting, employed to provoke panic on beasts of prey so that they could more easily be hunted down." Although some hunter-gatherers did occasionally use fire to drive game, it was more commonly employed to deliberately modify the ecosystem (Lewis 1985; Stewart et al. 2002; Williams 2005).
5. Sieferle (2011) argues, following Fischer-Kowalski and Haberl (1997), that "colonization of nature means that humans systematically construct and maintain controlled functional segments within the natural environment" and that "in a strict sense this was only the case with the emergence of agriculture" (Sieferle 2011, 318). But there is no sharp line separating the ways in which hunters and gatherers modify nature and what is done by agriculturalists as Keeley (1995) and Smith (2011) have documented.
6. These estimates employ most of the same data used in Rambo (1991), but have been reworked to use the most conservative available estimates of biomass accumulation.
7. Not only did hunters and gatherers have to spend less time working to meet their subsistence needs than most agriculturalists, but they were also largely free of the degenerative diseases (sometimes called the "diseases of civilization"), such as obesity, diabetes, high blood pressure, and heart disease, that afflict so many people in modern societies (Cordain et al. 2000; Milton 2000). They also enjoyed relatively long lifespans with a modal age of death of 72 years, which, although lower than the 85 years for the United States in 2002 (Gurven and Kaplan 2006, 334–335), is considerably longer than the lifespans of most traditional peasant agriculturalists.
8. The most detailed study, covering a total of 4 months at different times in the annual cycle, of an Aboriginal band in Arnhem Land that had been resettled but returned to the bush for extended periods, found that adults spent an average of 2.6 hours per day in subsistence activities and obtained 4.02 MJ/hr, so needed to work for 2.08 hours to collect sufficient food for 1 person for 1 day (Altman 1987, 92, Table 27; 109, Table 30). An earlier 14-day study of another group of partially sedentarized Aborigines, also in Arnhem Land, found that adults devoted an average of 3 hours and 45 minutes per day to food procurement. It was the height of the dry season, when wild tubers were difficult to find and wild game was relatively scarce, so they obtained 2.9 MJ/hr and spent almost 3 hours to obtain sufficient food to feed 1 person for 1 day (McCarthy and McArthur 1960). A third study by O'Connell and Hawkes (1981, 118, Table 5.A.2) of semisettled Aborigines in the central desert, recorded the time expended and the food energy gained by Aborigines on a number of plant-collecting trips. They report a range of returns from 1.1 to 8.6 MJ/hr (mean = 3.6 MJ/hr or 138 minutes to feed 1 person for 1 day). No data are presented on returns on hunting, which usually provides much greater energy returns per hour than plant foraging under Australian conditions, so actual productivity is probably considerably higher than this. Moreover, their time expenditure data include both procurement and processing time, so are not directly comparable to other studies on agricultural labor productivity.
9. Of course, the Kung San must spend additional time working to process and cook food, collect firewood and water, make and repair tools, and do other household chores (Lee 1984, 51–52), but that is also the case with traditional farmers. My concern in this analysis is solely with efficiency of food production.
10. That Hill and colleagues (1985, 44) found that "no significant difference can be shown to exist between amount of men's subsistence work in foraging societies and subsistence horticultural societies" can be seen as reflecting the fact that both modes of production enjoy very large, and generally unrecognized, subsidies of extrasomatic energy, in the form of fire.
11. Of course, if all of the labor time and energy expended in producing the tools and chemicals on which modern agriculture depends were to be counted, then its labor productivity would be very much lower. As Odum (1967, 60) has pointed out, "the bulk of the persons who work to support the farming process are in cities far

- away from the farm, but they are just as necessary to the farm as the man riding the tractor.”
12. Assuming that each person expended 4 hours per day on food procurement, this would represent human energy use of approximately 0.2 GJ/capita/yr. Energy utilized in biomass burning would represent 1,572 GJ/capita/yr. No reliable data on the energy value of food obtained are available, but it must have averaged at least 3.5 GJ/capita/yr, assuming that the basic metabolic requirements of the people were being met.
 13. Hunter-gatherers and swidden agriculturalists using biomass energy can be grouped together with industrial societies using FF energy into a single sociometabolic regime because none of these systems are constrained by energy. However, they differ in that the societies that depend on biomass energy are space-based systems that cannot support high population densities. In contrast, FF-based industrial societies are not constrained by space. Only the speed with which fossil energy can be extracted from geological deposits and, ultimately, the ability of the global biogeochemical system to absorb the waste products of burning FFs act as constraints on the growth of these societies. I am grateful to an anonymous reviewer for bringing this important distinction to my attention.
 14. Per capita energy use is undoubtedly a key metric for explaining differences in the quality of life of people in different societies, but it is largely irrelevant to the explanation of differences in the size and complexity of social systems at different stages of evolution. Trying to differentiate sociometabolic regimes on the basis of per capita energy use is comparable to employing the amount of energy used by individual cells in biological organisms to distinguish simple and complex life forms. Multicellular organisms consume more energy than single-celled ones, but that is a result of their being made up of multiple cells that are united by complex integrative mechanisms and not because each of their individual cells consumes more energy.
 15. The Vietnamese kingdom in the mid-1800s, before the French conquest, had a population of some 1.5 million peasant households. Most households were extremely poor, with only approximately 1 ha of rice land, which yielded approximately 1.5 t of paddy rice (Dumont 1935). This represents an energy value of 15.4 GJ, which is barely sufficient to feed a family of five for 1 year. Despite their poverty, each household would have been forced to contribute approximately 300 kg of grain (3 GJ) in taxes to the state (as well as also frequently being forced to send members to work as unpaid laborers on state projects). When multiplied by the 1.5 million peasant households in the kingdom, this represented a huge pool of energy (4.5 million GJ) that was used to support the functioning of the state's integrative institutions, allowing the state to expend more than 12,300 GJ/day of energy to maintain its integrative institutions (Rambo 1991).
 16. Operation of the telecommunications system in the United States consumes more than 274 TJ/day of electrical energy (Mathews 2003), whereas operation of television sets uses 454 TJ/day (Ostendorp et al. 2005).
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Agriculture in the Mountains of Northeastern Thailand: Current Situation and Prospects for Development

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Agriculture in the Mountains of Northeastern Thailand: Current Situation and Prospects for Development

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The mountains in northeastern Thailand cover an area of about 25,000 km², which is about 15% of the region's land surface. Although agriculture is the most important economic activity in the mountains, there has been little

previous research on it. This study presents a general description of mountain agriculture in northeastern Thailand, which is shown to be quite different from the better-known agriculture in Thailand's northern mountains. The northeastern mountains are diverse in environment, culture, and land use. Mountain agriculture is also diverse at the crop level. Field crops remain the main source of income, but in recent years, rubber has become increasingly important in

some areas. Specialty crops (eg grapes, strawberries, exotic flowers, and temperate vegetables) generate high income and serve as a magnet for tourism, but they are grown in only small areas in a few favored locations. Poor-quality soil, seasonality and variability of rainfall, scarcity of surface water, broken terrain and steep slopes, insufficient supply of land, land tenure insecurity, limited possibilities for mechanization, high cost of transportation, and competition with foreign imports are the main constraints on development. However, promotion of specialty crops and agritourism offer some potential for mountain agricultural development in northeastern Thailand.

Keywords: Mountain environment; mountain development; agricultural intensification; agritourism; specialty crop.

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Introduction

The northeastern region of Thailand (14–19°N, 101–106°E), although mostly covered by undulating terrain, contains 4 major mountain ranges with an area of about 25,000 km² (about 15% of the region's total land surface; Jarvis et al 2008). These mountains are home to almost 700,000 people (Department of Provincial Administration 2011). All major rivers in the region arise in the mountains, which are also important sources of raw materials, including timber and minerals. Although the mountains are recognized as constituting a distinctive agroecological zone within the region (Limpinuntana 2001), and although agriculture is the most important economic activity there, mountain agriculture has received little attention from researchers. This paper represents an initial attempt to fill this knowledge gap by describing the environmental and social characteristics of the mountains, identifying the main crops grown in different ranges, and examining factors influencing their spatial distribution. It then compares agriculture in the northeastern mountains with the better-known agriculture of the mountains of the northern Thailand. Finally, it examines some constraints and opportunities

for agricultural development in the northeastern mountains.

Methodology

In the Lao language spoken in most of northeastern Thailand, "mountain" (*phu*) refers to any landscape feature that is significantly higher than the surrounding relief. The distinction between mountains and "hills" (*nern khao*) is not clearly drawn, and all features of higher relief are likely to be called *phu*. The term "uplands," which is often encountered in descriptions of northeastern agriculture, does not refer to hills or mountains but instead is applied to those areas in the undulating terrain of the Khorat Plateau that are too high for construction of paddy fields and are instead used to grow dryland cash crops, such as cassava and sugarcane (Limpinuntana 2001). For the purpose of this research, "mountains" were defined as any land surfaces that rise higher than 300 meters above mean sea level (mamsl). Although this is a relatively low elevation threshold compared to mountains elsewhere in the world, in northeastern Thailand it effectively delineates the base of each of the main mountain ranges. A map of mountain areas in

northeastern Thailand was drawn using the digital elevation model (DEM) available through the Consortium for Spatial Information (Jarvis et al 2008). The area covered by mountains was calculated using the Reclassify tool in ArcGIS version 10.1 (Esri) geographical information software.

The administrative boundaries of mountainous subdistricts (*tambol*; defined as those subdistricts that have more than 50% of their total surface area with an elevation higher than 300 mamsl) were then plotted with ArcGIS using the administrative map at the subdistrict level in the shapefile format made by the Department of Environmental Quality Promotion, Ministry of Natural Resources and Environment.

Data on elevation and slope were obtained from the DEM. Geological, soil, and climatic data were obtained from provincial maps in the shapefile format (Department of Environmental Quality Promotion 2000; Office of Land Use Policy and Planning 2010). Data on climate, natural vegetation, and population were obtained from online government databases (Department of National Parks, Wildlife and Plant Conservation 2007; Department of Provincial Administration 2011; National Statistics Office 2013). These data were used to generate maps of topography, geology, soil, rainfall, and population density and to compile statistical tables. Information on distribution of crops was correlated with maps of environmental characteristics (topography, geology, soil, and rainfall) using ArcGIS.

Information about the areas devoted to agriculture and forests and the area under each crop was obtained from online government databases and local government offices (Office of Soil Resources Survey and Research 2008; District Office of Agriculture 2010). From December 2010 to May 2011, field trips were made to each of the mountain ranges to observe the pattern of land use and the occurrence of specific crops. Data on the production and marketing systems for each type of crop, including yields, methods of marketing, and prices received by the farmers, were collected in semistructured interviews with 30 farmers, 7 farmworkers, 8 businesspeople, and 6 local officials.

Physical, environmental, and social characteristics of the mountains in northeastern Thailand

The northeastern mountains are conventionally divided into 5 distinct ranges: Phetchabun, Dong Phrayayen, Sankamphaeng, Phanom Dongrak, and Phu Phan (Jintasakun 1985; Kunirat 1987). The Dong Phrayayen and the Phanom Dongrak ranges are not described in detail in this paper because only small areas of these ranges are used for agriculture. Because the northern and southern parts of the Phetchabun Range are physically and

ecologically quite different, they are treated in this study as two separate ranges. Thus, this study is focused on 4 mountain ranges: the northern Phetchabun, southern Phetchabun, Sankamphaeng, and Phu Phan (Figure 1). The main physical and environmental characteristics of these ranges are summarized in Table 1.

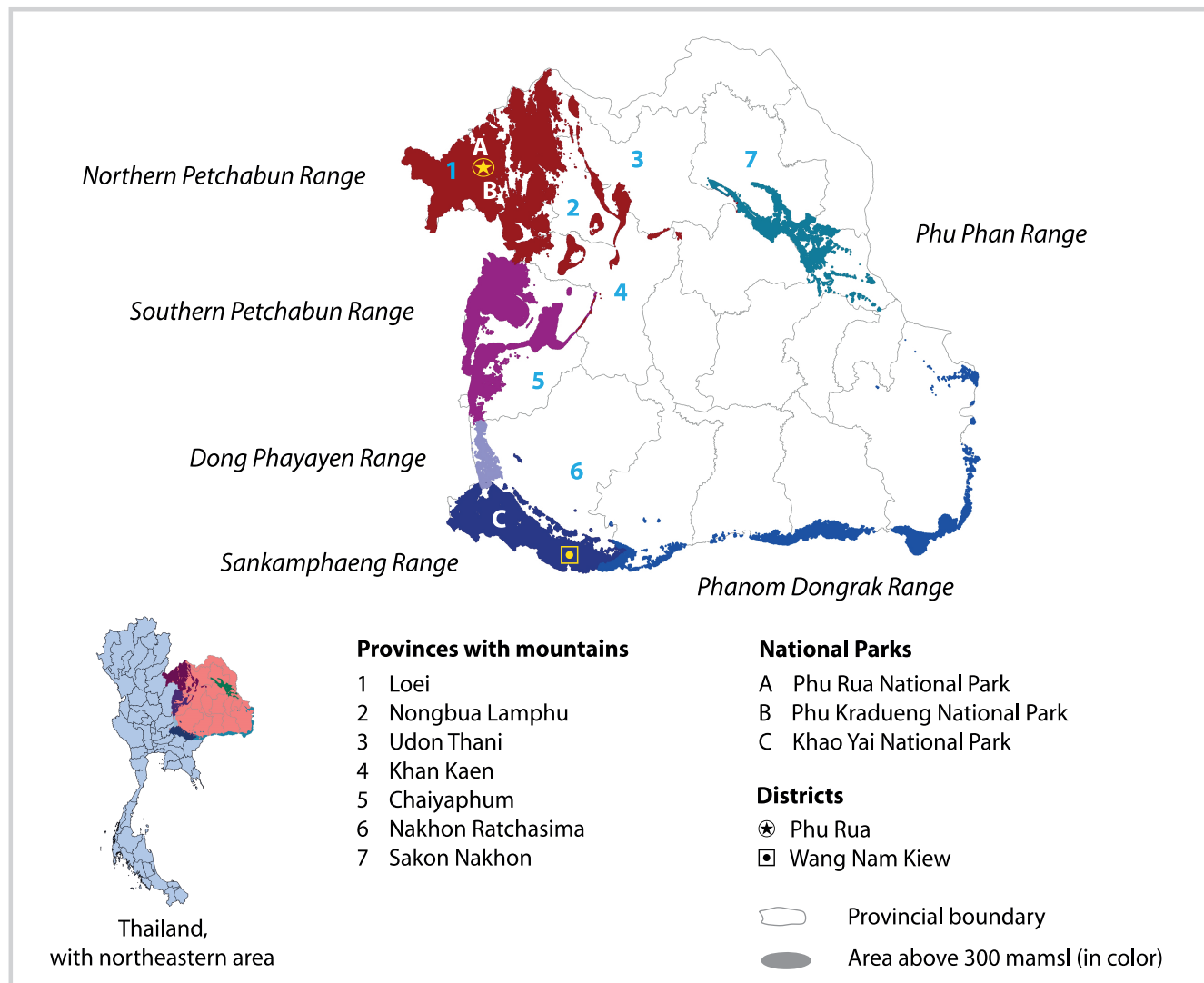
Elevations range from 300 to 2500 mamsl. The highest level at which people live is about 900 mamsl, with higher areas mostly covered by conservation forest. Two thirds of the mountain land has a slope of less than 8%, which, according to the Food and Agriculture Organization's land suitability classification system, does not constrain agriculture (Huddleston et al 2003).

The mountains are mostly composed of sandstone, shale, and granite, which produce infertile soils, but there are a few areas of limestone in the northern Phetchabun Range with more fertile soils. The soils in the mountains are diverse, belonging to more than 40 soil series, but about 40% of the area is classified as belonging to an undifferentiated "slope complex." In general, the mountain soils are shallow, are infertile, and have a low water-holding capacity, so they are considered only suitable for forests (Land Development Department 2005).

The climate is tropical savannah, according to the Köppen climate classification (Mongkolsawat et al 1994), with the rainy season occurring from May through September and a prolonged dry season during the remainder of the year. Average annual rainfall for each range for a 13-year period (2000–2012) is shown in Table 1. However, as is the case in most of the northeastern region, the amount of rainfall is highly irregular from year to year (Limpinuntana 2001). Thus, the Phu Phan Range is the wettest range, with an average annual rainfall of 1724 mm, but it had a minimum of 1301 mm in 2003 and a maximum of 2142 mm in 2008. Sankamphaeng is the driest range, with an average annual rainfall of 1143 mm; the maximum annual rainfall was 1470 mm in 2010, and the minimum was 767 mm in 2001 (National Statistics Office 2013). Average temperatures are also shown in Table 1. Although the mean minimum temperature in the northern Phetchabun Range is 9.3°C, temperatures as low as 0.1°C have been recorded occasionally at higher elevations (Northeast Meteorological Center [Lower Part] 2010b), and occurrences of hoarfrost are often reported in Thai newspapers. The minimum temperature in other ranges never goes below 0°C, although on rare occasions, the Phu Phan Range has recorded temperatures just above freezing.

The natural vegetation includes moist evergreen forest, dry evergreen forest, hill evergreen forest, dry dipterocarp forest, mixed deciduous forest, and coniferous forest (Department of National Parks, Wildlife and Plant Conservation 2007). Dry dipterocarp forest covers more than 50% of the total forest area of the

FIGURE 1 Location of mountain areas in northeastern Thailand. (Map by Sukanlaya Choenkwan)



region, while about 35% of the area is covered by dry evergreen forest (Sutthisrisinn and Noochdumrong 1998). In 2008, forestland and cultivated land covered approximately equal shares (47.5% each) of the mountain area, while other land uses, such as residential areas and water bodies, accounted for about 5% (Office of Soil Resources Survey and Research 2008). The proportions of forest and protected areas (eg national parks and wildlife sanctuaries) are shown in Table 1.

Administratively, the study area comprises 94 subdistricts in 26 districts in the 7 provinces of Chaiyaphum (southern Phetchabun), Loei, Khon Kaen, Udon Thani and Nongbua Lamphu (northern Phetchabun), Nakhon Ratchasima (Sankamphaeng), and Sakon Nakhon (Phu Phan). There were 672,067 inhabitants in these subdistricts in 2011, with a mean population density of 58 people/km² (compared to 129

people/km² for the whole northeastern region; Department of Provincial Administration 2011). The highest population density is 161 people/km² in a subdistrict in the Sankamphaeng Range, and the lowest population density is 14 people/km² in a subdistrict in the northern Phetchabun Range. However, the average population density of all ranges is similar, ranging from 54 people/km² in the northern Phetchabun Range to 69 people/km² in the Sankamphaeng Range.

Speakers of the Lao Isan dialect of the Thai language family constitute the majority population in the mountains (Lewis et al 2013). There are also several minority ethnic groups in different ranges, including the Tai Loei in the northern Phetchabun Range and the Kalaeng, Nyaw, and Phu Tai in the Phu Phan Range. The people in the southern Phetchabun Range are mainly Lao Isan, whereas those in the Sankamphaeng Range are

TABLE 1 Physical and environmental characteristics of the mountain ranges in northeastern Thailand.

Biophysical features		Mountain ranges			
		Northern Phetchabun	Southern Phetchabun	Sankampaeng	Phu Phan
Elevation ^{a)} (mamsl)	Maximum	1795	1007	1322	570
	Mean	512	430	423	344
Slope ^{a)} (% of total mountain range land)	<8%	63	79	64	84
	8%–<16%	35	20	34	16
	≥16%	2	1	2	0
Rainfall (13-year average) ^{b)}	Annual (mm)	1321	1225	1143	1724
	No. rainy d/y	125	103	111	133
	Daily maximum (mm)	93	91	94	117
Temperature (°C; 13-year average)	Mean maximum ^{b)}	40.4	40.0	39.3	39.7
	Mean minimum ^{b)}	9.3	13.2	12.6	10.6
	Daily maximum ^{c)}	43.1	42.6	42.7	43.9
	Daily minimum ^{d)}	0.1	6.3	4.6	0.5
Land cover (%)	Forest as share of total mountain land area ^{e)}	49	44	47	51
	Protected area as share of total forest land area ^{e),f)}	55	35	58	82
	Agriculture as share of total mountain land area ^{e)}	49	51	43	40
	Residential areas and water bodies ^{e)}	2	5	10	9

^{a)}Jarvis et al 2008.^{b)}National Statistics Office 2013.^{c)}Northeast Meteorological Center (Lower Part) 2010a.^{d)}Northeast Meteorological Center (Lower Part) 2010b.^{e)}Office of Soil Resources Survey and Research 2008.^{f)}Office of Land Use Policy and Planning 2010.

mostly Central Thai, along with a small group of Korat Thai (Premsrirat et al 2004). All of these ethnic groups belong to the T'ai language family, share many cultural patterns, and generally follow similar agricultural practices (Timsuksai 2014).

Types of crops grown in the northeastern mountains

Three types of crops—field crops, tree crops, and specialty crops—are cultivated (Table 2). About 88% of the total agricultural area is occupied by field crops, which include maize, cassava, wet rice, hill rice, sugarcane, soybeans, and Job's tears. Tree crops, including rubber, eucalyptus, teak, and local varieties of fruit trees (eg sweet tamarind, mango, custard apple, banana, orange, and

lychee), account for about 11% of the area, while specialty crops, including exotic fruits (0.5%), vegetables (0.1%), and flowers (0.1%), cover less than 1%. Detailed information about the main crops grown in the mountains is presented in Table 3.

Field crops

Field crops include maize, cassava, and sugarcane, which have been planted in mountains areas for more than 50 years. These crops are mostly planted as monocultures in large fields, but in a few areas maize and cassava are interplanted with fruit trees or rattan (Figure 2). The average maize yield for all ranges is about 5000 kg/ha compared to the regional average of 3625 kg/ha (Office of Agricultural Economics 2010). Farmers sell maize to middlemen, who come to the farms to purchase it, or to

TABLE 2 Agricultural land use in each mountain range in the mountains in northeastern Thailand.

Type of crops	Mountain ranges ^{a)}				All mountain ranges (%) ^{a)}
	Northern Phetchabun (%)	Southern Phetchabun (%)	Sankamphaeng (%)	Phu Phan (%)	
Field crops					
Rice	16.0	10.1	4.6	15.6	12.4
Maize	34.6	7.8	41.2	—	31.2
Sugarcane	8.5	5.9	11.6	2.0	8.7
Cassava	9.7	37.2	24.9	43.6	18.3
Soybean	—	—	0.5	0.5	0.1
Job's tears	0.1	—	—	—	0.0
Hill rice	0.1	—	—	—	0.1
Unclassified	18.7	37.0	0.6	34.4	17.7
Total	87.6	98.0	83.5	96.1	88.5
Tree crops					
Rubber	3.3	0.7	ND ^{b)}	ND ^{b)}	2.1
Eucalyptus	0.2	1.3	1.3	3.1	0.7
Teak	0.9	ND ^{b)}	0.3	ND ^{b)}	0.6
Orange	0.1	—	—	—	0.1
Lychee	0.1	—	—	—	0.1
Mango	0.3	ND ^{b)}	6.9	ND ^{b)}	1.8
Custard apple	—	—	5.8	—	1.3
Banana	2.0	—	—	—	1.1
Sweet tamarind	4.2	ND ^{b)}	0.7	0.2	2.7
Longan	1.0	—	0.1	0.4	0.6
Total	12.1	2.0	15.1	3.7	11.0
Specialty crops					
Edible rattan	—	—	—	ND ^{b)}	—
Exotic fruits	0.5	—	0.9	—	0.5
Vegetables	ND ^{b)}	—	0.7	—	0.1
Flowers	ND ^{b)}	—	0.3	—	0.1
Mushrooms	ND ^{b)}	—	ND ^{b)}	—	—
Total	0.5	—	1.9	0.1	0.7

^{a)}%, percentage of total agricultural land area occupied by each crop.

^{b)}ND, no data; however, crop was observed in field surveys.

Source: Office of Soil Resources Survey and Research 2008.

TABLE 3 Some important crops in the mountains in northeastern Thailand. (Table continued on next page.)

Crop	Location	Share of mountain agricultural land	Cropping system	Marketing system	Price paid to farmer ^{a)}
Maize	All ranges	31%	Mostly monoculture	Sold to middlemen, who come to the farms to purchase it, or directly to warehouses located in the area	US\$ 0.13–0.26/kg
Cassava	All ranges	18%	Mostly monoculture	Sold directly to warehouses located in the area	US\$ 0.03–0.06/kg
Sugarcane	All ranges	9%	Monoculture	Sold directly to nearby sugar mills	US\$ 0.02–0.03/kg
Rubber	All ranges	2%	Mostly monoculture but sometimes interplanted with crops such as cassava and rattan	Sold as uncured balls of dried latex to middlemen	US\$ 1.10–1.90/kg
Fruit trees (eg oranges, lychees, mangoes, custard apples, bananas, sweet tamarinds, and longans)	All ranges	8%	Monoculture or interplanted with other kinds of fruit trees or maize, cassava, or rattan	Sold directly in the market or to middlemen, who come to the farms to purchase it	US\$ 0.16–1.10/kg
Edible rattan (<i>Calamus</i> sp.)	Phu Phan Range	No data	Monoculture or interplanted with rubber, fruit trees, or cassava	Sold to middlemen from nearby provinces, who purchase the shoots directly from the farmers	US\$ 0.06–0.13/shoot
Grapes (table grapes and wine grapes)	Northern Phetchabun Range/ Sankamphaeng Range	0.1%	Monoculture	Wine grapes sold to middlemen; table grapes sold directly to tourists	Wine grapes US\$ 1.20–1.50/kg; table grapes US\$ 5.80–6.50/kg
Exotic flowers and ornamental plants (eg marigolds, China pinks, roses, white Christmas flowers, hydrangeas, poinsettias, bromeliads, African violets, petunias, and phlox)	Northern Phetchabun Range/ Sankamphaeng Range	0.1%	Grown in black plastic bags set on the ground in plots located along the road; some plots are open air, while others have plastic- or shade cloth-covered shelters	- Sold as potted plants - Sold as cut flowers - Purchased as plants in the field by sellers from provinces such as Chiang Mai, Khon Kaen, and Bangkok - Delivered to consumers if they submit advance orders - Sold directly to tourists	US\$ 0.10–3.20/pot

TABLE 3 Continued. (First part of Table 3 on previous page.)

Crop	Location	Share of mountain agricultural land	Cropping system	Marketing system	Price paid to farmer ^{a)}
Temperate vegetables (eg kale, several varieties of lettuce, spinach, broccoli, carrots, kohlrabi, leeks, spring onion, cucumbers, cauliflower, Chinese cabbage, Chinese radish, green peppers, and Chinese kale)	Northern Phetchabun Range/ Sankamphaeng Range	0.2%	Grown in beds	Sold to vendors in local markets, restaurants, and homestays, as well as directly to tourists	US\$ 1.90–3.20/kg
Mushrooms (shiitake, <i>Lentinus edodes</i> ; black poplar, <i>Agrocybe cylindracea</i> ; <i>eryngii</i> , <i>Pleurotus eryngii</i> ; and local varieties <i>Hedkhonkhao</i> , <i>Lentinus squarrosulus</i> Mont., and <i>Hedkhradang</i> , <i>Lentinus polychrous</i> Lev.)	Northern Phetchabun Range/ Sankamphaeng Range	About 20 mushroom farms	Grown in special packs placed inside purpose-built mushroom houses	Sold to vendors who have stalls along the roadside, in the local market, or directly to tourists	Local varieties US\$ 1.60–1.90/kg; shiitake, black poplar, <i>eryngii</i> US\$ 5.80–7.10/kg

^{a)}1 Thai baht = US\$ 0.0324 in September 2013.

Source: Interviews with farmers, farmworkers, and business owners.

nearby agricultural warehouses for US\$ 0.13–0.25/kg. The average cassava yield for all ranges is 19,500 kg/ha, compared to the regional average of 20,500 kg/ha (Office of Agricultural Economics 2010). Farmers sell cassava to agricultural warehouses for US\$ 0.03–0.06/kg. The average yield of sugarcane in the mountains is 63,000 kg/ha, compared to a regional average of 69,000 kg/ha (Office of Agricultural Economics 2010). The price paid for sugarcane at local mills is about US\$ 0.03/kg.

Tree crops

Tree crops include rubber, eucalyptus, teak, and local varieties of fruit trees, such as oranges, lychees, mangoes, custard apples, bananas, sweet tamarinds, and longans. Rubber is the most widespread plantation crop, although it was only introduced to the mountains about 20 years ago. It is planted both by local people and by experienced rubber farmers who have come to the northeastern region from the southern region (Tongkaemkaew 2013). Rubber mostly is grown as a monoculture, but while the trees are small many farmers interplant cassava or rattan with the rubber. Mature rubber plantations yield 1250–1600 kg of dry latex/ha, which the farmers sell to middlemen as uncured balls for US\$ 1.13–1.90/kg. The main kinds of fruit trees grown in the mountains are sweet tamarind,

mango, and custard apple. These trees are planted in monocultural plantations or are interplanted with other species of fruit trees or with maize, cassava, or rattan. Sweet tamarind yields 1250–1900 kg/ha, which sell for US\$ 1.10/kg, and custard apple and mango yield 6300–9400 kg/ha, with a price of US\$ 0.90/kg for custard apple and US\$ 0.80/kg for mango.

Specialty crops

Specialty crops include edible rattan, grapes, exotic flowers and ornamental plants, temperate vegetables, and mushrooms.

Edible rattan: Edible rattan, which is grown only in the Phu Phan Range, was originally collected from wild plants in the forest but has been domesticated for the past 10 years. Recently, the area of rattan has sharply decreased because farmers prefer to grow rubber, which earns much higher profits. Rattan is planted as a monoculture or is interplanted with other crops, such as rubber, fruit trees, or cassava. Rattan yields about 19,000–20,000 shoots/ha, which are sold for US\$ 0.06–0.10/shoot at the farm gate to middlemen from nearby provinces or to local vendors who have roadside stalls.

Grapes: Both table grapes and wine grapes are grown on both large and small vineyards in the northern Phetchabun

FIGURE 2 Mountain landscape in the Phu Phan Range showing cassava field, paddy field, and rubber trees. (Photo by Sukanlaya Choenkwan)



and Sankamphaeng ranges. Some vineyards are part of resorts, have their own wineries, and offer free tours for visitors. They also offer overnight accommodations for tourists and have spas, restaurants, and shops selling their products. Other large vineyards have no accommodations or restaurants but offer visitors free tours and wine tasting at the big shops where they sell their products. Table grapes are planted in small vineyards along the roadside. They often have small shops that sell fresh grapes, grape juice, and jelly directly to tourists. Table grapes yield 2500–6300 kg/ha and are sold for US\$ 5.80–6.50/kg.

Exotic flowers and ornamental plants: Several varieties of exotic flowers and ornamental plants are grown mainly in small farms in the northern Phetchabun Range. These farms, which were established beginning 20 years ago, are located along the roadside, making it convenient for middlemen to buy their products. Farmers can produce about 31,000–38,000 pots/ha, which are sold for US\$ 0.10–3.24/pot.

Temperate vegetables: Temperate vegetables (eg kale, several varieties of lettuce, spinach, broccoli, carrots, kohlrabi, leeks, spring onions, cucumbers, cauliflower, Chinese cabbage, Chinese radishes, green peppers, and Chinese kale) are mostly grown on small farms in the Sankamphaeng Range. These farms are often located next to homestay places or resorts to help attract tourists. Some resorts and homestays use the vegetables grown on these farms in preparing meals for their guests. Yields vary from 12,500–18,700 kg/ha. Vegetables are sold to vendors in local markets, restaurants, resorts, and homestays, as well as directly to tourists, for US\$ 1.90–3.24/kg, depending on variety and season.

Mushrooms: Small mushroom farms are found in both the Sankamphaeng and the northern Phetchabun ranges. Mushrooms yield 12,500–15,500 kg/ha. They are sold to vendors who have stalls along the roadside, in the local market, or directly to tourists who visit the farms for US\$ 1.60–1.90/kg for local mushrooms and US\$ 5.80–7.10/kg for shiitake, black poplar, and eryngii mushrooms. Most

farms are small, but there is one large farm in the Sankamphaeng Range that raises mushrooms in air-conditioned buildings. Visitors are allowed to observe the production system on the farm. Besides producing fresh mushrooms, the farm processes mushrooms into sauce, paste, ice cream, sausages, and dried forms. This farm has a shop to sell its products directly to tourists. Customers can also order the products online.

Spatial distribution of crops and probable factors influencing their distributions

As Table 2 shows, the spatial distribution of crops differs among the different ranges, reflecting the influence of various factors, including soil quality, temperature, and transportation time and cost. Maize is mostly planted in the northern Phetchabun and Sankamphaeng ranges, which have more fertile soils, whereas cassava is largely planted in the poorer soils of the southern Phetchabun and Phu Phan ranges. Sugarcane is widely grown in all ranges except the Phu Phan Range, which has no sugar mills nearby. Rubber is widespread in the northern Phetchabun, southern Phetchabun, and Phu Phan ranges, with only a small area in the Sankamphaeng Range, because farmers there can earn high income from growing specialty crops, in combination with tourism. Local varieties of fruit trees are planted in all mountain ranges but primarily in the northern Phetchabun and Sankamphaeng ranges. Sweet tamarind is largely planted in the northern Phetchabun Range, whereas custard apple is widely planted in the Sankamphaeng Range. Specialty crops, such as exotic flowers and ornamental plants, temperate vegetables, grapes, strawberries, and shiitake mushrooms, are found only in the northern Phetchabun and Sankamphaeng ranges, where they are often associated with tourism. Many factors favor growing specialty crops in the northern Phetchabun and Sankamphaeng ranges, including having optimum temperatures for these temperate species of plants. They are also endowed with beautiful scenery and pleasant climates that make them attractive destinations for tourists, have good-quality roads, and are easy to get to from Bangkok. Moreover, governmental agencies in both areas have attempted to promote agritourism to stimulate economic growth.

Comparison of mountain agriculture in the northeastern and northern regions of Thailand

When mountain agriculture in Thailand is mentioned, the image that is likely to spring to mind is of colorfully garbed hill tribe people planting opium or upland rice on swidden fields on the steep slopes of the high mountains that cover 80% of the northern region of the country. Numerous books, papers, and reports have been written describing the many types of shifting cultivation systems that were formerly practiced by different ethnic groups

living in different altitudinal zones (eg Kunstadter and Chapman 1978; Forsyth 1995; Rerkasem 1995; Turkelboom et al 1995). This image is largely outdated because, as a result of a multitude of agricultural development programs carried out by the Thai government, international aid agencies, and nongovernmental organizations (Dearden 1995; Jian 2001; Tungittiplakorn and Dearden 2002), northern mountain agriculture has been largely transformed into cash cropping on permanent fields (Van Keer et al 1998; Trebuil et al 2006). Hill tribe people still cultivate crops on the steep slopes but are now far more likely to plant cabbages than to plant poppies.

The mountains of northeastern Thailand are different from those in the north; consequently, development of mountain agriculture in the northeast needs to be understood in its own terms. The northeastern mountains cover only 15% of the area of the region and are relatively low and flat. The highest level at which people live is about 900 mamsl, whereas in the northern mountains people live as high as about 1500 mamsl. Most of the land in the northeastern mountains has a slope less than 8%, whereas most of the land in the northern mountains has a slope greater than 35%. Soils in the northeastern mountains are generally less fertile and temperatures are considerably warmer than in the north, which may explain why cultivation of cabbages for sale in lowland markets, which is now widely practiced by northern hill tribe farmers, occurs in the northeastern mountains in only one limited area in the northern Phetchabun Range. Ethnic diversity is limited, because the mountains are inhabited mostly by people who are culturally similar to the lowland Thai-Lao people. There is little or no swidden agriculture, and the crops grown in the permanent fields are mostly the same as the main crops planted in the surrounding lowlands. These include paddy rice, maize, cassava, sugarcane, and rubber. The main characteristic that distinguishes mountain agriculture from lowland agriculture in the northeast is the cultivation of high-value specialty crops, including temperate vegetables, exotic flowers, grapes, and strawberries, that cannot be grown in the lowlands. Although the area covered by such crops is still small, it is gradually expanding. This shift to specialized mountain agriculture primarily results from the efforts of private entrepreneurs because, in contrast to the north, few government programs are targeted at the development of mountain agriculture in the northeast.

Constraints on agricultural development in the northeastern mountains

Development of agriculture in the northeastern mountains is constrained by several factors, including poor-quality soils, seasonality and variability of rainfall, scarcity of surface water, steep slopes, land scarcity, land tenure insecurity, and competition from foreign imports.

FIGURE 3 Farmer watering a vegetable plot in the Sankamphaeng Range. (Photo by Sukanlaya Choenkwan)



Soils in the mountains are predominantly rocky, shallow, and infertile; have a low water-holding capacity; and have high erosion rates, which limit their suitability for agriculture (Vityakon et al 2004). To maintain soil quality and productivity, farmers have to apply large amounts of chemical fertilizer, which increases production costs. Water is also frequently a limiting factor on mountain agriculture. The occurrence of a prolonged dry season and the irregular pattern of rainfall during the rainy season are major constraints on growing high-value crops such as exotic flowers and temperate vegetables, which require frequent watering (Figure 3). So, to produce these crops, farmers often have to invest in costly irrigation systems.

The broken terrain and steep slopes in the mountains inhibit mechanization and increase transportation costs. Use of farm machinery in agriculture is limited by the prevalence of sloping land. For example, farmers cultivating maize on steep slopes in the northern Phetchabun Range must use human labor for most production steps, including sowing using dibble sticks,

applying fertilizer, and harvesting. Harvesting is difficult because the farmers have to carry heavy maize sacks on their backs on steep mountain trails. Usually, they hire neighbors to do this work for about US\$ 7.00/day. Even in areas with good roads, the steep terrain greatly increases travel time and transportation costs to lowland markets for mountain crops.

The scarcity of suitable land also constrains development of mountain agriculture. Because almost half of the mountain area is covered by protected forests and national parks, the amount of land legally available for cultivation is limited, and many farmers have encroached on protected areas, which has resulted in serious conflicts with the government. In some areas in the Sankamphaeng Range, the government has physically evicted agritourism enterprises that have illegally encroached on national park land. Even in areas where agriculture is allowed, farmers in the mountains have difficulty obtaining legal title to their land. In contrast to the lowlands, where most farmers have secure land titles,

official documents have only been issued in 35% of mountain subdistricts. Consequently, farmers cannot borrow money using their land as collateral to make long-term investments in agriculture (Thapa and Rasul 2005).

Even though many high-value temperate crops can be grown successfully in the mountains of the northeast, the cost of the production of some of these crops is higher than in the temperate countries because of environmental limitations. Consequently, these crops were only profitable as long as the Thai government followed protectionist trade policies that favored high-cost local products. After adoption of World Trade Organization rules opened Thai markets to cheap foreign imports, growing of some crops, such as wine grapes, was no longer profitable. On one formerly prosperous vineyard in the northern Phetchabun Range, large areas of vineyards have been abandoned.

Although many of these constraints on mountain agriculture, eg poor soils, seasonal rainfall, and steep terrain, are essentially fixed, some factors are subject to human modification. For example, changes in government policies allowing farmers to develop agritourism in buffer areas of national parks and providing them with more secure land titles could create a more favorable environment for mountain agriculture.

Potential opportunities for mountain agricultural development

The mountains have a distinct climatic advantage for the production of high-value temperate vegetables and fruits, which cannot be produced in the lowlands. Some areas in the northern Phetchabun and the Sankamphaeng ranges can produce high-value crops, including strawberries, table grapes, macadamia nuts, exotic flowers and ornamental plants, temperate vegetables, and mushrooms, that are highly desired by lowland consumers. Although the area devoted to such crops is quite small, considerable expansion is possible; roughly one third of the agricultural land that is planted with low-value field and tree crops in these two ranges has

conditions suitable for growing higher-value specialty crops.

The mountains also have beautiful scenery; many famous tourist spots, such as Khao Yai, Phu Kradueng, and Phu Ruea national parks; and a favorable climate that makes them an attractive destination for tourists. For example, the Wang Nam Kiew district in the Sankamphaeng Range and the Phu Ruea district in the northern Phetchabun Range attract many tourists who like to buy locally grown agricultural products, which benefits farmers by reducing their cost of shipping crops to lowland markets and allowing them to capture a higher share of the profit by eliminating middlemen. Tourism can create new sources of income for rural people who establish restaurants and homestays, as well as creating new employment opportunities for members of farm households to work as employees at enterprises catering to tourists. Because agritourism requires both suitable environment for growing temperate vegetables, flowers, and fruit, and suitable scenery to attract tourists, only a limited area has potential for further development of this highly profitable type of mountain agriculture.

Conclusions

Although Thailand's northeastern mountains cover only a relatively small share of the northeastern region, they support diverse types of agriculture. Because of their distinctive environmental conditions, the mountains offer unique opportunities for agricultural development, especially growing specialty crops, which can generate high income and serve as magnets for tourism. However, so far, only small areas have been used for this purpose, and most of the agricultural land in the mountains is still used for low-value crops, which can be grown equally well in the lowlands. Therefore, to develop agriculture in the mountains, farmers should be encouraged to take advantage of their unique agricultural environment by growing more specialty crops and establishing agritourism facilities. However, it must be recognized that limited supply of land and insecure land tenure remain serious obstacles to expansion of mountain agriculture.

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Does Agrotourism Benefit Mountain Farmers? A Case Study in Phu Ruea District, Northeast Thailand

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Agrotourism is widely advocated as a useful strategy to develop mountain agriculture and improve farmers' income and quality of life. However, the relationship between agriculture and tourism is complex, and the extent to which

tourism benefits farmers remains uncertain. This paper examines the relationship between agriculture and tourism and assesses to what extent agrotourism benefits farmers in Phu Ruea district, a popular tourist destination in the mountains of northeast Thailand. The Phu Ruea agrotourism system generated gross income for the district of almost US\$ 16 million in 2014. About 80% of this income came from sales from specialty-crop farms and of tourism services operated by the households of local farms. The agrotourism

system also created many employment opportunities for local people. There were 1500 people directly involved in the system, 90% of whom were farmers or members of farm households. Thus, there is no doubt that many local farmers derive significant benefits from their involvement in the agrotourism system. Although the Phu Ruea agrotourism system can be seen as a successful strategy for developing mountain agriculture, agrotourism is not a magic strategy to solve all the problems of rural development in the mountains. Only some localities are attractive to tourists, and only some farmers have the knowledge, skills, and resources to take advantage of the opportunities offered by tourism.

Keywords: Mountain area development; agricultural intensification; specialty cropping; agricultural diversification; income flows; employment generation; Thailand.

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Introduction

Agrotourism is a hybrid type of agricultural system that merges elements of farming and tourism to create markets for farm products and services and provide travel experiences for tourists (Wicks and Merrett 2003; Rogerson and Rogerson 2014). Other labels for this system, including "agricultural tourism," "agritourism," "farm tourism," "farm-based tourism," "farm stays," "vacation farms," "agritainment," and "rural tourism," are largely synonymous (Phillip et al 2010; Kokko 2011; Schilling et al 2012; Flanigan et al 2014). Agrotourism, which has existed in Europe, North America, and other parts of the "global North" for many years (Busby and Rendle 2000), has more recently gained growing attention in developing countries, including Thailand (Brscic 2006; Na Songkhla and Somboonsuke 2013; Choo and Petrick 2014; Rogerson and Rogerson 2014; Shaffril et al 2015). Although it would seem to be a useful strategy to develop mountain agriculture and improve farmers' income and quality of life, there has been relatively little research directed at mountain agrotourism in

developing countries, including in Southeast Asia (Ariffin 2014).

The relationship between tourism and agriculture is complex, and the extent to which tourism benefits farmers remains uncertain. Some agrotourism research has found that agriculture and tourism are mutually beneficial (Fleischer and Tchetchik 2005; Choo and Petrick 2014), but other studies have raised questions about the extent to which agriculture and tourism are truly symbiotic. In some cases, tourism may benefit agriculture by creating market opportunities for farmers to sell their products directly to tourists (Hjalager 1996; Srisomyong 2010; Torres and Momsen 2011). It may provide an incentive to farmers to diversify into producing high-value crops to meet new tourist demand (Hermas 1981; Bowen et al 1991; Cox et al 1995; Rilla 2011) and a secondary source of income to farmers who find part-time employment in the tourism service sector (Che and Wargenau 2011; Na Songkhla and Somboonsuke 2012; Schilling et al 2014; Shaffril et al 2015). Jeczmyk et al (2015) also found that around 28% of total farm household incomes were derived from agrotourism

activities. But in other cases, the relationship between agriculture and tourism is not mutually beneficial. Fleischer and Tchetchik (2005) found that agricultural activities did not provide significant benefits for tourism but that farmers benefited from selling their products to tourists at higher prices. Brscic (2006) reported that the development of agrotourism activities in Croatia did not significantly enhance the diversity of crops or improve agricultural production. In some situations, development of tourism was detrimental to local agricultural communities because of competition for labor, land, water, and investment (Torres and Momsen 2011). The tourism sector's high demand for labor and land can divert these resources from the agricultural sector (Bowen et al 1991; Torres and Momsen 2011). The move by farm laborers to work in tourism enterprises had negative impacts on agricultural production in Yucatan, Mexico. The high demand for laborers in the tourism sector meant that farmers had to pay very high wages to attract workers, causing some farmers to give up working in agriculture altogether and others to become part-time farmers (Torres 2011).

In Thailand, agrotourism has been officially promoted since 1999 to generate additional income for farmers, provide new occupations for unemployed people, and enhance local rural economies (Srisomyong 2010). The Department of Agricultural Extension, in cooperation with the Tourism Authority of Thailand, launched an agrotourism project with funding of 125 million baht (approximately US\$ 4 million at the time) to develop and promote agrotourism destinations in several parts of the country (Srisomyong 2010). In 2012, more than 400 villages were officially promoted as agrotourism destinations (Na Songkhla and Somboonsuke 2012). However, although agrotourism has existed in Thailand for more than a decade, no detailed studies of the extent to which it benefits farmers have been published. Similarly, while there is a growing body of literature on many aspects of agrotourism in different countries in the world, relatively little has been published on its benefits, especially to local farmers (Jeczmyk et al 2015).

In this paper, we conceptualize agrotourism as an agricultural system. We identify all key components of the system and the interactions that occur among them, especially flows of cash and labor, using a system approach (Rambo and Sajise 1984; Conway 1985; Marten 1986; McConnell and Dillon 1997). This allows us to measure the extent of both direct and indirect benefits received by farmers. The study was conducted in Phu Ruea district in the mountains of Loei province in northeast Thailand, one of the country's major agrotourism centers.

This study provides detailed empirical information about an important agrotourism site in Thailand that has not been previously described. It also illustrates the use of the agricultural system approach to analyze the structure and functions of an agrotourism system. This study should

be of interest both to the mountain research community and to policy-makers concerned with the development of mountain areas.

Methodology

Study area

Phu Ruea district is located in Loei province (Phu Ruea district office, 17°27'18"N, 101°21'48"E; Figure 1) in the Northern Petchabun mountain range in northeast Thailand. The district covers about 88,800 ha, with 70% of its total land area at an elevation higher than 700 masl (Jarvis et al 2008). The climate is tropical savannah, according to the Köppen classification (Mongkolsawat et al 1994). Average annual rainfall for a 13-year period (2000–2012) was about 1300 mm, with the rainy season occurring from May through September and a prolonged dry season during the rest of the year. The average maximum and minimum temperatures are about 40 and 9°C, respectively (National Statistics Office 2013). The winter season in Phu Ruea is unique in the northeast because of its cold temperatures (a record low of −0.3°C was recorded in 1974). The cold weather and occasional occurrence of hoarfrost (*mae-kaning*), which is often reported in Thai newspapers, are part of what makes Phu Ruea so attractive to Thai tourists from the always-warm lowlands.

There were 18,916 residents living in the district in 2014 (Department of Provincial Administration 2015). Agriculture is the main occupation. Major crops cultivated include maize; cassava; rice; rubber; ginger; fruits such as lychee, longan, sweet tamarind, and strawberries; shiitake mushrooms; and ornamental plants and exotic flowers (Choenkwan et al 2014).

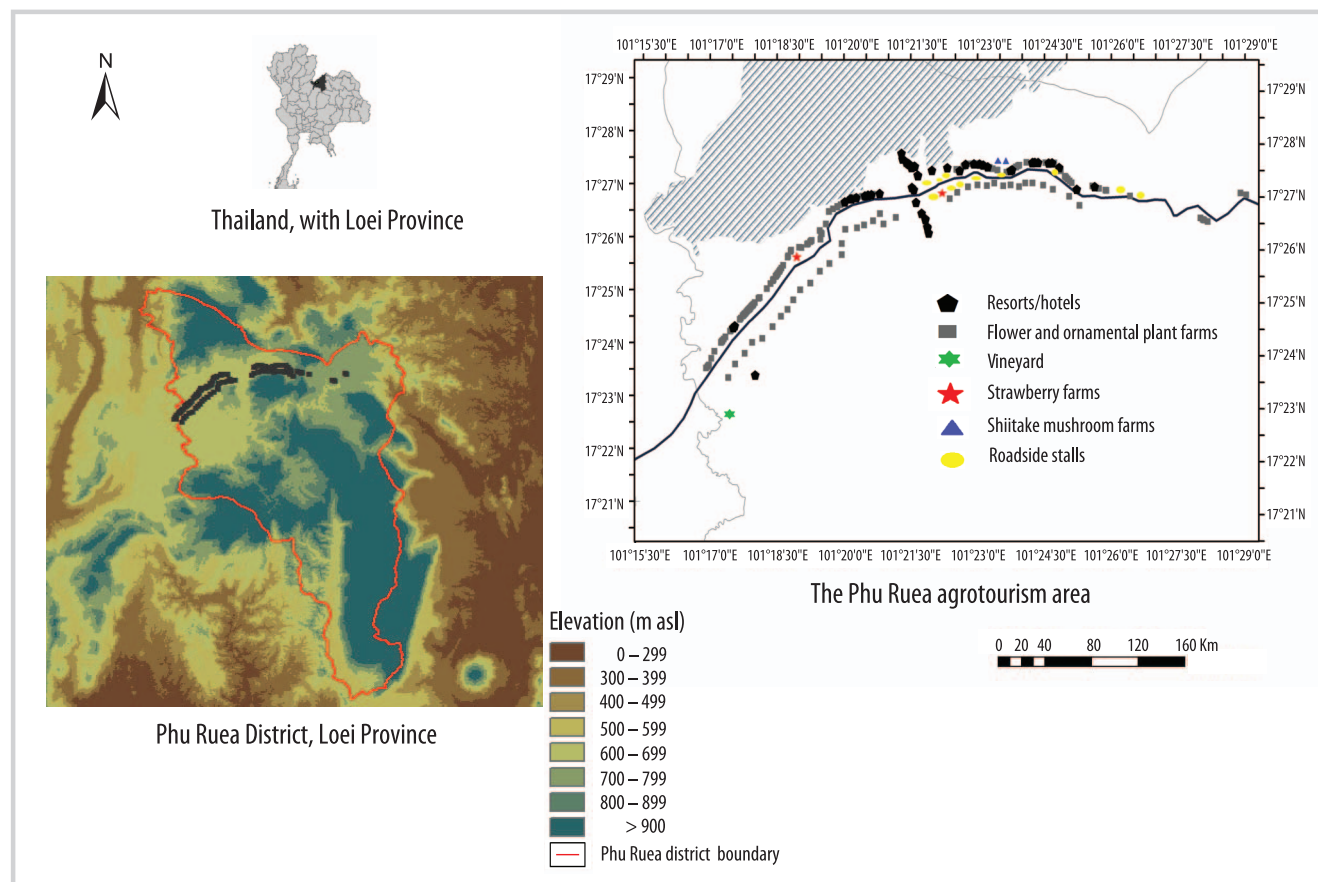
Data collection and analysis

Data for this study were obtained from several sources, including information from government records and offices, onsite observation of specialty-crop farms and agrotourism enterprises, and semistructured interviews with key individual informants. The use of multiple sources and data collection methods was necessary to understand the complex structure and functioning of the agrotourism system in this district.

Information about the background of the study area, agricultural activities, and promotion of agrotourism was obtained from local government agencies, including subdistrict administrative organizations and the Phu Ruea Municipality Office, Phu Ruea District Office of Agriculture Extension, Phu Ruea District Office, Phu Ruea District Office of Community Development, Loei Provincial Office of Agriculture Extension, and Loei Provincial Office of the Comptroller General.

Field research was conducted in the district during January 2014, March 2014, and May 2015 for 2 weeks at a time to investigate how agrotourism functions within Phu Ruea's agricultural system. Detailed information on

FIGURE 1 Location of the Phu Ruea district agrotourism system. (Map by Sukanlaya Choenkwan)



individual farms and tourist enterprises was collected using semistructured interviews with 81 key informants. These consisted of 15 village headmen, 17 specialty-crop farmers, 4 local officials, 40 businesspeople (26 hotel and resort owners, 2 restaurant owners, 2 souvenir shop owners, 5 roadside stall sellers, 3 souvenir producers, and 2 car-rental operators), and 5 hired workers. The farmers, businesspeople, and hired workers were selected because they were knowledgeable and willing to answer our questions. The village headmen were selected from villages that had hotels, resorts, restaurants, and tourist spots. The local officials were selected because they were responsible for agriculture or agrotourism promotion. The interviews consisted of informal conversations with questions about characteristics of activities, expenses and income from the activities, employment opportunities, and number of people engaged in each agrotourism activity. Interviews varied in length from 30 to 120 minutes. Data were entered into a Microsoft Excel database, which included detailed information on each farm and tourist enterprise, ie area, number of employees, length of time in operation, gross income, and costs. This database was used to create a matrix table to examine the interactions among the system components.

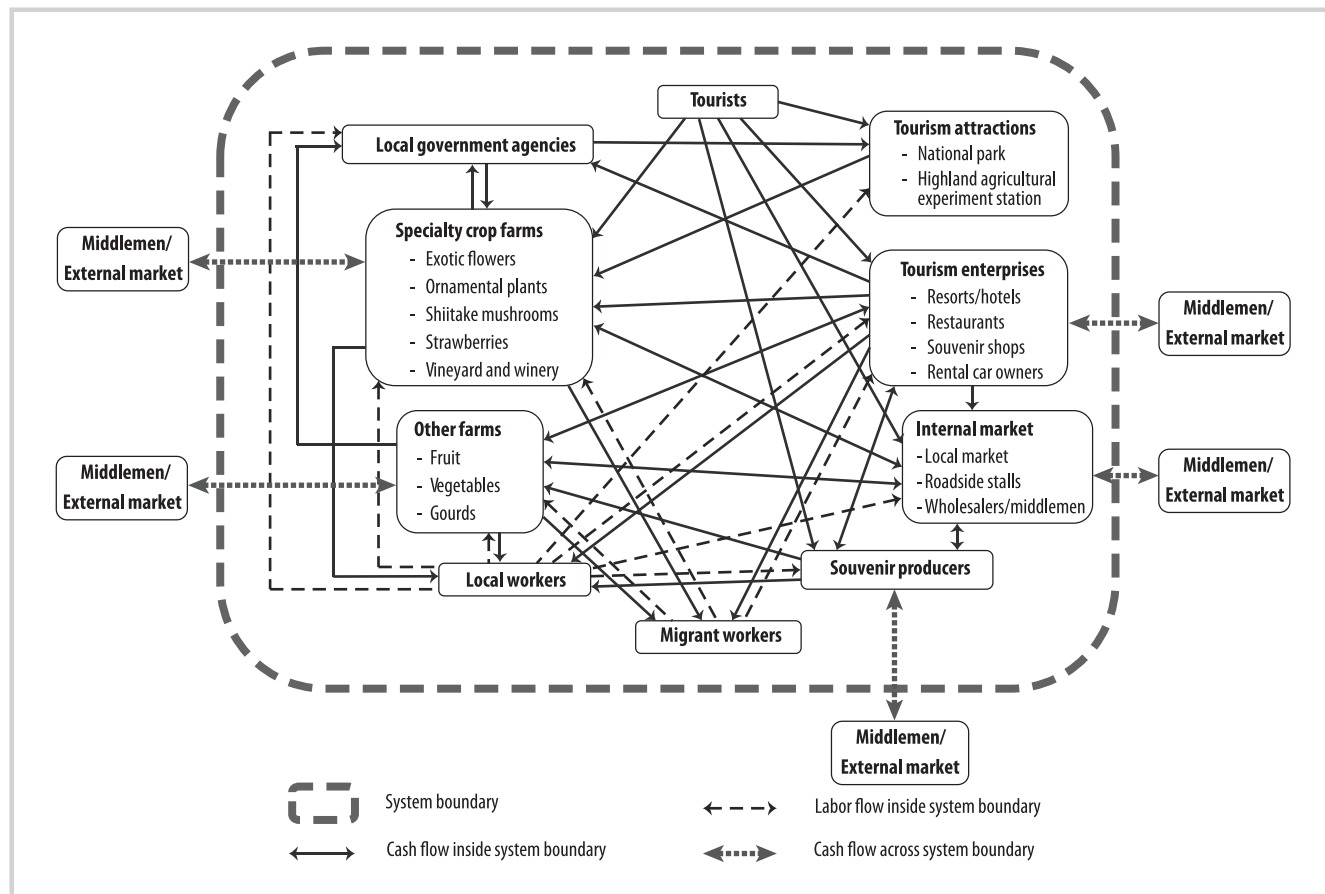
Results and discussion

The history of the development of agrotourism in Phu Ruea

Phu Ruea district has been a popular destination for Thai tourists since the establishment of Phu Ruea National Park in 1979. The district is also well known for growing ornamental plants, exotic flowers, and shiitake mushrooms, as well as for being the site of the country's first large vineyard and winery. These specialty crops have been grown in the district since the early 1990s.

Although Phu Ruea National Park was established in 1979, the first tourism enterprises in Phu Ruea were only started in 1992. According to Chamroonsiri (2002), during 1992–1996, some villagers sold their land to outsiders at a high price. These in-migrants were entrepreneurs who sought to develop new businesses in the area, such as hotels, resorts, restaurants, shiitake mushroom farms, orange orchards, vineyards, and ornamental plant and flower farms. Some people who sold their land became workers on these farms and learned how to grow mushrooms, ornamental plants, and flowers, and later they used their knowledge of these high-value crops to begin growing them on farms that they established on rented land.

FIGURE 2 A model of the Phu Ruea agrotourism system.



The Loei Provincial Agricultural Extension Office officially began to promote agrotourism in Phu Ruea in 2001. The Tourism Authority of Thailand, in cooperation with the Department of Agricultural Extension, launched an agrotourism project to promote agricultural products in conjunction with tourism and thus develop the local economy. Several agrotourism events were initiated under this project, such as the Phu Ruea winter flower festival. In addition, the Phu Ruea Highland Agricultural Experiment Station was established to carry out research on upland crops and serve as a tourist attraction.

The Phu Ruea agrotourism system

Figure 2 is a model showing the cash and labor flows among the components of the agrotourism system within Phu Ruea district. The system boundary is the district border. Key components are the tourists; government agencies and projects promoting agrotourism; specialty-crop farms; other farms; souvenir producers; roadside stalls, souvenir shops, and local markets; tourism service enterprises such as hotels, resorts, and restaurants; and local and migrant hired workers.

Tourists: No reliable figures are available on the number of tourists visiting Phu Ruea each year, but in calendar year 2013, 171,056 tourists, mostly domestic, visited Phu Ruea National Park (Phu Ruea National Park 2014). In addition, officially organized tour groups of 20–30 people each from about 30 government organizations in other parts of the country visited agrotourism destinations in Phu Ruea district (Nong Bua Sub-district Administrative Organization 2014). There were also many tourists who visited the district on privately organized trips but did not enter the national park, so the total number of tourists visiting Phu Ruea may be close to 200,000 per year. Most tourists visited during October to February, and most stayed for only 1 or 2 nights.

Government agencies and projects: Local government agencies, including the Phu Ruea Municipality, several subdistrict administrative organizations, and the Phu Ruea District Agricultural Extension Office, help to promote agrotourism and distribute information to tourists. They provide financial support to farmer groups to develop their farms as agrotourism attractions, coordinate with farmer groups to arrange for visits by tourists, organize

FIGURE 3 Tourists visiting a flower farm. (Photo by Sukanlaya Choenkwan)



Phu Ruea's winter flower festival, and operate a market selling local handicrafts and agricultural products.

The Phu Ruea winter flower festival is held from November to January at a large flower park established by local government agencies. In addition to flower displays, the festival features flower parades and flower competitions. The flowers and ornamental plants used in this festival are bought from flower farms in the district. According to the responsible official, the budget in 2014 for buying these flowers was about US\$ 57,000. This festival also provides a market for farmers to sell their agricultural products, such as ornamental plants, flowers, vegetables, local fruit, shiitake mushrooms, and handicrafts. There are about 50 locally owned shops selling products at this festival.

Specialty-crop farms: Specialty-crop farms are the main agrotourism destinations. The specialty crops grown in Phu Ruea include exotic flowers and ornamental plants, shiitake mushrooms, strawberries, and grapes. There are 209 farms growing exotic flowers and ornamental plants, such as marigolds, China pinks, roses, white Christmas plants, hydrangeas, poinsettias, bromeliads, African violets, petunias, and phlox. These plants help attract tourists to the area by making the landscape more

beautiful. Tourists can visit farms to learn how these plants are grown and buy them directly from farmers (Figure 3). But tourists are not the main customers for the flower farms, which sell most of their products wholesale to middlemen who come to them from all over Thailand. On average, these farms generate only 10% of their income from direct sales to tourists, although some farms sell most of their products directly to tourists. However, many farmers do not like dealing with tourists, complaining that they take up too much of their time and annoy them by bargaining too much. The farmers also have to provide plastic bags for the tourists to carry away the plants, increasing their costs, whereas when they sell to wholesale buyers they do not need to provide bags. One farmer said, "I don't like to sell the flowers to tourists. I have to provide plastic bags for them, which increases my cost and wastes my time. They usually ask for extra and bargain for a low price." Most farmers sell their products to tourists at the same price as to wholesale buyers, but some charge tourists higher prices.

There are 9 shiitake mushroom farms, all operated by a group of closely related families. Shiitake mushrooms are not usually sold directly to tourists, restaurants, and hotels or resorts but are instead marketed through middlemen in local markets and roadside stalls. Because

shiitake mushroom dishes are a signature of Phu Ruea, however, all restaurants, resorts, and hotels buy mushrooms to serve to their tourist customers. The mushrooms are also sold to middlemen in the market in the provincial capital, accounting for about 30% of total sales. Tourists can visit the shiitake mushroom farms to learn about how the mushrooms are grown, and they can buy mushrooms from the farm if any are left over after supplying the middlemen. Most groups visiting the mushroom farms are organized by government organizations from other provinces that want to learn about growing the mushrooms to develop their own localities. They come to Phu Ruea because the shiitake mushroom farmers there have developed ways to control diseases, which are a threat to successful cultivation of this species. The farmers are remunerated by the local government agencies for hosting these visits.

There are 2 small strawberry farms in the district that were established within the past 5 years. The farmers came to the district from northern Thailand, where strawberries have been grown commercially for many years. Tourists can visit the strawberry farms and buy the fruit at roadside stalls close to the strawberry farms. Strawberries are only grown to sell to tourists at a high price.

There is 1 large vineyard and winery that was established in 1995 by a wealthy family from Bangkok. The vineyard and tourism directly benefit each other. Tourists are allowed to drive around the vineyard to observe grape production and taste wine free of charge at the on-farm shop, where they can buy bottles of wine.

Despite their profitability, the number of farms growing specialty crops is limited by many factors. Their cultivation requires specialized skills and knowledge that are difficult to acquire and only a few farmers possess. In the case of flower farmers, they need detailed knowledge of the growing requirements of each species; only a few of them are able to successfully grow roses and poinsettias. Shiitake mushrooms are vulnerable to disease, which only some farmers have the skills to control. Even people who previously worked on mushroom farms, or who attended a training course organized by the district agricultural office before establishing their own farms, were unable to successfully control diseases and therefore stopped growing mushrooms. Growing specialty crops also needs high initial investments. Flower farms also require an abundant supply of water for irrigation and a good location alongside the main road, where they are easily visible to passing vehicles. One farmer who moved her flower farm from inside the village to a site next to the main road said she now has many more customers than before the move. However, the supply of suitable land in the district is limited. Most roadside land is owned by rich people from outside the district from whom most flower farmers rent the land.

Other farms: Other crops related to agrotourism include fruits such as lychees, sweet tamarinds, mangoes, bananas, longans, and dragon fruit and vegetables such as lettuce, cabbage, Chinese cabbage, kale, chili, and yardlong beans. Small quantities of these crops are sold to tourists via roadside stalls, local markets, and restaurants, but most of them are sold wholesale to middlemen from outside of the district. Gourds, which were formerly grown as vegetables consumed by the farmers, are now produced by some farmers to sell to souvenir producers.

Souvenir producers: Souvenirs made in the district include gold- and silver-decorated gourds (Figure 4), knitted clothes, hats and gloves, and Phu Ruea T-shirts and key rings. There are about 100 people producing souvenirs. Some sell their products directly to tourists via roadside stalls, shops at the flower festival, or their own shops, while others sell them wholesale to roadside sellers, souvenir shops, or middlemen from other provinces.

Roadside stalls, souvenir shops, and local markets: Roadside stalls and souvenir shops, which are located along the main road, are important marketing outlets for selling agricultural products and souvenirs to tourists. There are about 30 permanent stalls that sell both agricultural products and souvenirs year round. These products are both locally produced and imported. There are 35 temporary stalls that sell seasonal agricultural products such as lychees (April–May), longans and dragon fruit (July–August), and oranges and jujube (November–December). Lychees, longans, and dragon fruit are all locally grown and imported, whereas oranges and jujubes are imported from nearby districts. Local farmers sell their products to tourists from stalls at the local market. Restaurants catering for tourists also buy farm produce at the market, which features both local and imported produce. In addition, there are 2 large souvenir shops located in Phu Ruea. These shops sell mainly products imported from other districts or provinces, with only 20% of their stock locally made.

Tourism service enterprises: There are 3 large resorts, 47 small resorts and hotels, and 7 large restaurants that cater to tourists visiting the district. Most of these enterprises are owned and operated by local businesspeople. They buy locally grown shiitake mushrooms and other agricultural products to serve to their tourist customers. They also employ many members of local farm households as maids, waiters, gardeners, and receptionists.

Tourists can rent cars with drivers to take them to visit local tourist destinations. There are about 100 rental cars that are owned and operated by local people. However, the number of rental-car operators is limited by a cartel controlled by local officials.

FIGURE 4 Workers transforming gourds into souvenirs. (Photo by Sukanlaya Choenkwan)



Hired workers: There are about 1000 hired workers, most of whom (90%) are local residents from farm households. The remaining 10% are temporary migrants who come mostly from Laos. Maids in the hotels or resorts are usually middle-age females, and waitresses in the restaurants are usually young females. Workers on the flower farms are usually middle-age people of both sexes.

Most local workers only perform tourism-related work during the high season from October to February, when there is little work on their own farms. The daily wage for these laborers is usually US\$ 8.50 but can reach US\$ 14 during the high season. Many farm owners complain that it is difficult to hire local people because they constantly seem to be busy. Moreover, some maize and cassava farmers complain that local laborers prefer working on flower farms because the work is easier and the pay is better. Thus, to attract local laborers, farmers have to pay higher wages, increasing their costs. Therefore, they often hire migrant laborers from Laos, who are willing to work harder and accept lower wages than are Thai laborers. However, the Lao migrants generally prefer to work in bigger cities in

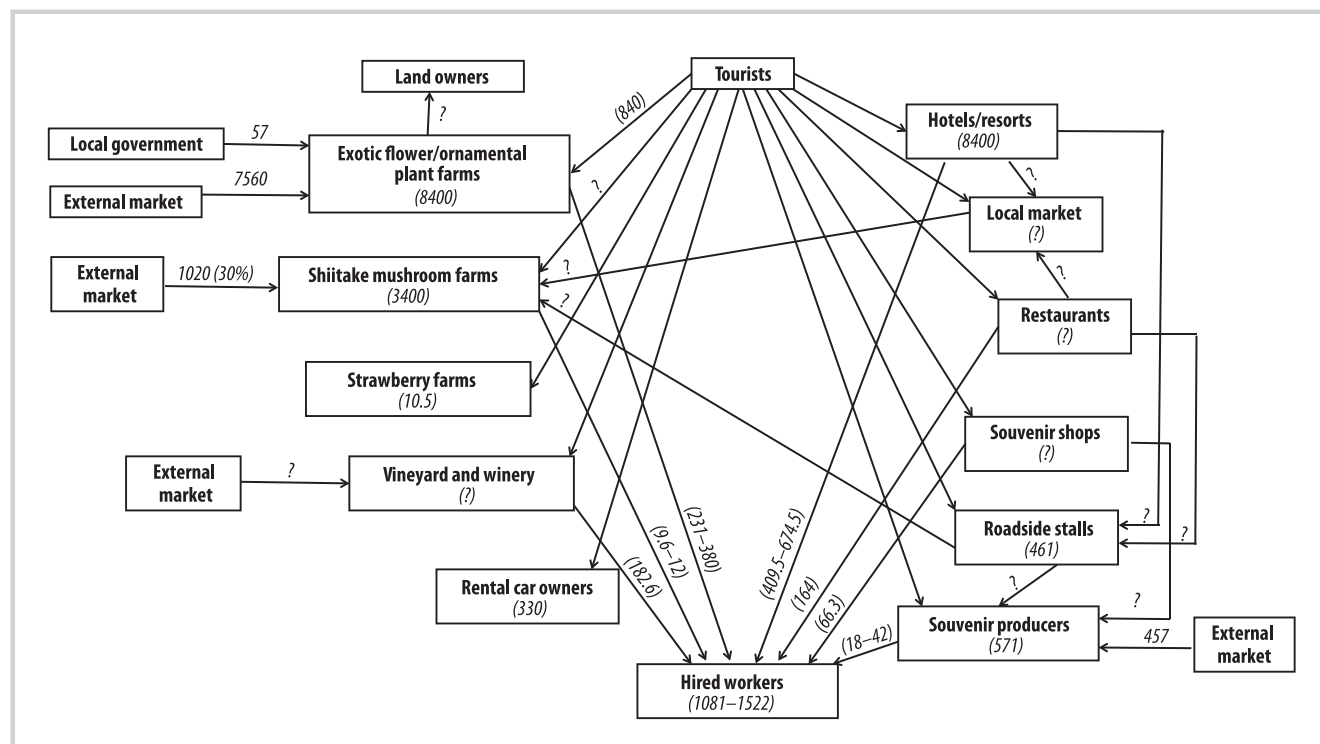
Thailand, so farmers in Phu Ruea encounter difficulties in recruiting enough workers to meet their needs. There are about 300 migrant laborers from Laos working in this district, mostly on cassava and maize farms, although about 50 are employed in tourism service enterprises.

Benefits of the Phu Ruea agrotourism system

The Phu Ruea agrotourism system generates a large amount of income for the district and creates many employment opportunities for local people. The income from agrotourism is shared among specialty-crop farmers, tourism enterprises, agricultural workers, land owners renting land to farmers, and members of farm households employed by tourism enterprises. Figure 5 traces the flows of gross income in the agrotourism system.

As shown in Table 1, the total annual gross income generated in the district by this system in 2014 was almost US\$ 16 million, of which almost US\$ 12 million (74% of the total) came from the sales of specialty-crop farms, which are mostly operated by local people. These specialty-crop farms generate very high net income per

FIGURE 5 Flows of gross income (×US\$ 1000) in the Phu Ruea agrotourism system; flows to middlemen are not shown.



hectare. The flower farms generate about US\$ 22,300/ha/y. Although most flower farms are quite small, with an average area of only 0.5 ha, they can generate net income of US\$ 30/d, which is more than 3 times the minimum daily wage in Thailand. The mushroom farms generated US\$ 58,000/ha/y, and the strawberry farms generated about US\$ 35,700/ha/y. The income per hectare earned by specialty crops is much higher than the US\$ 1900/ha earned from conventional field crops (eg cassava and maize) in the northeastern mountains (Choenkwan 2015).

Although the flower farms receive only 10% of their total income from direct sales to tourists, they gain some additional income from selling their products to local government agencies for the annual flower festival. An additional indirect benefit comes from the publicity that the flower farms receive from tourism promotion: this attracts more middlemen to the district, thus increasing their sales. Before the promotion of agrotourism, many consumers were unaware that Phu Ruea was an important source for ornamental plants and exotic flowers.

The mushroom farmers have also benefited from agrotourism. While not selling directly to tourists, they benefit from the increased demand for their produce from local hotels and restaurants catering to tourists. Before, the growers had to transport their mushrooms to sell in other provinces, but since tourism became popular

in Phu Ruea, they can sell all their mushrooms in the district, sometimes even producing too little to meet local market demand.

Roadside stalls, souvenir producers, and rental-car services—all enterprises owned by local people, mostly farmers—generate gross income of about US\$ 1.4 million/y. The resorts, hotels, and restaurants generate annual gross income of about US\$ 2.8 million (comprising 18% of their total income) from agrotourism. Although most (70%) of these enterprises are owned by residents of the district, they are not farmers. Instead, most owners are government officials who moved to the district on official assignments and could afford to buy land and invest in establishing tourism enterprises. The total gross income of hired workers is about US\$ 1–1.5 million, of which about US\$ 600,000–800,000 is earned from tourism service enterprises and the rest comes from farms and souvenir producers. Most local hired workers are from farm households.

About 1500 people directly earn an income from the agrotourism system, of whom approximately one-third are owners of their own farms or enterprises and two-thirds are hired workers. Most (90%) are local residents, which represents about 10% of the working-age population (15–60 years old) of the district (Official Statistics Registration Systems 2015). If only 1 person per household was involved in the system, then about 22% of all households in the district would directly benefit from

TABLE 1 Information on components of the Phu Ruea agrotourism system.

Enterprises	Areas (ha)	No. of enterprises	Estimated no. of hired workers	Required labor: estimated d/y	Wages (US\$ ^a /d)	Estimated gross income of enterprises (US\$/y)	Estimated gross income of hired workers (US\$/y)
Exotic flowers and ornamental plant farms	112	209	418	27,170	8.50–14.00	8,400,000 ^b	230,945–380,380
Shiitake mushroom farms	2.8	9	45	1125	8.50–11.00	3,400,000 ^b	9562–12,375
Vineyard and winery	400	1	90	21,480	8.50	NA ^c	182,580
Strawberry farms	0.3	2	0	0	0	10,500	0
Small resorts or hotels ^d	7.5	47	188	41,548	8.50–14.00	1,800,000 ^f	353,158–581,672
Large resorts or hotels ^e	9.5	3	30	6630	8.50–14.00		56,355–92,820
Large restaurants	0.3	7	70	19,292	8.50	1,000,000 ^f	163,982
Large souvenir shops	0.3	2	25	7800	8.50	NA ^c	66,300
Roadside stalls	0.04	65	0	0	0	461,500	0
Souvenir producers	0	100	100	3000	6.00–14.00	571,000	18,000–42,000
Rental-car owners	0	100	0	0	0	330,000	0
Total	532.74	545	966	128,045	6.00–14.00	15,973,000	1,080,882–1,522,109

^aUS\$ 1 = 35 Thai baht in July 2015.^bLoei Provincial Agricultural Extension Office 2014.^cNA, not applicable.^dGross income less than US\$ 51,400/y.^eGross income more than US\$ 51,400/y.^fLoei Provincial Office of the Comptroller General Center 2014.

agrotourism, but because some households are likely to have more than 1 member involved in these activities, the actual percentage is probably somewhat lower. Nevertheless, the agrotourism system provides incomes to a substantial number of residents of the district, most of whom are farmers or members of farm households. Similar findings about the benefits of agrotourism to farmers have been reported by other researchers.

Schilling et al (2012, 2014) and Jeczmyk et al (2015) found that agrotourism enhances farmer incomes. Das and Rainey (2010) also found that it generates more jobs, which helps to reduce the unemployment rate. Jeczmyk et al (2015) emphasized that agrotourism not only helps increase farm incomes but is also a crucial channel for farmers to sell their products directly to tourists and tourism enterprises. However, Schilling et al (2012, 2014)

reported that agrotourism does not equally improve all farm household incomes: it mainly benefits small-scale farms.

Conclusions

This study shows that agricultural system analysis can help to identify both direct and indirect benefits of agrotourism to the local population. Benefits from agrotourism promotion are not limited to farmers who grow specialty crops; other local farm households benefit from associated job creation and employment opportunities in the tourism services sector. Farmers obtain a direct income from the sale of their products to tourists. They also earn an income from the sale of their crops to middlemen who resell this produce to tourists at roadside stalls or the local market, as well as to hotels and restaurants that serve locally grown food to their customers. Thus, in the case of shitake mushrooms, 70% are sold to middlemen who either resell them to local hotels and restaurants or to tourists shopping at roadside stalls or at the local market. The flower farms earn additional income by selling flowers to local government agencies for display at the annual flower festival, which attracts many tourists to the district. Farm households also supplement their income through the wages earned by household members employed by tourism enterprises. The influx of tourists helps to create employment opportunities for local people, who are mostly from farm households, working as roadside stall vendors, souvenir producers, and rental-car drivers. It also helps to increase market demand for fruits, gourds, and vegetables grown by other local farmers, thereby increasing their household incomes. A considerable share of the income generated by agrotourism flows to nonfarmers, including the owners of

large hotels and resorts (many of whom are government officials who moved to the district from other places), as well as the wealthy outsiders who own land alongside the main road that they rent to the flower farmers. But there is no doubt that many local farmers derive significant benefits from their involvement in the agrotourism system of Phu Ruea.

However, because this conclusion is based on a single case study of one mountain district in northeast Thailand, it needs to be replicated in different types of agrotourism systems in mountain areas in other parts of the world. Also, this study was limited to assessing the short-term economic benefits gained by farmers from agrotourism in Phu Ruea and did not address issues of agrotourism's environmental and social impacts and externalities nor examine the long-term sustainability of the system. These are issues that deserve further research in the future.

Although it has benefited farmers in the case of Phu Ruea, agrotourism is not a magic strategy to solve all the problems of agricultural development in mountain environments in northeast Thailand or elsewhere in the world. Therefore, development planners seeking to extend agrotourism into new areas should recognize that only some mountain areas are endowed with the scenic landscapes and pleasant climates sought by tourists and only some of these locations are easily accessible from large population centers. Moreover, even in those areas where local conditions are suitable for development of agrotourism, only some mountain farmers have the knowledge, skills, and resources needed to take advantage of the opportunities offered by such development. Nevertheless, our study shows that under the appropriate circumstances, agrotourism development can be beneficial to mountain farmers.

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การใช้ประโยชน์ที่ดินทางการเกษตรบนพื้นที่ภูเขาของ ภาคตะวันออกเฉียงเหนือ

Agricultural land uses in the mountain areas of Northeast Thailand

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บทคัดย่อ: ถึงแม้ว่าภาคตะวันออกเฉียงเหนือมีพื้นที่ภูเขาประมาณร้อยละ 15 ของพื้นที่ของภูมิภาค แต่มีงานการศึกษาเกี่ยวกับการเกษตรบนพื้นที่นี้ค่อนข้างจำกัด ดังนั้นการศึกษานี้จึงมีวัตถุประสงค์เพื่อนำเสนอข้อมูลเกี่ยวกับการใช้ที่ดินในการทำการเกษตรบนพื้นที่ภูเขา ซึ่งอาจเป็นประโยชน์กับงานวิจัยและพัฒนาและการพัฒนาทางด้านการเกษตรบนพื้นที่นี้ การศึกษานี้แบ่งภูเขาออกเป็น 4 ทิวเขาหลัก ได้แก่ ทิวเขาเพชรบูรณ์เหนือ ทิวเขาเพชรบูรณ์ใต้ ทิวเขาสันกำแพง และทิวเขาภูพาน พื้นที่ศึกษาครอบคลุม 94 ตำบล ใน 7 จังหวัด ได้แก่ เลย หนองบัวลำภู อุดรธานี ขอนแก่น ชัยภูมิ นครราชสีมา และสกลนคร ดำเนินการศึกษาโดยการทบทวนวรรณกรรม วิเคราะห์ข้อมูลทุติยภูมิร่วมกับการใช้โปรแกรม Arcgis 10.1 พร้อมกับการสำรวจการใช้ที่ดินในแต่ละทิวเขา ผลการศึกษา พบว่า พื้นที่ภูเขามีการปลูกพืชมากกว่า 20 ชนิด เช่น ข้าว ข้าวโพด อ้อย มันสำปะหลัง ลูกเดือย ถั่วเหลือง ข้าวไร่ ยางพารา ยูคาลิปตัส สัก ส้ม ลิ้นจี่ มะม่วง น้อยหน่า กะล่อน มะขามหวาน ลำไย หวาย ไม้ดอกและไม้ประดับเมืองหนาว ผักเมืองหนาว องุ่น สตรอเบอรี่และเห็ดหอม แต่มากกว่าร้อยละ 80 ของพื้นที่เกษตร ใช้ปลูกพืชไร่ ได้แก่ ข้าวโพด มันสำปะหลังและอ้อย ซึ่งเป็นพืชที่มีมูลค่าต่ำ การปลูกพืชมีมูลค่าสูง เช่น ผักเมืองหนาว ไม้ดอกและไม้ประดับ องุ่น สตรอเบอรี่ และเห็ดหอม มีไม่ถึงร้อยละ 1 ของพื้นที่เกษตร และปลูกเฉพาะในทิวเขาเพชรบูรณ์เหนือและทิวเขาสันกำแพงเท่านั้น อย่างไรก็ตาม ถึงแม้ว่าการปลูกพืชมีมูลค่าสูงยังมีอยู่อย่างจำกัด แต่ก็ เป็นเครื่องบ่งชี้ว่า ภูเขาของภาคตะวันออกเฉียงเหนือมีศักยภาพในการผลิตพืชที่มีมูลค่าสูง ดังนั้น คำถามที่สำคัญต่อไปคือ ทำไมบางพื้นที่สามารถปลูกพืชมีมูลค่าสูงได้ และทำอย่างไรจึงจะขยายสู่พื้นที่อื่นๆ ได้

คำสำคัญ: การใช้ประโยชน์ที่ดิน, เกษตรภูเขา, การพัฒนาพื้นที่ภูเขา, พืชมีมูลค่าสูง, เกษตรประณีต

ABSTRACT: Although the mountains in Northeastern Thailand cover almost 15% of the region's area, there has been little previous agricultural research in the area. This study aims to present a general description of mountain agricultural land use which might be useful for agricultural research and development in the Northeastern mountains areas. In this, the four main mountain ranges chosen for this study included: Northern Petchabun Range, Southern Petchabun Range, Sankamphaeng Range and Phu Phan Range. The study area includes 94 sub-districts (*tambol*) in 7 provinces: Loei, Nongbua Lamphu, Udon Thani, Khon Kaen, Chaiyaphum, Nakhon Ratchasima and Sakon Nakhon. Statistical data from government agencies was analyzed with the Arcgis program and field surveys were made in each of the mountain ranges to observe patterns of land use. The study showed that mountain agriculture is very diverse with more than 20 types of crops planted including rice, maize, sugarcane, cassava, soybeans, Job's tears, upland rice, rubber, eucalyptus, teak, oranges, lychees, mangoes, custard apples, bananas, sweet tamarinds, longans, edible rattan, exotic flowers and ornamental plants, temperate vegetables, grapes, strawberries and shiitake mushroom. However, more than 80% of agricultural land is used to plant low value field crops such as maize, cassava and sugarcane. High value crops such as temperate vegetables, exotic flowers and ornamental plants, grapes,

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strawberries and shiitake mushroom are planted in very small areas (less than 1% of all mountain agricultural land) in only the Northern Petchabun and the Sankampaeng ranges. Although, high value crops are currently planted in very small areas in the mountain areas, it is evident that the Northeastern mountains areas have the potential to produce high value crops. Therefore, the important questions that we should consider are that of why some areas can produce these high value crops and how we can expand them to other areas?

Keywords: land use, mountain agriculture, mountain development, high value crops, agricultural intensification

บทนำ

การทำการเกษตรบนพื้นที่ภูเขามีความแตกต่างจากการทำการเกษตรบนพื้นที่ภูมิฐานอื่น ๆ เนื่องจาก ความสูงของพื้นที่ ความลาดชัน และสภาพภูมิอากาศที่หนาวเย็น นอกจากนั้นเกษตรกรรมบนพื้นที่ภูเขาจะต้องเผชิญกับปัญหาหลายอย่าง เช่น การชะล้างพังทลายของหน้าดิน (soil erosion) น้ำป่าไหลหลาก (water run-off) และการพัฒนาทางด้านสาธารณูปโภคต่างๆ เช่น ถนน ไฟฟ้า ที่มีความยากลำบาก ทำให้การเข้าถึงเทคโนโลยีเพื่อพัฒนาทางการเกษตรมีข้อจำกัด (Shah, 1994) แต่เนื่องจากลักษณะทางภูมิอากาศที่แตกต่างจากลักษณะพื้นที่อื่นๆ ทำให้พื้นที่ภูเขามีศักยภาพในการปลูกพืชบางชนิด ซึ่งไม่สามารถปลูกได้ที่พื้นที่อื่นๆ และส่วนใหญ่เป็นพืชที่มีมูลค่าต่อหน่วยสูง ซึ่งถือเป็นข้อได้เปรียบของการเกษตรบนพื้นที่ภูเขา และเป็นแนวทางหนึ่งที่ได้รับค่านิยมในการนำมาพัฒนาการเกษตรภูเขา (Jodha, 1992)

ภาคตะวันออกเฉียงเหนือมีสัดส่วนของพื้นที่ภูเขาประมาณร้อยละ 15 ของพื้นที่ทั้งหมดของภูมิภาค (Choenkwan et al., 2014) ซึ่งส่วนใหญ่วางตัวล้อมรอบบริเวณขอบของภูมิภาคซึ่งทำหน้าที่เสมือนแนวเขตแดนกั้นระหว่างภาคอีสานกับภูมิภาคอื่นๆ ประกอบด้วย ทิวเขาเพชรบูรณ์ ทิวเขาดงพญาเย็น ทิวเขาสันกำแพง และทิวเขาพนมดงรัก ทำให้ภาคอีสานมีลักษณะคล้ายแอ่งกระทะขนาดใหญ่ (Syncline) (ชรินทร์ และคณะ, 2549) แต่เมื่อก้าวถึงการเกษตรบนพื้นที่ภูเขาของประเทศไทย ผู้คนส่วนใหญ่จะนึกถึงภูเขาในภาคเหนือ ซึ่งจะมีภาพของชาวเขาเผ่าต่างๆ การทำนาขั้นบันได การทำไร่หมุนเวียน การทำไร่

เลื่อนลอย พืชผัก ผลไม้ ไม้ดอก เมืองหนาว มากมายหลายชนิด ซึ่งถูกนำเสนอจากงานการศึกษาและงานพัฒนาต่างๆ ที่ดำเนินการโดยนักวิจัยและนักวิชาการทั้งจากภายในและภายนอกประเทศ (Kunstadter and Chapman, 1978; Forsyth, 1995; Rerkasem, 1995; Turkelboom et al., 1995; Darden, 1995; Jian, 2001; Van Keer et al., 1998; Tungittiplakorn and Dearden, 2002; Trebil et al., 2006) จากการค้นคว้าและทบทวนวรรณกรรมเบื้องต้น พบว่า งานวิจัยเกี่ยวกับการเกษตรบนพื้นที่ภูเขาของภาคตะวันออกเฉียงเหนือมีค่อนข้างจำกัด และทั้งหมดเป็นเป็นรายงานวิจัยที่ทำเฉพาะพื้นที่ (Choenkwan et al., 2014) ซึ่งไม่สามารถให้ภาพรวมเกี่ยวกับการทำการเกษตรบนพื้นที่ภูเขาของภูมิภาคได้ ดังนั้น การศึกษารุ่นนี้จึงนำเสนอข้อมูลเกี่ยวกับภูเขาของภาคอีสาน โดยการรวบรวมข้อมูลเบื้องต้นเกี่ยวกับ ลักษณะทางกายภาพ ชีวภาพ ภูมิศาสตร์ ประชากร การใช้ที่ดิน โดยเฉพาะการใช้พื้นที่สำหรับการเกษตรกรรม เพื่อเป็นฐานข้อมูลเบื้องต้นสำหรับนักศึกษาและนักวิจัยที่สนใจและต้องการพัฒนางานวิจัยทางการเกษตรในพื้นที่ภูเขา และอาจมีประโยชน์ต่อนักพัฒนาในการตัดสินใจและข้อได้เปรียบของพื้นที่ภูเขามาวางแผนการพัฒนา ให้มีประสิทธิภาพมากขึ้น

วิธีการศึกษา

พื้นที่ศึกษา

โดยทั่วไปพื้นที่ภูเขาของภาคตะวันออกเฉียงเหนือถูกแบ่งเป็น 5 ทิวเขาหลัก ได้แก่ ทิวเขาเพชรบูรณ์ ทิวเขาดงพญาเย็น ทิวเขาสันกำแพง ทิวเขาพนมดงรัก และทิวเขาภูพาน (รัตน, 2525; ประเทือง, 2528;

ประสิทธิ์, 2530) อย่างไรก็ตาม การศึกษาครั้งนี้ ไม่ได้รวม ทิวเขาตองพญาเย็นและทิวเขาพนมดงรัก เนื่องจากจากการศึกษาข้อมูลเบื้องต้น พบว่า พื้นที่ส่วนใหญ่ของทิวเขาทั้งสองปกคลุมด้วยพื้นที่ป่า และมีพื้นที่การเกษตรน้อยมาก นอกจากนั้น ทิวเขาเพชรบูรณ์มีความยาวถึง 350 กิโลเมตร (ประเทือง, 2528) ซึ่งยาวมากกว่า ทิวเขาสันกำแพงถึงสองเท่า และจากการสำรวจพื้นที่เบื้องต้นยังพบอีกว่า ทิวเขาเพชรบูรณ์ที่อยู่ด้านเหนือ และที่อยู่ทางด้านใต้ มีลักษณะค่อนข้างแตกต่างกัน ทั้งลักษณะทางกายภาพและการใช้ประโยชน์ที่ดิน ดังนั้น การศึกษานี้ดำเนินการศึกษาโดยแบ่งภูเขาออกเป็น 4 ทิวเขาหลัก ได้แก่ ทิวเขาเพชรบูรณ์เหนือ ทิวเขาเพชรบูรณ์ใต้ ทิวเขาสันกำแพง และทิวเขาภูพาน

คำว่า “ภูเขา” ในการศึกษาครั้งนี้ หมายถึง พื้นที่ที่มีความสูงมากกว่า 300 เมตรจากระดับน้ำทะเล มีพื้นที่ศึกษาครอบคลุมทั้งหมด 94 ตำบล ใน 7 จังหวัด ได้แก่ จังหวัดเลย, หนองบัวลำภู, อุดรธานี, ขอนแก่น, ชัยภูมิ, นครราชสีมา และสกลนคร (Figure 1) โดยคัดเลือกจากตำบลที่มีสัดส่วนของพื้นที่ที่มีความสูง ตั้งแต่ 300 เมตรจากระดับน้ำทะเล เกินกว่าร้อยละ 50 ซึ่งพื้นที่ศึกษาถูกจำแนกโดยการใช้โปรแกรม Arcgis 10.1 ในระบบสารสนเทศทางภูมิศาสตร์ และใช้ข้อมูลทุติยภูมิ ได้แก่ แบบจำลองระดับสูงเชิงเลขของภาคตะวันออกเฉียงเหนือ (Digital Elevation Model: DEM) (Jarvis et al., 2008) แผนที่ขอบเขตการปกครองในระดับตำบลของภาคตะวันออกเฉียงเหนือในรูปแบบ shapefile จัดทำโดย กรมพัฒนาคุณภาพสิ่งแวดล้อม กระทรวงทรัพยากรธรรมชาติและสิ่งแวดล้อม ประกอบการวิเคราะห์

การศึกษาลักษณะทางกายภาพ ชีวภาพ ลักษณะทางภูมิศาสตร์ และประชากรของภูเขาของภาคตะวันออกเฉียงเหนือ

ลักษณะทางกายภาพ ชีวภาพ ลักษณะทางภูมิศาสตร์ และประชากร ศึกษาโดยการ ทบทวนวรรณกรรม และจากการรวบรวมข้อมูลทุติยภูมิจากหลายแหล่งข้อมูล ได้แก่ ข้อมูลความลาดชัน และความสูง (Jarvis et al., 2008), ปริมาณน้ำฝน และอุณหภูมิระหว่างปี พ.ศ. 2543-2555 (สำนักงานสถิติแห่งชาติ, 2556; ศูนย์กรมอุตุนิยมวิทยาภาคตะวันออกเฉียงเหนือตอนล่าง, 2553ก; ศูนย์กรมอุตุนิยมวิทยาภาคตะวันออกเฉียงเหนือตอนล่าง, 2553ข) และจำนวนประชากรปีพ.ศ. 2554 จากกรมการปกครอง และใช้โปรแกรม Arcgis 10.1 ร่วมวิเคราะห์

การศึกษาการใช้ที่ดินและการทำการเกษตรบนพื้นที่ภูเขาของภาคตะวันออกเฉียงเหนือ

การใช้ที่ดิน และการทำการเกษตรบนที่ภูเขาของภาคตะวันออกเฉียงเหนือ ศึกษาโดยการวิเคราะห์ข้อมูลทุติยภูมิที่ได้รับรวบรวมจากรายงานเขตการใช้ที่ดินในระดับตำบล จัดทำโดยสำนักสำรวจและวางแผนการใช้ที่ดิน กรมพัฒนาที่ดิน (สำนักสำรวจดินและวางแผนการใช้ที่ดิน, 2551) รายงานแผนพัฒนาเศรษฐกิจระดับตำบล และข้อมูลการปลูกพืชจากเกษตรอำเภอ ปีพ.ศ. 2552 และการสำรวจภาคสนามในทุกทิวเขา ระหว่างเดือนธันวาคม พ.ศ. 2553 ถึงเดือน พฤษภาคม พ.ศ. 2554 โดยการเดินทางบนถนนเส้นหลัก สังเกตและจดบันทึกการใช้ประโยชน์พื้นที่ดิน

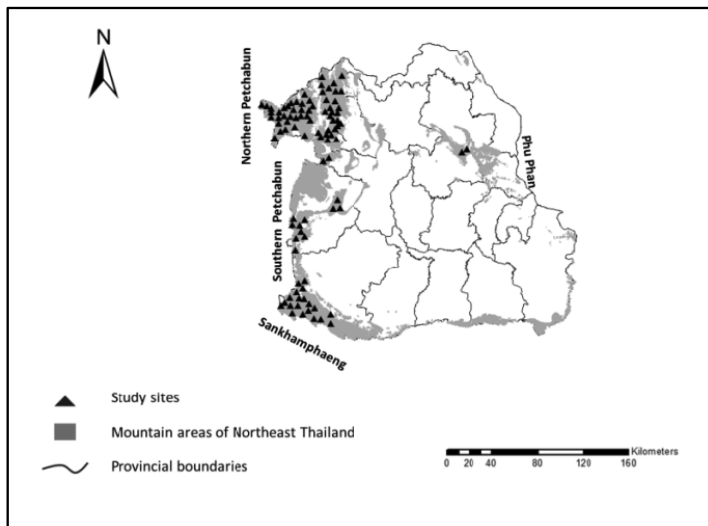


Figure 1 Study areas

ผลการศึกษาและวิจารณ์

1. ภูเขาของภาคตะวันออกเฉียงเหนือ

ภาคตะวันออกเฉียงเหนือ มีพื้นที่ภูเขาประมาณร้อยละ 15 ของพื้นที่ทั้งภาค ในปี พ.ศ. 2554 มีประชากรอาศัยอยู่ประมาณ 670,000 คน หรือคิดเป็นประมาณร้อยละ 3 ของประชากรทั้งหมดของภูมิภาค และมีความหนาแน่น ของประชากรประมาณ 52 คน/ตารางกิโลเมตร ซึ่งถือว่ามีความหนาแน่นน้อยมาก เมื่อเปรียบเทียบกับความหนาแน่นของประชากรทั้งภาคตะวันออกเฉียงเหนือ 129 คน/ตารางกิโลเมตร (กรมการปกครอง, 2555)

ภูเขาในภาคตะวันออกเฉียงเหนือ มีความสูงที่สุดอยู่ที่ประมาณ 2500 เมตรจากระดับน้ำทะเล แต่บริเวณที่สูงที่สุดที่มีคนอาศัยอยู่ อยู่ที่ประมาณ 900 เมตรจากระดับน้ำทะเล ในเขตจังหวัดเลย บนทิวเขาเพชรบูรณ์ พื้นที่ส่วนใหญ่มีความลาดชันน้อย ประมาณสองในสามของพื้นที่ มีความลาดชันน้อยกว่า 8 เปอร์เซ็นต์ ซึ่งถือว่าไม่เป็นอุปสรรคต่อการทำการเกษตร ตามการจำแนกความเหมาะสมของพื้นที่ขององค์การอาหารและยา (Huddleston et al., 2003) ลักษณะทางธรณีวิทยา พื้นที่ส่วนใหญ่ ประกอบด้วย หินทราย (sand stone) หินดินดาน (shale) และ หินแกรนิต

(granite) ซึ่งให้กำเนิดดินที่มีความอุดมสมบูรณ์ต่ำ ไม่เหมาะสมสำหรับการทำเกษตร อย่างไรก็ตามในบางพื้นที่ของทิวเขาเพชรบูรณ์เหนือ และทิวเขาสันกำแพง มีส่วนประกอบของหินปูน และหินบะซอลต์ (ประเทือง, 2528) ซึ่งให้กำเนิดดินที่มีความอุดมสมบูรณ์สูง เหมาะสมสำหรับการทำเกษตร ลักษณะดินในพื้นที่ภูเขามีความหลากหลายมาก ประกอบด้วยดินมากกว่า 40 ชุดดิน แต่ประมาณร้อยละ 40 ของพื้นที่ภูเขา ถูกจำแนกเป็น พื้นที่ความลาดชันเชิงซ้อน (slope complex) ซึ่งหมายความว่า ไม่สามารถจำแนกชนิดดินได้ ข้อมูลลักษณะภูมิอากาศ (ปี พ.ศ. 2543-2555) แสดงว่า ทิวเขาภูพานมีปริมาณน้ำฝนรายปีเฉลี่ยมากที่สุด 1,724 มิลลิเมตร และทิวเขาสันกำแพงมีปริมาณน้ำฝนรายปีเฉลี่ยต่ำสุด 1,143 มิลลิเมตร อุณหภูมิสูงสุดและต่ำสุดเฉลี่ย ในแต่ละทิวเขาไม่มีความแตกต่างกันมากนัก แต่ทิวเขาเพชรบูรณ์เหนือและภูพานมีอุณหภูมิต่ำกว่าทิวเขาอื่นๆ

ลักษณะทางพืชพรรณธรรมชาติ ประกอบด้วย ป่าดงดิบชื้น ป่าดิบเขา ป่าเต็งรัง ป่าเบญจพรรณ และ ป่าสน โดยป่าเต็งรังมีสัดส่วนมากที่สุด มากกว่าร้อยละ 50 และประมาณร้อยละ 30 เป็นป่าดิบแล้ง (Sutthisrisinn and Noochdumrong, 1998) การเปรียบเทียบลักษณะต่างๆ ของแต่ละทิวเขาแสดงใน Table 1

2. การใช้ที่ดินบนพื้นที่ภูเขาของภาคตะวันออกเฉียงเหนือ

การใช้ประโยชน์ที่ดินแบ่งออกเป็น 3 ประเภท ได้แก่ พื้นที่ป่า พื้นที่ทางการเกษตร และพื้นที่แหล่งน้ำ และที่อยู่อาศัย จากข้อมูล พบว่า การใช้ประโยชน์ที่ดินเพื่อเป็นพื้นที่ป่าและพื้นที่เกษตรมีสัดส่วนเท่ากัน คือ ประมาณร้อยละ 47.5 โดยส่วนที่เหลือแบ่งเป็นแหล่งน้ำและที่อยู่อาศัย ประมาณร้อยละ 5

Figure 2 แสดงการใช้ที่ดินเปรียบเทียบในแต่ละทิวเขา ทิวเขาเพชรบูรณ์เหนือมีสัดส่วนของพื้นที่ป่าและพื้นที่เกษตรไม่แตกต่างกันมากนัก คิดเป็นประมาณร้อยละ 49 โดยที่ร้อยละ 55 ของพื้นที่ป่าเป็นพื้นที่อนุรักษ์ และจากการสำรวจภาคสนาม พบว่า อุทยานแห่งชาติภูเรือ และ อุทยานแห่งชาติภูกระดึง จังหวัดเลย เป็นแหล่งท่องเที่ยวที่ได้รับความนิยมจากนักท่องเที่ยวทั้งชาวไทย และต่างชาติ นอกจากนั้น ในพื้นที่อำเภอภูเรือ จังหวัดเลย มีการส่งเสริมการท่องเที่ยวเชิงเกษตร ทำให้มีการใช้พื้นที่เพื่อเป็น โรงแรม รีสอร์ท ร้านอาหาร และร้านสะดวกซื้อต่างๆ เพื่อรองรับนักท่องเที่ยวจำนวนมาก

ทิวเขาเพชรบูรณ์ใต้มีสัดส่วนการใช้พื้นที่เกษตรมากที่สุด ร้อยละ 51 และมีพื้นที่ป่าไม้ร้อยละ 44 โดยประมาณ ร้อยละ 35 ของพื้นที่ป่าเป็นพื้นที่อนุรักษ์

ทิวเขาสันกำแพง มีสัดส่วนของพื้นที่ป่าประมาณร้อยละ 47 โดยแบ่งเป็นพื้นที่อนุรักษ์ประมาณร้อยละ

58 ได้แก่ อุทยานแห่งชาติเขาใหญ่และอุทยานแห่งชาติทับลาน ซึ่งเป็นแหล่งท่องเที่ยวที่เป็นที่นิยมของนักท่องเที่ยวเป็นอย่างมาก นอกจากนี้ ทิวเขาสันกำแพงยังมีแหล่งท่องเที่ยวอื่นๆ อีกเช่น เขาแผงม้า และอำเภอน้ำเขียว จังหวัดนครราชสีมา ซึ่งได้รับการส่งเสริมให้เป็นแหล่งท่องเที่ยวเชิงเกษตร ทำให้มีนักท่องเที่ยวเข้ามาเที่ยวมากมาย ส่งผลให้การใช้พื้นที่สำหรับ โรงแรม รีสอร์ท ร้านอาหาร เพื่ออำนวยความสะดวกให้กับนักท่องเที่ยวมีมากขึ้น

ทิวเขาภูพาน มีพื้นที่ป่าไม้ร้อยละ 51 โดยส่วนใหญ่เป็นพื้นที่อุทยานแห่งชาติภูพาน ร้อยละ 82 พื้นที่ทางการเกษตรคิดเป็นร้อยละ 40 และพื้นที่อยู่อาศัยและแหล่งน้ำประมาณร้อยละ 9

เมื่อเปรียบเทียบสัดส่วนการใช้พื้นที่ดินระหว่างพื้นที่ป่าไม้และพื้นที่เกษตรในแต่ละทิวเขา พบว่า ไม่มีความแตกต่างกันมากนัก ทิวเขาภูพานมีสัดส่วนการใช้พื้นที่ดินสำหรับป่าไม้มากที่สุด เมื่อเทียบกับทิวเขาอื่นๆ คือร้อยละ 51 และมีสัดส่วนของพื้นที่อนุรักษ์ต่อพื้นที่ป่ามากที่สุด คือร้อยละ 82 ทิวเขาเพชรบูรณ์ใต้มีสัดส่วนของพื้นที่เกษตรมากที่สุด คือประมาณร้อยละ 51 และทิวเขาสันกำแพงมีสัดส่วนของพื้นที่แหล่งน้ำและที่อยู่อาศัยมากที่สุดเมื่อเทียบกับทิวเขาอื่นๆ คือประมาณร้อยละ 11

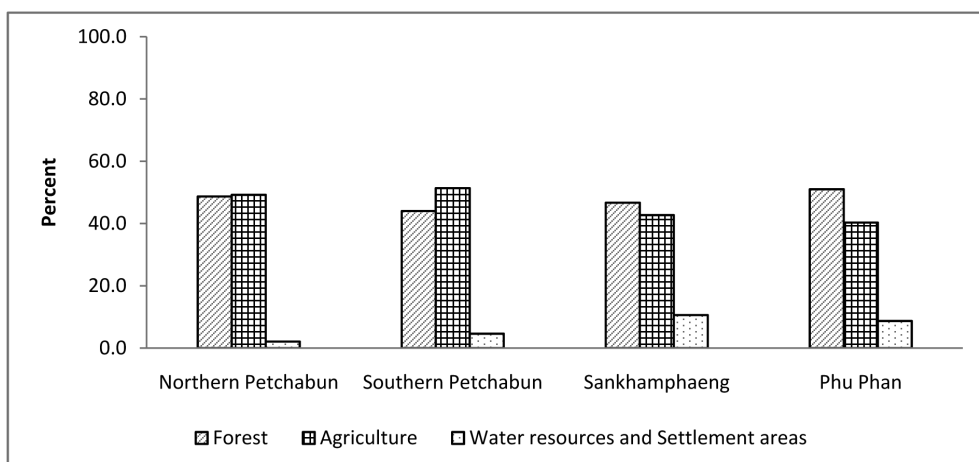


Figure 2 Comparison of types of land use in different mountain ranges of Northeast Thailand

Table 1 Characteristics of mountain ranges in Northeast Thailand

Characteristics	Mountain Ranges			
	Northern Petchabun	Southern Petchabun	Sankhampaeng	Phu Phan
Locations	Loei, Nongbua Lamphu, Udon Thani, Khon Kaen	Chaiyaphum	Nakhon Ratchasima	Sakon Nakhon
Orientation ²	North to South	North to South	East to West	Northeast to South West
Geology ^{2,3}	Limestone, interfused with slate, siltstone, conglomerate, sandstone and volcanic tuff, Scattered igneous rocks include porphyry, granite, basalt and tuff	Mostly siltstone, conglomerate and sandstone, scattered conglomeratic sandstone containing rounded pebbles of quartz and chert. A large area of thick porphyry is found in the western part	Conglomeratic sandstone containing rounded pebbles of quartz and chert. A large area of thick porphyry is found in the western part	Sandstone with conglomerate, siltstone, and slate.
Maximum elevation ⁴ (m.amsl)	1,795	1,007	1,322	570
Slope ⁵	63	79	64	84
(% of total mountain area)	35	20	34	16
≥ 16 %	2	1	2	0

² Source: 1.ระพีพร (2528)
³ Source: รัตนา (2525)
⁴ Source: Jarvis et al. (2008)

Table 1 Characteristics of mountain ranges in Northeast Thailand (continued)

Characteristics	Mountain Ranges		
	Northern Petchabun	Southern Petchabun	Sankhampaeng
Rainfall ⁵	1,321	1,225	1,143
Annual (mm)			1,724
(13 year average: 2000-2012)			
No. of rainy (days/year)	125	103	111
Daily Maximum (mm)	93	91	94
Temperature			
Mean maximum ⁶	40.4	40.0	39.3
Mean minimum ⁶	9.3	13.2	12.6
Daily maximum ⁷	43.1	42.6	42.7
Daily minimum ⁸	0.1	6.3	4.6
Population			
Average	54	61	63
Density ⁸			
Lowest population density in a subdistrict	14	32	21
Highest population density in a subdistrict	155	79	161
Ethnic identity of inhabitants ⁹	Tai Loei, Lao Isan	Lao Isan, Korat Thai, Central Thai	Central Thai, Korat Thai, Lao Phu Tai, Kalaeng, Nyaw, Lao Isan

⁵ Source: สำนักงานสถิติแห่งชาติ (2556)

⁶ Source: ศูนย์อุตุนิยมวิทยาภาคตะวันออกเฉียงเหนือตอนล่าง (2553ก)

⁷ Source: ศูนย์อุตุนิยมวิทยาภาคตะวันออกเฉียงเหนือตอนล่าง (2553ข)

⁸ Source: กรมการปกครอง (2555)

⁹ Source: สุวิไล และคณะ (2547)

3. การใช้พื้นที่ทางการเกษตรบนพื้นที่ภูเขาของภาคตะวันออกเฉียงเหนือ

การศึกษาการใช้ที่ดินทางการเกษตร ได้แบ่งพืชออกเป็น 4 กลุ่ม ได้แก่ (1) พืชไร่ ประกอบด้วย ข้าว (ข้าวนาลุ่มและข้าวไร่) ข้าวโพด อ้อย มันสำปะหลัง ถั่วเหลือง และถั่วเขียว (2) ไม้ยืนต้นที่ไม่ใช่ไม้ผล ประกอบด้วย ยางพารา ยูคาลิปตัส และต้นสัก (3) ไม้ผล ประกอบด้วย ลิ้นจี่ มะม่วง น้อยหน่า กัลยัมชะมหวาน และลำไย และ (4) พืชชนิดพิเศษ (specialty crops) ได้แก่ ไม้ดอกและผักเมืองหนาว เช่น กุหลาบ ดาวเรือง คริสมาสต์ พวงแสด ดอกผีเสื้อ ไม้ประดับต่างๆ ผักสลัดชนิดต่างๆ เห็ดหอม และเห็ด โดยพืชไร่ ครอบคลุมพื้นที่ส่วนใหญ่ประมาณร้อยละ 88 ของพื้นที่ทางการเกษตร รองลงมาเป็นไม้ผล ครอบคลุมพื้นที่ร้อยละ 8 ไม้ยืนต้น ครอบคลุมพื้นที่ร้อยละ 3 และ พืชชนิดพิเศษครอบคลุมพื้นที่ประมาณร้อยละ 1 รายละเอียดแสดงใน Table 2

การใช้พื้นที่ทางการเกษตรและพื้นที่ปลูกพืชในแต่ละทิวเขา (Table 2) ประมาณร้อยละ 88 ของพื้นที่เกษตรของทิวเขาเพชรบูรณ์เหนือ ถูกใช้สำหรับพืชไร่ ข้าวโพดเป็นพืชที่นิยมปลูกมากที่สุด (ร้อยละ 34) รองลงมาคือ พื้นที่นา (ร้อยละ 16) และมีพื้นที่สำหรับไม้ดอกและผักเมืองหนาวประมาณร้อยละ 0.5 และจากการสำรวจภาคสนาม ในพื้นที่อำเภอภูเรือ จังหวัดเลย พบการเพาะเห็ดหอมและไม้ดอกเมืองหนาวมากกว่า 20 ชนิด แต่มีการปลูกในพื้นที่ค่อนข้างจำกัด และยังพบสวนองุ่นขนาดใหญ่ พร้อมกับโรงผลิตไวน์ จำนวน 1 แห่ง ซึ่งได้เปิดบริการให้นักท่องเที่ยวได้เที่ยวชมพร้อมชิมไวน์ฟรี

ประมาณร้อยละ 98 ของทิวเขาเพชรบูรณ์ใต้ ถูกใช้สำหรับการปลูกพืชไร่ เช่น มันสำปะหลัง (ร้อยละ 37) และพื้นที่นา (ร้อยละ 10) ไม้ยืนต้น ประมาณร้อยละ 2 ได้แก่ ยูคาลิปตัส (ร้อยละ 1) และยางพารา (ร้อยละ 1) จากข้อมูลทุติยภูมิ ไม่พบการปลูกไม้ผล ไม้ดอกและผักเมืองหนาว แต่จากการสำรวจภาคสนาม พบการปลูกไม้ผล ได้แก่ มะขามหวาน และมะม่วง แต่ในพื้นที่ไม่ใหญ่มาก

ทิวเขาสันกำแพง มีพื้นที่ทางการเกษตร แบ่งเป็นพื้นที่พืชไร่ ประมาณร้อยละ 83 โดยแบ่งเป็นข้าวโพดประมาณร้อยละ 41 และมีพื้นที่สำหรับพืชชนิดพิเศษ ได้แก่ ดอกไม้เมืองหนาว องุ่น ผักเมืองหนาว และเห็ดหอม ประมาณร้อยละ 2

ทิวเขาภูพาน แบ่งเป็นพื้นที่พืชไร่ ประมาณร้อยละ 96 พืชที่นิยมปลูกมากที่สุด คือ มันสำปะหลัง ประมาณร้อยละ 44 และจากการสำรวจภาคสนาม พบว่า หวายชนิดกินได้เป็นพืชที่สำคัญและได้รับความนิยมเป็นอย่างมากซึ่งเป็นแหล่งรายได้ที่สำคัญของเกษตรกรในทิวเขานี้ โดยพบหวายทั้งที่ปลูกแบบเชิงเดี่ยวและปลูกร่วมกับพืช ชนิดอื่น เช่น ยางพารา มันสำปะหลัง หรือ ไม้ผล และมีทั้งปลูกในพื้นที่ขนาดใหญ่และปลูกในสวนหลังบ้าน นอกจากนั้น ยังพบพื้นที่ปลูกยางพาราบนทิวเขานี้ แต่ไม่มีข้อมูลแสดงในข้อมูลทุติยภูมิ

โดยสรุป สามารถกล่าวได้ว่า การใช้พื้นที่ทางการเกษตรในแต่ละทิวเขาส่วนใหญ่ถูกใช้สำหรับพืชไร่ ได้แก่ ข้าวโพด มันสำปะหลัง ข้าว และ อ้อย ซึ่งเป็นพืชที่มีมูลค่าต่ำ จากการสรุปมูลค่าผลิตภัณฑ์มวลรวมสาขาเกษตรของเกษตรกรในปี 2552 (เกษตรอำเภอน้ำหนาว 2553) ระบุว่า ผลตอบแทนสุทธิที่เกษตรกรได้จากข้าวโพดคิดเป็นเงิน 3,242 บาท/ไร่/ปี ข้าว 3,919 บาท/ไร่/ปี มันสำปะหลัง 4,366 บาท/ไร่/ปี และอ้อย คิดเป็นเงิน 2,371 บาท/ไร่/ปี โดยทิวเขาเพชรบูรณ์ใต้ มีสัดส่วนการใช้ที่ดินของพืชไร่มากที่สุด คือ ร้อยละ 98 เมื่อเทียบกับทิวเขาอื่นๆ

ทิวเขาเพชรบูรณ์เหนือมีการปลูกไม้ยืนต้นมากที่สุด ประมาณร้อยละ 4 ของพื้นที่ทั้งทิวเขา รองลงมาเป็นทิวเขาภูพาน มีพื้นที่ปลูกไม้ยืนต้นประมาณร้อยละ 3 โดยยางพาราเป็นไม้ยืนต้นที่ได้รับความนิยมอย่างมาก เนื่องจากราคาและการส่งเสริมโดยภาครัฐ ซึ่งยางพาราให้ผลตอบแทนสุทธิคิดเป็น 6,037 บาท/ไร่/ปี สำหรับการขายแบบแผ่นยางดิบในปีพ.ศ. 2555 (สำนักงานเศรษฐกิจการเกษตร, 2556) แต่ยางพาราเป็นพืชที่มีราคาผันผวนอย่างมาก เมื่อเปรียบเทียบกับราคาในปี พ.ศ. 2554 ยางพาราให้ผลตอบแทนสุทธิคิดเป็น 18,793 บาท/ไร่/ปี และ 15,077 บาท/ไร่/ปี ใน

ปีพ.ศ. 2553 (สำนักงานเศรษฐกิจการเกษตร, 2556) แต่สำหรับการขายแบบยางก้อนถ้วย จะได้ผลตอบแทนสุทธิประมาณ 1,440 บาท/ไร่/ปี ในปีพ.ศ. 2557 (ชลธิชา และคณะ, 2558)

ทิวเขาชันกำแพงใช้พื้นที่สำหรับไม้ผลมากที่สุด เมื่อเทียบกับทิวเขาอื่นๆ คือประมาณร้อยละ 13 รองลงมาคือทิวเขาเพชรบูรณ์เหนือคิดเป็นประมาณร้อยละ 8 ของพื้นที่เกษตร โดยมะขามหวาน และ มะม่วง เป็นไม้ผลที่มีพื้นที่มากที่สุด มะขามหวานให้ผลตอบแทนสุทธิ

ประมาณ 2,350 บาท/ไร่/ปี มะม่วง 8,654 บาท/ไร่/ปี (เกษตรอำเภอวังน้ำเขียว, 2553)

พืชชนิดพิเศษ ไม้ดอก ผลไม้ และผักเมืองหนาว ทั้งจากข้อมูลทุติยภูมิและการสำรวจภาคสนาม พบการปลูกแคในทิวเขาชันกำแพงและทิวเขาเพชรบูรณ์เหนือเท่านั้น ประมาณ ร้อยละ 2 และร้อยละ 0.5 ตามลำดับ เกษตรอำเภอวังน้ำเขียว (2553) ระบุว่า อุ่นให้ผลตอบแทนสุทธิ 131,644 บาท/ไร่/ปี เห็ดหอม 87,489 บาท/ไร่/ปี ผักเมืองหนาว 129,706 บาท/ไร่/ปี และเบญจมาศ 143,420 บาท/ไร่/ปี

Table 2 Agricultural land use in each mountain range in Northeast Thailand

Type of crops	Mountain Ranges (% of total agricultural area of each range)				Ranges
	Northern Petchabun	Southern Petchabun	Sankamphaeng	Phu Phan	
Field crops					
Rice	16.0	10.1	4.6	15.7	4.6 - 16.0
Maize	34.5	7.8	41.2	-	0 - 41.2
Sugarcane	8.5	5.9	11.6	2.0	2.0 – 11.6
Cassava	9.6	37.2	24.8	43.7	9.6 – 43.7
Soybeans	-	-	0.5	0.5	0 – 0.5
Job's tears	0.1	-	-	-	0 – 0.1
Upland rice	0.1	-	-	-	0 – 0.1
Unclassified	18.7	37.0	0.6	34.4	0.6 – 18.7
Total	87.5	98.0	83.3	96.3	83.3 – 98.0
Tree plantations					
Rubber	3.3	0.7	_*	_*	0 – 3.3
Eucalyptus	0.2	1.3	1.3	3.1	0.2 – 3.1
Teak	0.9	-	0.3	-	0 – 0.9
Total	4.4	2	1.6	3.1	1.6 – 4.4
Fruit trees					
Orange	0.1	-	-	-	0 – 0.1
Lychee	0.1	-	-	-	0 – 0.1
Mango	0.3	_*	6.8	-	0 – 6.8
Custard apple	-	-	5.7	-	0 – 5.7
Banana	1.9	_*	-	-	0 – 1.9
Tamarind	4.2	_*	0.6	0.2	0 – 4.2
Longan	1.0	_*	0.1	0.4	0 – 1.0
Total	7.6	-	13.2	0.6	0 – 13.2
Specialty crops					
Edible rattan	-	-	-	_*	-
Exotic fruits	0.5	-	0.9	-	0 – 0.9
Vegetables	_*	-	0.7	-	0 – 0.7
Flowers	_*	-	0.3	-	0 – 0.3
Mushrooms	_*		_*		-
Total	0.5	-	1.9	-	0 – 1.9

- * no data in Choenkwan et al., 2014 which used the data from Office of Soil Resources Survey and Research in 2008 but crops were observed by the present authors in field survey in 2011 (Choenkwan et al., 2014)

4. การกระจายตัวของพืชที่มีมูลค่าสูง

พืชมูลค่าสูงสำหรับการศึกษาครั้งนี้ คือ พืชที่ให้ผลตอบแทนสุทธิมากกว่า 50,000 บาท/ไร่/ปี ได้แก่ องุ่น ไม้ดอกเมืองหนาว ผักเมืองหนาว และเห็ดหอม จาก Figure 3 แสดงว่า พืชที่มีมูลค่าสูงสามารถพบเฉพาะในทิวเขาเพชรบูรณ์เหนือ ได้แก่ ตำบลร่องจิก ตำบลหนองบัวและตำบลสนทม อำเภอภูเรือ จังหวัดเลย และทิวเขาสันกำแพง ได้แก่ อำเภอปากช่องและอำเภอด่านช้าง Cheonkwan et al. (2014) อภิปรายว่า มีหลายปัจจัยที่มีผลต่อการปลูกพืชมูลค่าสูงเหล่านี้ ได้แก่ อุณหภูมิที่เหมาะสม เนื่องจาก ไม้ดอก ผักผลไม้เมืองหนาว และเห็ดหอม เป็นพืชที่ต้องการอุณหภูมิต่ำ นอกจากนี้ ลักษณะทางภูมิประเทศที่สวยงามที่สามารถดึงดูดนักท่องเที่ยวเข้ามาในพื้นที่จำนวนมาก โดยทั้งสองทิวเขาเป็นที่ตั้งของอุทยานแห่งชาติที่มีชื่อเสียง ได้แก่ อุทยานแห่งชาติภูเรือ บนทิวเขาเพชรบูรณ์เหนือ และอุทยานแห่งชาติเขาใหญ่ บนทิวเขา

สันกำแพง เพราะการที่นักท่องเที่ยวเข้ามาในพื้นที่เป็นจำนวนมาก ทำให้เกษตรกรมีช่องทางในการขายสินค้า นักท่องเที่ยวกลายเป็นกลุ่มตลาดที่สำคัญ นอกจากนั้น เกษตรกรอาจได้กำไรมากขึ้นเนื่องจากสามารถขายให้กับนักท่องเที่ยวได้โดยตรง โดยไม่ต้องผ่านพ่อค้าคนกลาง

นอกจากการให้ผลตอบแทนที่สูงแล้ว องุ่น ไม้ดอกเมืองหนาว ผักเมืองหนาวและเห็ดหอม สามารถนำมาช่วยส่งเสริมการท่องเที่ยวเชิงเกษตรของอำเภอภูเรือ และอำเภอด่านช้าง ได้อีกด้วย โดยมีกิจกรรม ได้แก่ เทศกาลงานไม้ดอกเมืองหนาว เที่ยวชมสวนดอกไม้เมืองหนาว ชมสวนองุ่นและชิมไวน์ฟรี เรียนรู้ การทำการเกษตรที่สูง การเพาะเห็ดหอมและการกิน ผักเมืองหนาวปลอดสารพิษ ซึ่งเป็นส่วนดึงดูดนักท่องเที่ยวให้เข้ามาเยี่ยมชมและพักผ่อนในพื้นที่ได้เป็นอย่างดี ส่งผลให้เศรษฐกิจภายในท้องถิ่นพัฒนาดีขึ้น

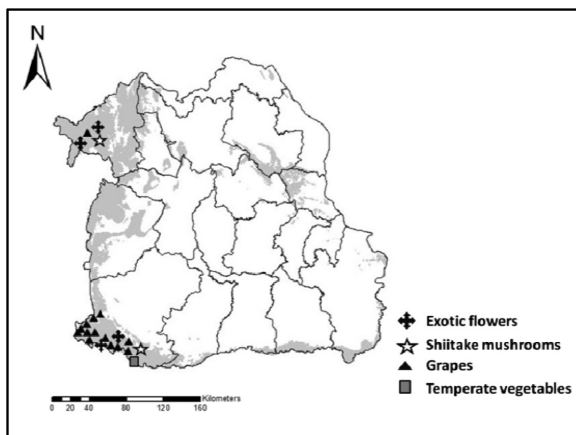


Figure 3 Distribution of high value crops in the mountains of Northeast Thailand.

คำขอบคุณ

การศึกษานี้ ได้รับทุนสนับสนุนการวิจัยจาก โครงการปริญญาเอกกาญจนาภิเษก (คปก.) ภายใต้ กองทุนสนับสนุนการวิจัย (สกว) ทุนสนับสนุนผู้ได้รับ ทุนโครงการปริญญาเอกกาญจนาภิเษก จาก สำนัก

บริหารการวิจัย มหาวิทยาลัยขอนแก่น และ ทุนวิจัย พื้นฐานจากสำนักงานกองทุนสนับสนุนการวิจัย (BRG5680008) โดย Prof. Dr. A Terry Rambo โดยที่ ความคิดเห็นใดๆในบทความชิ้นนี้ ไม่เกี่ยวข้องกับ สำนักงานกองทุนสนับสนุนการวิจัย

สรุป

พื้นที่ภูเขาของภาคตะวันออกเฉียงเหนือมีความหลากหลาย ทั้งลักษณะภูมิประเทศ ลักษณะกายภาพ ประชากรและการเกษตร ซึ่งมีพืชมากกว่า 20 ชนิด ปลูกในพื้นที่นี้ อย่างไรก็ตาม พื้นที่ส่วนใหญ่ มากกว่าร้อยละ 80 ถูกใช้สำหรับการปลูกพืชไร่ ได้แก่ ข้าวโพด มันสำปะหลังและอ้อย ซึ่งเป็นพืชที่ให้มูลค่าต่ำ แต่ในบางพื้นที่ของทิวเขาเพชรบูรณ์เหนือ และทิวเขาสันกำแพง พบการปลูกพืชที่ให้มูลค่าสูง ได้แก่ ไม้ดอกไม้ประดับเมืองหนาว พืชผักเมืองหนาว องุ่น และเห็ดหอม ซึ่งถึงแม้ว่าพืชเหล่านี้จะปลูกอยู่ในพื้นที่จำกัด แต่เป็นเครื่องบ่งชี้ว่า ภูเขาของภาคตะวันออกเฉียงเหนือมีศักยภาพในการปลูกพืชเมืองหนาวที่ให้มูลค่าสูง ซึ่งคำถามต่อไปที่สำคัญก็คือ บัณฑิตหรือเงื่อนไขอะไร ที่ทำให้เกิดการผลิตพืชที่มีมูลค่าสูง เพื่อนำไปสู่การขยายพื้นที่ปลูกออกไป และนอกจากนั้น ยังพบการส่งเสริมพัฒนาการท่องเที่ยวเชิงเกษตรในทิวเขาเพชรบูรณ์เหนือและทิวเขาสันกำแพง ซึ่งอาจเป็นแนวทางเลือกใหม่ในการพัฒนาการเกษตรบนพื้นที่แห่งนี้ได้

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Urban Demand for Wild Foods in Northeast Thailand: A survey of edible wild species sold in the Khon Kaen municipal market

Yuko Shirai and A. Terry Rambo

Research

Abstract

Rural people in Northeast Thailand consume a wide range of wild species. Little is known, however, about the extent to which the urban populations of the region's rapidly growing towns and cities consume these products, and no detailed study has been made of the edible wild species that are sold in urban markets. To help fill this knowledge gap, this paper presents findings of a survey about the wild species sold in the main urban market in Khon Kaen Municipality. The survey included identification of all species of plants, fungi, and animals being sold and recording of the quantities and prices of each species. Data were obtained by interviewing vendors selling these products in the market on 18 randomly selected nights in the dry season and 12 nights in the rainy season.

The diversity of wild species sold in the market is high. Eighty-one species were identified, of which 54 were plants, 6 were fungi, and 21 were animals. Species diversity was greater in the rainy season, when 65 species were on sale, than in the dry season, when 49 species were available. Plant species were much more diverse in the rainy season than in the dry season, reflecting the better growth conditions for vegetation when water is not a limiting factor. Many species were available only in a specific season.

The wild species were obtained from several different habitats. Upland fields were the habitat for the largest number of species, followed by house areas, forests, and paddy fields. Gardens and aquatic ecosystems were habitats for a smaller number of species.

The supply-shed for the urban market in Khon Kaen Municipality is quite a large one. Wild species sold in the market are obtained from 8 provinces in the Northeast, al-

though rural areas of Khon Kaen Province itself are the source of the largest number of species.

Collection of wild species to supply the urban market can have both negative and positive effects on rural biodiversity in Northeast Thailand. In their desire to earn cash income, villagers may over-exploit some of these species, causing wild populations to decline in numbers or even become locally extinct. On the other hand, villagers may intensify their efforts to cultivate them so as to allow more stable production, thus contributing to biodiversity conservation. This has already begun to happen in the case of some highly valued species.

Introduction

Previous research on collection and consumption of edible wild species in Northeast Thailand has been mostly focused on rural areas. Relatively little attention has been paid to the consumption of wild species by urban people. This paper presents findings of a survey of the edible wild

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and cultivated species of plants, fungi, and animals sold in the urban market system in Khon Kaen Municipality in Northeast Thailand.

There is much literature related to people's collection and use of wild and semi-domesticated products in different parts of the world that raises many important issues in terms of conservation of forests and biodiversity, economic value of wild products, and the evolution of domestication and commercialization of wild products (Catling & Small 2006, Chamberlain *et al.* 2004, Chardonnet *et al.* 2002, FAO 1995, Lindsay 1999, Sather 2002). These issues are relevant for Thailand, which is situated in one of the richest areas of the world with regard to biological resources (Baimai & Brockelman 1998). It is hardly surprising that wild products play important roles in the livelihoods of rural people there, especially in the Northeast Thailand region (Isan), which remains the most rural and poorest part of the kingdom. It is estimated that approximately 80% of Isan households engage in collection of various kinds of non-timber forest products (NTFPs), both edible and non-edible (Boonchote & Pasandhanatorn 1998). Numerous studies have been published on the collection and use of edible wild species by rural people in Northeast Thailand (Miyagawa 1993, Moreno-Black 1994, Moreno-Black *et al.* 1996, Moreno-Black & Somnasang 2000, Prachiyo 2000, Shibahara 2002, Somnasang *et al.* 1986, 1988, 1998). Some attention has also been paid to collection of non-edible wild products. For example, Wanida (1994) reported on the importance of rattan, bamboo, lac, honey, gums and resins, bark, agarwood, and medicinal plants in terms of harvesting and the processing, exports, and imports. Northeast Thai villagers collect natural products from all of the components of their agroecosystems including forests, upland fields, rice paddies, gardens, and house areas, as well as various water sources e.g., canals, ponds, swamps, rivers, and reservoirs (Grandstaff 1986, Somnasang *et al.* 1988). It is now widely recognized that wild products make an important contribution to the livelihoods and nutritional status of rural people in the Northeast.

As is true in other countries in the world, research on collection and consumption of wild products in Northeast Thailand has been largely focused on rural areas, with almost no attention paid to urban areas, although for the past 20 years the region has been undergoing very rapid urbanization. However, other than a brief study of edible insects sold in a market in Khon Kaen Municipality (Watanabe & Satrawaha 1984), no detailed research has been done about the edible wild plant and animal species that are consumed by urban people. In order to help fill this gap in knowledge, a study was conducted during 2006 of all of the edible wild species on sale in the central urban market in Khon Kaen Municipality. In this paper we seek to: 1) identify all wild and cultivated species that are sold in the urban market, 2) describe seasonal variations in their availability, 3) assess the domestication status of

these species, 4) identify the habitats in the rural environment from which they are obtained, and 5) delineate the rural areas that are impacted by urban demand for these products.

Research Design and Methods

The study site

This research was carried out in Khon Kaen Municipality, the capital city of Khon Kaen Province, which is located approximately 450 km northeast of Bangkok (Figure 1). Although it was connected to Bangkok by a railroad in 1933, Khon Kaen remained a rather small provincial town until it was designated as a development center for the Northeast Thailand region in 1962. Following this decision, Khon Kaen University was established as the first national university in the Northeast and the regional offices of many government agencies were relocated into the city. The completion in 1964 of the Friendship Highway, which runs from Bangkok to Nong Khai on the border with Laos, and the construction of a nearby airport greatly improved the city's connections to Bangkok and the outside world and created a favorable situation for the rapid development of cash crop production in its rural hinterland (Fukui 1988, 1993).

In 2006, the population of Khon Kaen Municipality was 121,283, making it the ninth largest city in the country (Wikipedia contributors 2007). The Municipality has an area of 46 km², making Khon Kaen a relatively low-density city (2,637 persons/km²).

The urban population is supplied with food by a well-developed system of government and private markets. In 2003, there were four government fresh markets and seven private fresh markets (Khon Kaen Municipality 2006). In addition, there are several supermarkets, but these rarely sell any wild foods. After conducting a preliminary survey of all city markets, Bang Lam Phu Market was found to be the central market for edible wild species where collectors and traders from the countryside bring these products. In the market there are 139 vendors who sell these products, either selling them directly to consumers or distributing them to dealers from all of the other markets in the city for sale to consumers there (Figure 1). Bang Lam Phu Market is open around the clock, but most of the vendors of wild products come to the market at about 2:00 A.M. and stay until they sell out all their products around 9:00 A.M.

Data collection

In an initial survey, all of the vendors engaged in selling edible wild and semi-domesticated products in the market were identified. Thailand does not require researchers to obtain written consent from respondents, but, before interviewing each vendor, the researchers identified themselves, explained the purpose of the research, and

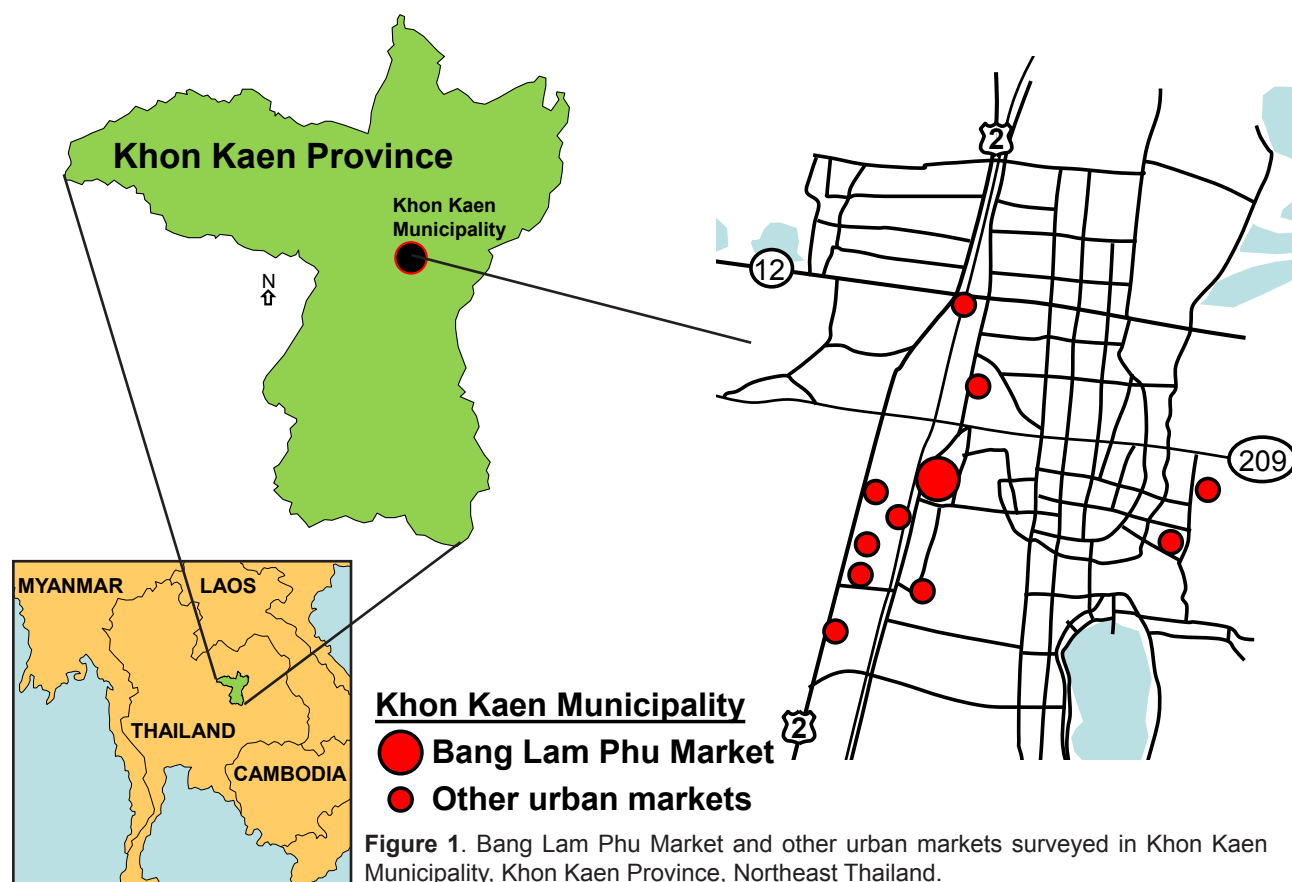


Figure 1. Bang Lam Phu Market and other urban markets surveyed in Khon Kaen Municipality, Khon Kaen Province, Northeast Thailand.

asked permission to collect needed information. Anonymity of respondents has been protected, and no vendors were identified by name in any study reports. This information was used to draw a map of Bang Lam Phu Market that showed the relative location of all vendors. The market area was divided into three blocks (A, B, and C) with each block containing approximately 20 vendors of wild and semi-domesticated products were selected from the total in each block (Figure 1).

Sampling plan

There were 139 vendors, mostly female, who sold edible wild and semi-domesticated products in the Bang Lam Phu Market on a regular or occasional basis. However, only 65 of these sold wild products on a regular basis. It was this group of 65 vendors, of whom all but 3 were female, who were the focus of data collection for this study. Because of the very large number of vendors, it was impossible for a single researcher to interview all of them in one night. Therefore, it was necessary to limit data collection to vendors in just one block on any one night. Data were then collected from vendors in a different block on a subsequent night, followed by the third block on yet another night. The data collected from the three different blocks were aggregated to estimate the total volume of wild and

semi-domesticated products sold in the market on an average night.

Because the supply of different kinds of edible wild and semi-domesticated products to the market is affected by seasonal variation, the sampling plan had to include data collection in different seasons. Generally, the climate of Northeast Thailand is differentiated into three seasons: 1) the cool dry season from November to February, 2) the hot dry season from March to May, and 3) the wet season from May to October (Moreno-Black 1996). The sampling plan was designed to include data collection in each of these seasons. In 2006, however, the rains started unusually early so that there was no true hot season. Consequently, data collection was only possible in the wet season and the cool dry season.

Each of the nights and blocks for collecting data were randomly selected. On any single night all the vendors in one block were interviewed to record the kinds, quantities, prices, and sources of all edible wild and semi-domesticated products they were selling. On a subsequent night all the vendors in the second block were interviewed, and then on a following night all the vendors in the third block were interviewed. This data collection cycle was repeated for eighteen nights (representing 6 composite "nights") during the cool dry season in 2006 and twelve nights (rep-

representing 4 composite “nights”) during the rainy season of 2006.

Data collection method

On a given sample night, each vendor in the selected block was interviewed to ascertain the kinds, quantities, values, and sources of all the edible wild and semi-domesticated products that she or he was selling. In order to identify wild and semi-domesticated products, each vendor was asked if these products had come from natural sources or not and then asked what they were called in both standard Thai and the Isan dialect. Species of 54 plants were collected and deposited as voucher specimens at the Herbarium of the Department of Biology, Faculty of Science, Khon Kaen University (KKU). Associate Professor Sam-ang Homchuen (Faculty of Science, Khon Kaen University) helped us to identify the plant species. References on Thai taxonomy were consulted:

For fish, fungi, and insects: Somnasang *et al.* (1988) and Mahasarakam University (n.d.).

For amphibians, birds, crustaceans, mammals, mollusks, and reptiles: Somnasang *et al.* (1988), Agriculture Extension Department (2007), Rice Department Thailand (2007), Surathane School (2007), Ubonrachathane University (n.d.).

All the data obtained from each vendor were recorded on a standardized data collection sheet. When the situation did not permit a full interview, we just observed and took note of the names and amounts of products. Color photographs were taken for later analysis of species. Each product was weighed in order to estimate the total annual

sales value of wild and semi-domesticated products in an urban market in Khon Kaen Municipality (Shirai & Rambo 2008).

Data analysis

All data were entered into an Excel database. They were separated by day of collection, number of block, name/gender/address of vendor, types, local names, total amount, purchase and selling prices, and source of products. The habitat classification is based on Moreno-Black *et al.* (1996) and extensive discussions with key informants in Nong Ben Village (Shirai *et al.* 2007).

Identification of the sources of wild and semi-domesticated products sold in Bang Lam Phu Market

The sources of all edible wild and semi-domesticated products were plotted on maps of Khon Kaen Province and Northeast Thailand to identify the boundaries of edible wild and semi-domesticated products supply shed for the Bang Lam Phu Market.

Results

The following describes the diversity, seasonal availability, cultivation status, habitat in the rural ecosystem, and geographical area of collection of the edible wild species that we observed being sold in the Ban Lam Phu market in Khon Kaen Municipality. The market channels observed are presented in Figure 2.

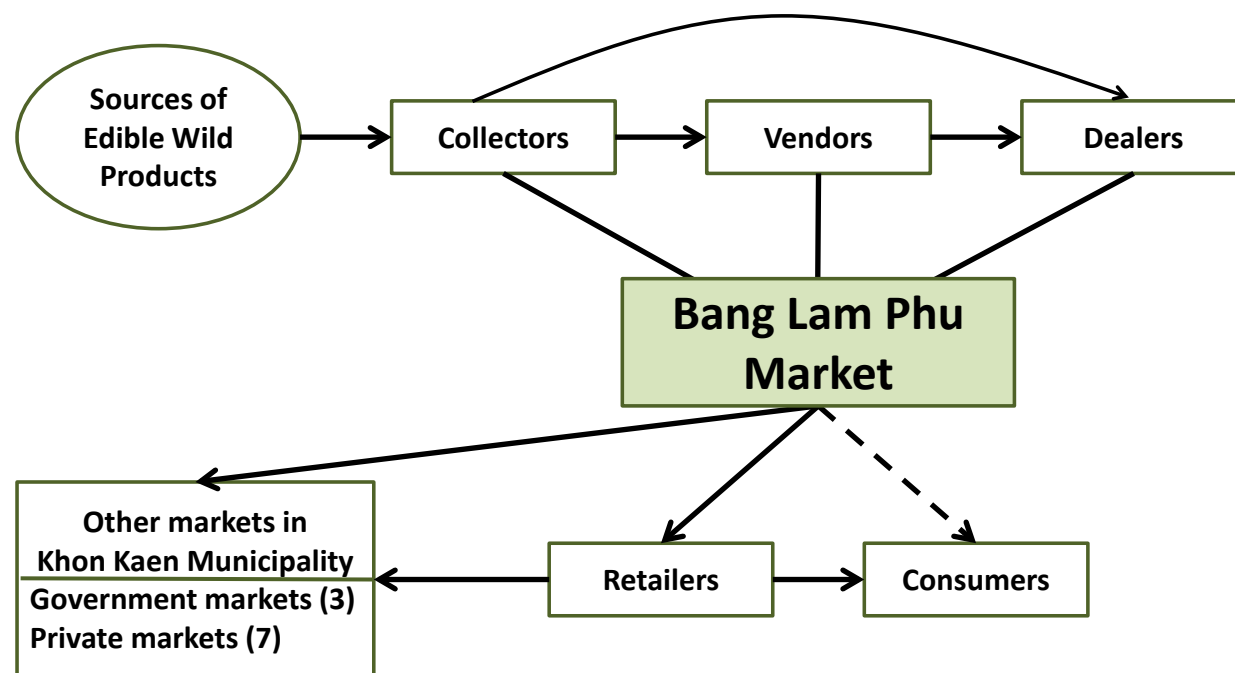


Figure 2. Market channels for edible wild products in Khon Kaen Municipality markets, Northeast Thailand.



Figure 3. Phak tiew kao (Thai & Isan), *Cratoxylum formosum* (Jacq.) Benth. & Hook.f. ex Dyer, in the Bang Lam Phu Market, Khon Kaen, Thailand.

Species diversity

Appendix A presents a comprehensive list of all species we observed. A total of 81 species were identified, of which 54 are plants, 6 are fungi, and 21 are animals. The animals can be further divided into 2 species of amphibians (frog, toad), 1 bird species, 2 species of crustaceans (crab, prawn), 3 species of fishes (fish, eel), 6 species of insects, 2 species of mammals, 2 mollusk species, and 3 reptile species (lizards, terrapin). Some species are available frequently and in large quantities, but most are

available infrequently and in very small quantities. Only 31 species were encountered 10 times or more, including 23 plants, 2 amphibians, 1 crustacean, 3 insects, and 2 mollusks. Figures 3-8 illustrate some of the diversity.

Seasonal availability

Table 1 shows the availability in the market of different species in different seasons. Species diversity is considerably greater in the rainy season, when 65 species were recorded, than in the dry season, when 49 species were

Table 1. Seasonal availability of edible wild species sold in the Bang Lam Phu Market in 2006. Orders of animals: Amphibians (A); Birds (B); Crustaceans (C); Fish (F); Insects (I); Mammals (M); Mollusks (O); Reptiles (R).

Season	Number of edible wild species											
	Kingdoms			Orders of animals								Total
	Plants	Fungi	Animals	A	B	C	F	I	M	O	R	
Dry	35	0	14	1	0	2	1	4	2	2	2	49
Rainy	44	6	15	2	1	2	3	4	0	2	1	65
Total	54	6	21	2	1	2	3	6	2	2	3	81
Only Dry	10	0	6	0	0	0	0	2	2	0	2	16
Only Rainy	19	6	7	1	1	0	2	2	0	0	1	32
Both Seasons	25	0	8	1	0	2	1	2	0	2	0	33



Figure 4. Ma kok (Thai & Isan), *Spondias pinnata* (L.f.) Kurz, in the Bang Lam Phu Market, Khon Kaen, Thailand.



Figure 5. Hed ra ngok (Thai & Isan), *Amanita* sp., in the Bang Lam Phu Market, Khon Kaen, Thailand.



Figure 6. Honey comb of **Peung** (Thai & Isan), *Apis florea* Fabricius, 1787, in the Bang Lam Phu Market, Khon Kaen, Thailand.



Figure 7. **Mang daa** (Thai & Isan), *Oecophylla smaragdina* Fabricius, 1775, in the Bang Lam Phu Market, Khon Kaen, Thailand.



Figure 8. Yea (Thai & Isan), *Liolepis reevesii* Gray, 1831, in the Bang Lam Phu Market, Khon Kaen, Thailand.

observed. Many species are available only in a specific season. Forty percent of all species recorded in the survey were only available in the rainy season, 20% were only available in the dry season, while 40% were available in both seasons. Mushrooms, for example, are only found in the rainy season, whereas rats and lizards are only sold in the dry season. Land crabs are available in both seasons, but their price and quantity is different between the seasons. In the dry season, the quantity of land crabs is higher than in the rainy season, but the price of crabs in the rainy season is higher than in the dry season. This may reflect the different conditions of the paddy fields, where most land crabs are collected, in the different seasons. In the rainy season, the villagers prepare the paddy fields to plant their major rice crop and apply chemical fertilizers and pesticide to the fields, so people prefer not to eat land crabs caught during this season. Moreover, the land crabs in the dry season are bigger and tastier than in the rainy season.

Cultivation status

Figure 9 shows the percent of species in each cultivation category. Of the total 81 species sold in the market, 59% are only wild, 19% are mostly wild, 12% mostly cultivated,

and 10% only cultivated. Plants have been most effected by human efforts at cultivation, with only 23 species

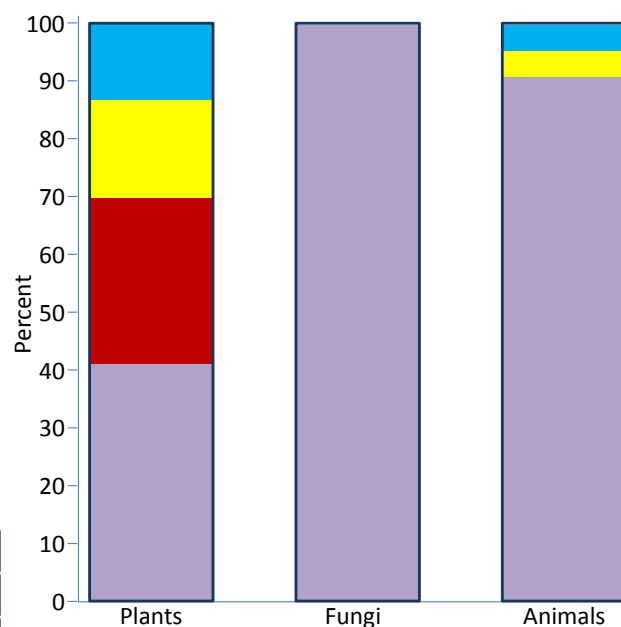


Figure 9. Cultivation status of edible wild products in Bang Lam Phu Market, Khon Kaen, Northeast Thailand.

Table 2. Habitats of edible wild species sold in the Bang Lam Phu Market in 2006, Khon Kaen, Thailand. Note that species may occur in more than one habitat.

	Forests	Paddy Fields	Upland Fields	Gardens	House Areas	Canals	Ponds	Swamps	Rivers
Plants	18	11	21	13	28	1	5	4	4
Fungi	6	0	6	0	0	0	0	0	0
Animals	6	16	8	0	1	6	8	11	10
Orders of animals									
Amphibians	0	2	0	0	0	0	0	2	2
Birds	0	1	1	0	0	0	0	0	0
Crustaceans	0	1	0	0	0	1	1	2	1
Fish	0	3	0	0	0	3	3	3	3
Insects	2	3	3	0	1	0	1	1	1
Mammals	2	2	2	0	0	0	0	0	0
Mollusks	0	2	0	0	0	2	2	2	2
Reptiles	2	2	2	0	0	0	1	1	1
Total	30	27	35	13	29	7	13	15	14

(42%) classified as still entirely wild, 15 species (28%) mostly wild, and 16 species (30%) either mostly or only cultivated. In contrast, all 6 fungi species and 19 out of 21 animal species are classified as only wild.

Habitats of wild species in the rural ecosystem

Edible wild species are obtained from several different habitats in the rural ecosystems of Northeast Thailand, including forests, upland fields, upland gardens, home gardens in house areas, paddy fields, canals, ponds, swamps, and rivers. Some species are found in only a single habitat while others may be found in several habitats. Table 2 shows the number of species found in each type of habitat.

Upland fields are the habitat for the largest number of species (35 species), followed by forest (30 species), home gardens in house areas (29 species), and paddy fields (27 species). Upland gardens and aquatic ecosystems (e.g., swamps, ponds, canals) provide habitats for smaller numbers of species.

The highest diversity of plant species is found in home gardens in house areas (28), followed by upland fields (21), forest (18), upland gardens (13), and paddy fields (11). Between 1 and 5 species are found in each of the aquatic habitats.

The 6 species of fungi are all found both in forests and upland fields. Animal species diversity is highest in paddy fields (16 species), followed by swamps (11 species), rivers (10 species), ponds and upland fields (8 species each), and forest (6 species). No animal species are found in upland gardens and only one species (crickets) in home gardens in house areas.

Sources of supply of wild species to the urban market

Figure 10 shows the provinces from which wild species flow to the urban market in Khon Kaen Municipality. Species are obtained from 8 provinces in the Northeast. Rural areas of Khon Kaen Province itself are the source of the largest number of species (68 out of a total 81 species found in the market). Mahasarakham and Kalasin provinc-

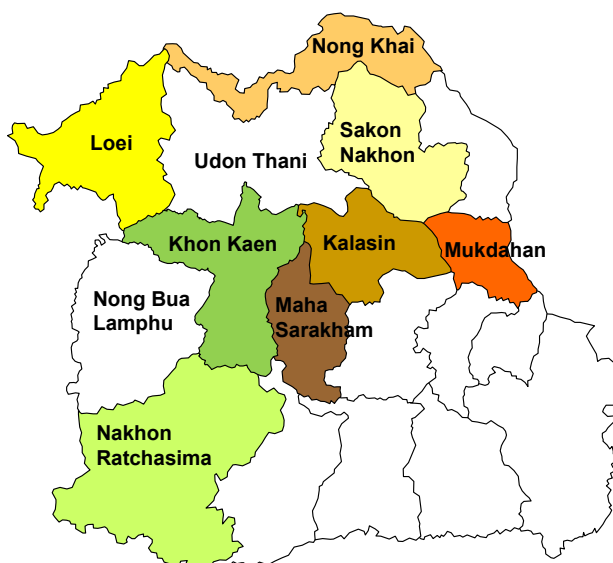


Figure 10. Supply-shed in Northeast Thailand of edible wild species sold in the Bang Lam Phu Market, Khon Kaen, with number of species from each province. Provinces (number of species): Khon Kaen (69); Maha Sarakham (34); Kalasin (27); Loei (6); Sakon Nakhon (4); Nong Khai (1); Nakhon Ratchasima (1); and Mukdahan (1).

es, which border Khon Kaen Province on the east, also supply many species (34 and 27 species, respectively). Smaller numbers of species come from mountainous Loei Province to the west and Sakon Nakhon to the northeast.

Discussion

Species diversity

The edible wild species sold in the Ban Lam Phu market are diverse. However, the number of species that we recorded in the Khon Kaen urban market is considerably smaller than the total of 212 species of plants, fungi, and animals that were found by a survey conducted in 11 village, town, and peri-urban markets in Northeast Thailand at the beginning of the 1990s (Moreno-Black *et al.* 1996). In that survey, conducted over the course of 2 years, 110 non-cultivated plant species, 19 species of fungi, 46 varieties of fish, 15 insect species, 9 crustaceans, 7 amphibians, 2 reptiles (lizard, turtle), 2 mammals, and 2 bird species were recorded. However, many of the species recorded in the earlier survey were isolated individuals that were observed in only one or a few markets. Only 37 species were commonly encountered, including 20 plant species, 4 species of fungi, 5 species of insects, 4 species of fish, 2 species of crustaceans, and 2 species of mollusks (Moreno-Black *et al.* 1996:109-110).

Somewhat surprisingly, the diversity of edible wild species available in the urban market in Khon Kaen Municipality is about the same as is now found in rural villages in the Northeast. A survey in 2006 of wild food species collected by farmers in Nong Ben Village in Khon Kaen Province identified a total of 96 species, including 38 plant species, 4 species of fungi, and 54 animal species (Shirai *et al.* 2007). This is a smaller number of species than was found by a survey conducted in 8 villages in several provinces in the Northeast in the mid-1980s. In that survey, 122 species, including 49 plants, 15 fungi, and 58 animals, were recorded as being consumed as food by villagers (Somnasang *et al.* 1988).

Two factors may explain the decrease in the number of species observed in our survey compared to the numbers recorded in surveys conducted in rural villages and markets 15 or 20 years ago (Moreno-Black *et al.* 1996, Somnasang *et al.* 1988). Some of the decrease may reflect an actual decline in rural biodiversity resulting from widespread habitat changes in the Northeast Thailand region in the past several decades (Vityakon *et al.* 2004) while some of the decrease may be the consequence of recent major changes in the rural economy, particularly the increase in employment of villagers as wage laborers, which has reduced the amount of time that villagers have available to collect species occurring in less accessible habitats.

Seasonal availability

Because of the pronounced differences in temperature and rainfall in the different seasons in Northeast Thailand, the supply of wild products to the market is not constant, but varies according to the season of the year. Moreover, there is also a great deal of year-to-year variation in the weather which also causes fluctuations in the supply of wild products. The amount of rain each year is the major factor affecting the availability of natural food (Somnasang *et al.* 1988).

Cultivation status

Given the extent to which rural ecosystems in Northeast Thailand have been subject to continuing human interference for hundreds of years, it is often difficult to determine if a species is truly wild or not. Wild species are defined as species that normally grow under natural conditions without deliberate human management. Semi-domesticated species are formerly wild species that are now to a greater or lesser extent actively managed by humans. Some species that were identified by our informants as being "wild" would appear to be cultivated species that have moved back into wild or cultivated status. For example, star fruit (*Averrhoa carambola* L.) and tamarind (*Tamarindus indica* L.) have long histories of cultivation but can voluntarily propagate themselves to some extent in upland fields and gardens in Northeast Thailand. People who collect fruit from these volunteer trees consider them to be wild. Our classification of the cultivation status of species is based on statements of collectors and market vendors. This is a process that has been underway in Northeast Thailand for some time. Thus, a report on wild food species found in rural markets in the early 1990s states that a significant proportion of vendors indicated that the plant items they sold could be transplanted to make them more accessible and to conserve them, since much of the area is being rapidly deforested. Plant vendors were knowledgeable about a wide variety of management practices for the nurture and maintenance of plants that were transplanted (Moreno-Black *et al.* 1996:113).

Quite a number of species are in transition, being sometimes collected from the wild and other times cultivated. Thus, species have been further classified according to whether they are only wild, mostly wild, mostly cultivated, or only cultivated. Moreno-Black *et al.* (1996:113) report that rural market vendors surveyed in the early 1990s raised some captured wild animal species in captivity, mostly fish, but that other than frogs, no one bred any animal species.

Interestingly, the domestication status of some species in urban markets is quite different from the general pattern. For example, most honey in Thailand is now obtained from domesticated honeybees, but in the urban market, only honey obtained from the hives of wild bees is sold.

Crickets sold in the market, on the other hand, were all raised by farmers, although it is still possible to collect them from nature. It may be that the heavy demand by urban consumers exceeds the supply of wild crickets so that people have to depend on the cultivated products.

Habitats of wild species in the rural ecosystem

A survey of wild species sold in nonurban markets in the early 1990s (Moreno-Black *et al.* 1996:113) reported that edible plants and fungi were obtained from several different habitats, including forests (28%); paddies (23%); upland gardens (23%); water sources such as ponds, canals, and swamps (22%); and home gardens in house areas and upland gardens (4%).

Although most species in this study are found living in two or more habitats, 17 plant species and 2 insect species are restricted to only a single habitat: 3 plant species occur only in paddy fields, 1 species only in upland fields, 5 species only in upland gardens, and 9 species only in house areas; 1 insect species is found only in paddy fields and 1 species only in home gardens in house areas. Species found in only a single habitat are likely to be at higher risk from human-induced changes in the rural environment, e.g., the conversion of upland crop fields to monocultural plantations of eucalyptus or rubber that is now occurring quite rapidly in many parts of Northeast Thailand.

Sources of supply of wild species to the urban market

Curiously, no species are obtained from Udon Thani and Nong Bua Lamphu, which are Khon Kaen's neighboring provinces to the north. It may be that urban markets in Udon Thani city can absorb the whole available supply of locally collected wild products. Similarly, only one species comes from Nakhon Ratchasima Province to the south. Again, it is likely that the urban markets in the provincial capital of Khorat, which is the largest city in Northeast Thailand, absorb almost all locally collected products.

Conclusions

This research has revealed the diversity of edible wild species that are sold in the main urban market in Khon Kaen Municipality. Despite undergoing many social and cultural changes associated with urbanization, urban people continue to desire many of the same wild foods as have been traditionally consumed by rural villagers. Urban demand for these species may have an important impact on rural biodiversity since species are obtained from many different habitats in an extensive supply-shed that covers eight provinces in Northeast Thailand.

The collection of wild species to supply urban markets can have both negative and positive effects on rural biodiver-

sity in Northeast Thailand. In their desire to earn cash income, villagers may over-exploit some of these species, causing wild populations to decline in numbers or even become locally extinct. On the other hand, faced with a growing scarcity of wild species that bring a high price in urban markets, the villagers may intensify their efforts to cultivate them so as to allow more stable production, thus contributing to preservation of rural biodiversity. This has already begun to happen in the case of wild boar. Farmers living in the vicinity of Khon Kaen Municipality have recently begun to raise this formerly wild species in captivity in order to meet the heavy demand for wild game meat from urban restaurants (Shirai & Praweenwongwuthi 2007). However, understanding all of the ways in which urban demand for wild food species affects rural biodiversity will require much more research than it was possible to conduct as part of this study, which was explicitly focused on the place of these species in the urban markets.

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Appendix A. Inventory of edible wild and semi-domesticated species sold in the Bang Lam Phu Market in 2006. **Seasonal availability:** Rainy (R), Dry (D). **Sources:** Wild only (W), Mostly (more than 50%) wild (MW), Mostly (more than 50%) cultivated (MC), Cultivated only (C). **Habitats:** Canals (C), Forests (F), Gardens (G), Ponds (P), Paddy fields (PF), Rivers (R), Swamps (S), Upland fields (U), Yards (Y). **References:** 1=Smitinand 2001; 2=Somnasang *et al.* 1988; 3=Agriculture Extension Department 2007; 4=Rice Department Thailand 2007; 5=Surathane School 2007; 6=Vichakran.com 2007; 7=Ubonrachathane University n.d.; 8=Maharakam University n.d.; 9=Wilkin & Thapayai 2009; 10=Hedge 1997; 11= Hedge & Lamond 1992; 12= Wong 1995; 13= The International Plant Names Index. n.d.; 14. Meyer 2011. Author-collected plant specimens (Yuko numbers) were deposited in the KKKU (KKU numbers) herbarium.

Frequency	Names			Season		Source	Habitat	References	Specimens	
	Scientific	Thai	Isan	R	D				Yuko	KKU
	Plants									
167	<i>Ipomoea aquatica</i> Forssk.	Pak bung na	Phak bung na	X	X	W	PF	1	10	22586
106	<i>Spondias pinnata</i> (L.f.) Kurz	Ma kok	Ma kok	X	X	MW	U, Y	1	18	22587
66	<i>Azadirachta indica</i> A.Juss. var. <i>indica</i>	Sa dao	Ka dao	X	X	MW	F, U, Y	1	26	22588
40	<i>Sesbania grandiflora</i> (L.) Pers.	Khae ban	Dok khae	X	X	MC	Y	1	05	22589
39	<i>Barringtonia acutangula</i> (L.) Gaertn.	Chik na	Phak ka doan	X	X	MW	F, U, Y	1	22	22590
39	<i>Limnocharis flava</i> (L.) Buchenau	Ta lapat ruesi	Phak kan jong	X	X	MW	PF, S	1	06	22591
36	<i>Senna siamea</i> (Lam.) H.S.Irwin & Barneby	Khi lek ban	Phak khi lek	X	X	MW	F, U, Y	1	04	22592
35	<i>Bambusa nutans</i> Wall. ex Munro	Pai bong	Pai wan	X		MC	G	1	43	22593
34	<i>Cratoxylum formosum</i> (Jacq.) Benth. & Hook.f. ex Dyer	Phak tiew kao	Phak tiew kao	X	X	MW	F, U, Y	1	23	22594
33	<i>Nymphaea pubescens</i> Willd.	Bua sai	Bua sai	X	X	W	P, S R	1	27	22595
32	<i>Tiliacora triandra</i> (Colebr.) Diels	Ya nang	Ya nang	X	X	MW	G, Y	1	01	22596
27	<i>Bambusa multiplex</i> (Lour.) Raeusch. ex Schult.	Pai liang	Pai liang	X	X	MC	G	1	19	22597
26	<i>Piper sarmentosum</i> Roxb.	Cha phlu	Phak e lerd	X	X	MC	G, Y	1	07	22598
21	<i>Syzygium antisepticum</i> (Blume) Merr. & L.M.Perry	Phak mek	Phak mek	X	X	W	U	1	08	22599
20	<i>Limnophila aromatica</i> (Lam.) Merr.	Phak kha yaeng	Phak ka ngieng	X	X	MW	PF	1	03	22600
19	<i>Telosma cordata</i> (Burm.f.) Merr.	Salit	Kik	X	X	MC	G	1	29	22601
17	<i>Colocasia gigantea</i> Hook.f.	Khun	Thun	X	X	MC	Y	1	13	22602

Frequency	Names			Season		Source	Habitat	References	Specimens	
	Scientific	Thai	Isan	R	D				Yuko	KKU
16	<i>Vietnamosasa ciliata</i> (A.Camus) T.Q.Nguyen	Pai chot	Chot	X		W	F, U	1	44	22603
13	<i>Glinus oppositifolius</i> (L.) Aug.DC.	Sadao din	Phak kaeng khom		X	MW	Y	1, 13	17	22604
12	<i>Garcinia cowa</i> Roxb. ex Choisy	Chamuang	Phak som mong	X	X	W	F, U, Y	1	50	22605
12	<i>Tamarindus indica</i> L.	Ma kham	Mak kham	X	X	MC	PF, U, G, Y	1	09	22606
10	<i>Sauropus androgynus</i> (L.) Merr.	Phak waan ban	Phak waan ban	X	X	MW	PF, P	1	02	22607
10	<i>Schleichera oleosa</i> (Lour.) Merr.	Ta kho	Mak kho	X		MW	F, U	1	45	22608
9	<i>Calamus</i> sp.	Wai	Wai	X		MC	G	1	24	22609
7	<i>Cyclea barbata</i> Miers	Bai kon pit	Ked ma noi		X	W	F, U, Y	1	12	22610
6	<i>Amaranthus viridis</i> L.	Phak kom	Phak kom	X	X	W	Y	1	21	22611
6	<i>Basella alba</i> L.	Phak plang	Phak pang	X		MC	Y	1	28	22612
4	<i>Adenia viridiflora</i> Craib	Phak sab	Phak sab	X	X	W	Y	1	32	22613
3	<i>Colocasia esculenta</i> (L.) Schott	Bon	Bon	X	X	C	Y	1	25	22614
3	<i>Oenanthe javanica</i> (Blume.) DC.	Phak chi lom	Phak chi nam		X	W	PF, G, Y	1	33	22615
3	<i>Phyllanthus emblica</i> L.	Ma kam pom	Mak kam pom	X	X	MW	F, PF, U	1	34	22616
3	<i>Spirogyra</i> sp.	Thao	Thao		X	W	C, R	1	35	22617
3	<i>Terminalia chebula</i> Retz.	Samo thai	Samo	X	X	MW	F, U	1	16	22619
3	Unknown	Phak phai	Phak phai	X		MW	PF, P	-	11	22618
2	<i>Aegle marmelos</i> (L.) Corrêa ex Roxb.	Ma tum	Mak tum	X	X	C	F, U, Y	1	30	22620
2	<i>Diospyros decandra</i> Lour.	Chan	Mak chan	X		C	U, Y	1	42	22622
2	<i>Emilia sonchifolia</i> (L.) DC. ex DC.	Hang pla chon	Phak lin pii	X		MW	Y	1	15	22623
2	<i>Feroniella lucida</i> (Scheff.) Swingle	Ma sang	Dok sang		X	W	F, PF, U, G	1	36	22624
2	<i>Maranta arundinacea</i> L.	Sakhu	Sakhu		X	C	F, G, Y	1	46	22621
2	<i>Marsilea crenata</i> C.Presl	Phak waen	Phak waen	X		W	PF, R	1	31	22625
1	<i>Acmella oleracea</i> (L.) R.K.Jansen	Phak Khrat	Phak kaad	X		W	G, Y	1	52	22634
1	<i>Averrhoa carambola</i> L.	Ma fueang	Mak fueang	X		W	G	1	20	22626
1	<i>Azadirachta indica</i> A.Juss. var. <i>siamensis</i> Valetton	Phak khi nin	Phak khi nin		X	W	F, U, Y	1	37	22628

Frequency	Names			Season		Source	Habitat	References	Specimens	
	Scientific	Thai	Isan	R	D				Yuko	KKU
1	<i>Bambusa bambos</i> (L.) Voss	Pai paa	Pai paa	X		W	F, U	12	47	22627
1	<i>Dialium cochinchinense</i> Pierre	Khleng	Kheng	X		W	F, U	1	51	22629
1	<i>Dioscorea</i> sp.	-	Man mak heb		X	W	F, U	9	53	22638
1	<i>Diplazium esculentum</i> (Retz.) Sw.	Phak kut khao	Phak kut		X	C	G, Y	1	48	22630
1	<i>Flacourtia rukam</i> Zoll. & Moritzi	Ta khp thai	Mak ben	X		W	F, U	1	38	22631
1	<i>Lasia spinosa</i> (L.) Thwaites	Phak nam	Phak nam	X		W	Y	1	39	22632
1	<i>Monochoria hastata</i> (L.) Solms	Phak top thai	Phak top	X		W	P, S, R	1	49	22633
1	<i>Raphanus sativus</i> L.	Hua phak kat khao	Phak pong	X		W	PF	10	40	22636
1	<i>Schinus terebinthifolia</i> Raddi	Phak tum sa u	Phak tum sa u	X		C	Y	14	41	22639
1	<i>Trachyspermum roxburghianum</i> (DC.) H. Wolff	Phak sa ngea	Phak sa ngea		X	C	Y	11	14	22637
1	<i>Wolffia globosa</i> (Roxb.) Hartog & Plas	Khai name	Khai phlam	X		W	P, S	1	54	22635
Fungi										
2	<i>Amanita</i> sp.	Hed ra ngok	Hed la ngok	X		W	F, U	2		
1	<i>Lentinula edodes</i> (Berk.) Pegler	Hed kho	Hed kho	X		W	F, U	2		
1	<i>Russula delica</i> Fr.	Hed kai	Hed kai	X		W	F, U	2		
1	<i>Russula nigricans</i> Fr.	Hed than	Hed than	X		W	F, U	2		
1	<i>Russula rosea</i> Pers.	Hed na dang	Hed na dang	X		W	F, U	8		
1	<i>Russula</i> sp.	Hed na lae	Hed na lae	X		W	F, U	8		
Amphibians										
14	<i>Occidozyga</i> spp.	Keyad	Keyad	X	X	W	PF, S, R	7		
11	<i>Hoplobatrachus tigerinus</i> Daudin, 1803	Kob	Kob	X		MC	PF, S, R	6		
Birds										
1	<i>Coturnix chinensis</i> L., 1766	Nok kum see	Nok kum	X		W	PF, U	5		
Crustaceans										
73	<i>Somanniathelpusa</i> spp.	Pu naa	Ka puu	X	X	W	PF, S	2		

Frequency	Names			Season		Source	Habitat	References	Specimens	
	Scientific	Thai	Isan	R	D				Yuko	KKU
4	<i>Macrobrachium lanchesteri</i> de Man, 1911	Kung foi	Kung	X	X	W	C, P, S, R	2		
	Fish									
2	<i>Channa striata</i> Bloch, 1793	Pla chon	Pla kor	X	X	W	PF, C, P, S, R	2		
1	<i>Esomus</i> spp.	Pla siew	Pla siew	X		W	PF, C, P, S, R	2		
1	<i>Monopterus albus</i> Zuiew, 1793	Pla lai	len	X		W	PF, C, P, S, R	2		
	Insects									
43	<i>Oecophylla smaragdina</i> Fabricius, 1775	Mod dang	Mod dang		X	W	F, U	2		
14	<i>Gryllus</i> sp.	Jing lid	Jii lid	X	X	C	Y	2		
11	<i>Lethocerus indicus</i> Lepeletier & Serville, 1825	Mang daa	Mang daa	X	X	W	PF, P, S, R	2		
2	<i>Apis florea</i> Fabricius, 1787	Peung	Peung		X	W	F, U	8		
2	<i>Cyrtacanthacris tatarica</i> L., 1766	Taka taen (Panangka)	Taka taen (Panangka)	X		W	PF, U	2		
1	<i>Gryllotalpa africana</i> Palisot de Beauvois, 1805	Malang kra chon	Meng ki son	X		W	PF	2		
	Mammals									
1	<i>Rattus argentiventer</i> Robinson & Kloss, 1916	Nu tong kaow	Nu na		X	W	F, PF, U	4		
1	<i>Rattus losea</i> Swinhoe, 1871	Nu puk	Nu puk		X	W	F, PF, U	4		
	Mollusks									
17	<i>Filopaludina martensi</i> Frauenfeld, 1864	Hoi kom	Hoi juub	X	X	W	PF, C, P, S, R	2		
16	<i>Pomacea canaliculata</i> Lamarck, 1819	Hoi chery	Hoi chery	X	X	W	PF, C, P, S, R	3		
	Reptiles									
3	<i>Liolepis reevesii</i> Gray, 1831	Yea	Yea		X	W	F, PF, U	2		
3	<i>Malayemys subtrijuga</i> Schlegel & Müller, 1845	Tao	Tao	X		W	PF, P, S, R	7		
1	<i>Calotes versicolor</i> Daudin, 1802	Jing kaa	Ka pom		X	W	F, U	2		

Homegardens of the Cao Lan, a Tai-Speaking Ethnic Minority in Vietnam's Northern Mountains

Pijika Timsuksai,* Nguyen Dinh Tien,** and A. Terry Rambo***

The Cao Lan are a Tai-speaking ethnic group living in the Midlands of Northern Vietnam. Homegardens are an important component of their agroecosystem. The ecological structures of each homegarden of 17 households of the Cao Ngoi village in Tuyen Quang province were described and modal patterns identified. Most homegardens have organically shaped planting areas with indeterminate boundaries, polycentric planting patterns, and contain multiple species within the same bed or planting area. All of the gardens have multiple vegetation levels, with the largest share having 5 levels and a majority having more than 50% of their planting area covered by overlapping vegetation layers. Biodiversity is high with a total of 113 species recorded. Most plant species are used for food, but smaller numbers have ornamental, medicinal, and construction uses or are used for animal fodder, as stimulants, or for other purposes.

Comparison of the modal structure of the Cao Lan homegardens with several Tai minority groups in Northeast Thailand, shows that, although the Cao Lan have been geographically isolated from other Tai groups for many centuries, their homegardens share a similar structural pattern, one commonly referred to as the tropical forest type. This structure is very different from the temperate type gardens of the Kinh in Vietnam with whom the Cao Lan share a common environment and are in frequent contact. The persistence of a common structural pattern among these related Tai ethnic groups, despite their inhabiting different environments, and having had no direct contact with each other for a very long time, suggests that culture exerts a strong influence over agroecosystem structure.

Keywords: Cao Lan ethnic minority, ethnobotany, agroecosystem structure, indigenous knowledge, biodiversity

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Introduction

After Terra's pioneering descriptions of the different types of homegardens associated with different ethnic groups in the Indo-Malayan region (Terra 1952–53; 1954; 1958), few additional studies were published about Southeast Asian homegardens until the 1980s when homegardens emerged as a major focus of agroforestry research. Much of this research was concerned with describing the architecture, species composition, and functions of homegardens of different ethnic groups in the tropics. Since that time, a considerable number of studies have been published describing the structure, species diversity, and functions of homegardens of ethnic groups in different Southeast Asian countries, including Burma (Terra 1954), Indonesia (Soemarwoto and Soemarwoto 1984; Wiersum 2006), Laos (Kou *et al.* 1990; The SUAN Secretariat 1990; Dyg and Saleumsky 2004; Nawata *et al.* 2009), Thailand (Moreno-Black *et al.* 1996; Jiragorn and Nantana 1999; Nawata *et al.* 2009; Thanakorn *et al.* 2010; Kamonnate *et al.* 2012), and the Philippines (Snelder 2008). There has also been considerable research on homegardens in Vietnam (Le Trong Cuc *et al.* 1990; Karyono *et al.* 1993; Hodel *et al.* 1999; Dao Trong Hung *et al.* 2001; Luu Ngoc Trinh *et al.* 2003; Vlkova *et al.* 2011) but it has mostly been focused on the Kinh (ethnic Vietnamese), the majority ethnic group. Only a very few studies have been done on the homegardens of ethnic minorities. In the case of the Cao Lan, a Tai speaking minority group living in the Northern Mountain region, there are only 2 brief reports (Gilligly and Nghiem Phuong Tuyen 1992; Le Trong Cuc and Rambo 2001) which describe the species composition of their homegardens but not their ecological structure or the functions of the different species.

It was in order to obtain information about the structure and species composition and functions of Cao Lan homegardens, that we carried out a short field study in a Cao Lan community in Tuyen Quang province in Northern Vietnam. This case study was done as part of a larger comparative study of the ecological structures of homegardens of different ethnic groups in Northeast Thailand and Vietnam which was designed to assess the relative importance of culture and environment as determinants of agroecosystem structure (Pijika 2014). The aims of this paper are to describe the modal ecological structure of the Cao Lan homegardens, identify all of the plant species grown in these gardens and categorize their functions, and compare the modal structure of the Cao Lan gardens with those of their Kinh neighbors and ethnically related Tai minority groups in Northeast Thailand.

Background

The Cao Lan Ethnic Group

The Cao Lan speak a language belonging to the Tai family of languages. They are one of 54 officially recognized ethnic groups in Vietnam. They are known officially as San Chay (also often called Cao Lan-San Chi). They first immigrated to Vietnam from China beginning in the 1600s. The Cao Lan numbered about 169,000 people in 2009. They are mainly settled in Tuyen Quang, Bac Can, and Thai Nguyen provinces. Settlements of this ethnic group are also scattered in Yen Bai, Vinh Phuc, Phu Tho, Bac Giang, and Quang Ninh provinces (Dang Nghiem Van *et al.* 2000; Sumitre *et al.* 2003; Ethnologue: Languages of the World 2013). According to the 1999 census, a few thousand San Chay live in the Central Highlands, mostly in Dac Lac with smaller numbers in Binh Phuoc, Dong Nai, Gia Lai, and Kon Tum provinces (General Statistical Office 2001). It is likely that these people migrated south to the New Economic Zones in the 1980s.

According to Gregerson and Edmondson (1998), the Cao Lan-San Chay ethnic group is actually a composite of two groups with two different languages and two non-overlapping cultures. The Cao Lan language has been classified as a Central Tai language of the Kam-Tai sub-branch of the Tai-Kadai language family, while the San Chay language is Han Chinese. In their view “. . . the Cao Lan and San Chay do not live in a classical diglossic situation of high language vs low language, but as two groups with mostly different identities despite a small overlap today and a common link in the past,” when these groups lived in close proximity along the border areas of Hunan, Guangdong, and Guangxi provinces of China (*ibid.*, 152).

According to Gregerson and Edmondson's field study, some Tai speaking Cao Lan groups refer to themselves as San Chay, although this is the official name of the Han-speaking group. Both Cao Lan and San Chay write using Chinese characters. Some older San Chay people can also speak a Tai language just as some elderly Cao Lan can speak and write in the Han language. It can be concluded that, “All these facts tell us that the two were in some sense one nationality with two partially overlapping speech communities whose original bilingualism has developed into separated mostly monolingualism through separation, as the majority of the San Chay live in Quang Ninh and the Cao Lan live mostly in Tuyen Quang, Thai Nguyen, and Bac Giang” (*ibid.*).

The Study Village

Cao Ngoi village is in Dong Loi commune, Son Duong district of Tuyen Quang province. This village is quite isolated and far away from the main road. The distance from the Son Duong district capital to the village is about 50 km, or 2 hours travel by bus (Fig. 1). The

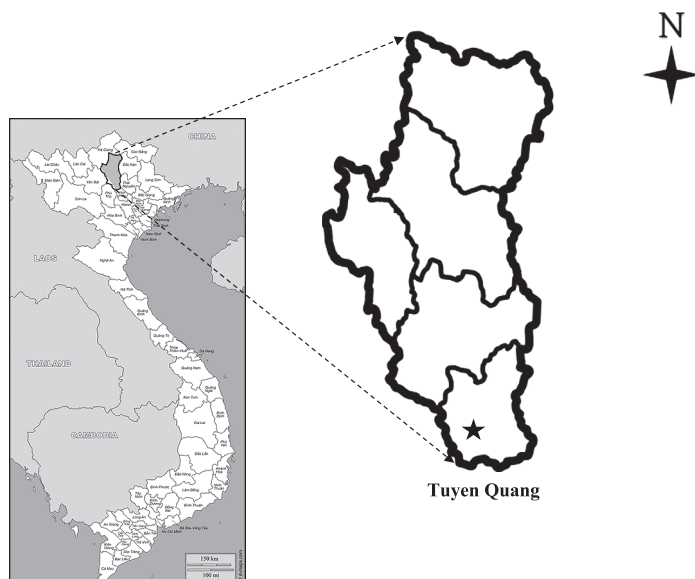


Fig. 1 Map Showing Location of Cao Ngoi Village, Son Duong District, Tuyen Quang Province

narrow and very rough dirt road that connects the village to the main highway crosses paddy fields in lowlands, then climbs up on to the upper terrace with sugarcane fields and acacia tree plantations, before it descends into the narrow valley hidden between steep sloped mountains where Cao Ngoi village is located.

According to the oral traditions of the villagers, Cao Ngoi village was established about 200 years ago by a group of 7 Cao Lan households who migrated there from Hoa Binh province. There are now 21 households with 76 people living there. They all speak the Cao Lan language in their daily activities in the village and also can converse in Vietnamese when dealing with outsiders. Traditionally, Cao Lan was written using Chinese characters but now only one older man in the village can read it. Nowadays the villagers wear Vietnamese style clothes for daily life but they still wear the traditional Cao Lan dress on special occasions.

The villagers live in the traditional Cao Lan style houses which are built on stilts made from large tree trunks. The bottom of each stilt rests on a large flat stone. Most houses have palm leaf roofs. Some houses have walls and floors made of wooden planks and others have woven bamboo walls and floors. They are entered by a wooden ladder on the side of the house. The space underneath the floor of the house is used to store firewood, agricultural equipment, motorcycles and bicycles, and wooden planks for house repairs. A fire-place made of clay is set on the floor of the house and is used for cooking

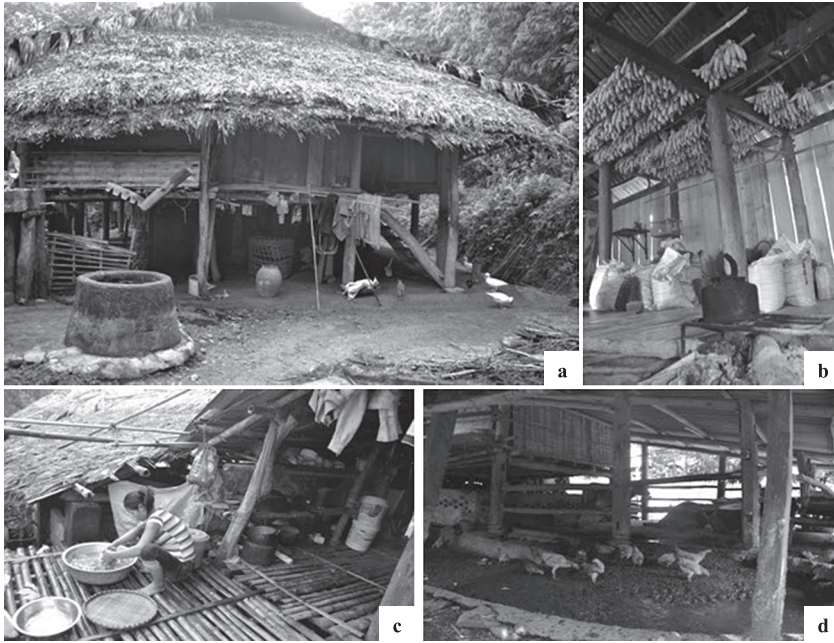


Fig. 2 Traditional Cao Lan Style House and Components; (a) Cao Lan House, Well, and Courtyard, (b) Fire-place inside the House, (c) Balcony, (d) Animal Pens under the House

and heating. The ancestral shrine is mounted on a side wall of the house. Agricultural products such as rice grain and dried maize are stored inside the house. Some houses have large attached balconies built from bamboo where they do laundry and sun-dry food (Fig. 2).

The nearest neighboring Cao Lan village is about 4 km away, or 30 minutes by motorcycle, and the nearest market is about 10 km away. The nearest Kinh (ethnic Vietnamese) village is more than 5 km away. A rudimentary 1 room kindergarten in the village has 1 volunteer teacher and 2 very young students. The nearest primary and secondary schools are about 17 km away in Kinh villages. The older children have to ride bicycles to school there early in the morning and return in the afternoon. The trip takes them almost 3 hours each way.

Natural Conditions of the Study Village

Cao Ngoi village is situated at 169 m above sea level at 21°35'40.18"N, 105°20'52.38"E. The climate is classified as humid subtropical. The soil is infertile sandy loam, with poor drainage in the mountain valley. Although this area has scattered rain all year round with a mean annual rainfall of 1,500 mm (Nguyen Thi Mui 2006), there is a relatively dry

season from August through January and a relatively wet season from February through July. The rains start from late February, with the heaviest rain in July, and then decrease after that with only a slight amount of rain in December. According to the village headman mean temperatures range from 15°C in winter to 35°C in summer. In the village there is a waterfall which the villagers use for electricity generation, for daily household use, to irrigate paddy fields, and which now serves as a tourist attraction in the summer.

The Agricultural System and Its Components

The agricultural system in the village includes paddy fields, upland fields, homegardens, and livestock. The total area of paddy fields is about 5 ha, with an average area per household of about 1,000 m². Two rice crops are grown per year with an average yield of about 4 tons of unhusked rice per crop. The fields are irrigated with water from the stream flowing down from the mountainside into the village. Upland field crops are planted under 3 systems: 1) sugarcane on land belonging to the villagers (under contract to the sugar mill), 2) Acacia trees (*Acacia mangium* Willd) on their own land (under contract to the State Forest Enterprise [SFE]), and 3) Acacia on SFE land (the villagers work as wage laborers for the SFE). The 16 household-owned sugarcane fields cover 8.8 ha. The sugar mill provides the farmers with seedlings and fertilizer. After the harvest, they have to repay the cost of these inputs to the mill. Fourteen hectares, owned by 16 households, are planted with Acacia under contract to the SFE, with the owners receiving 63% of the income at harvest. On the Acacia land owned by the SFE, the villagers who are employed by the SFE receive a regular wage for caring for the trees.

Seventeen households have homegardens (*an toon* in the Cao Lan language). Homegardens include vegetable plots and fruit trees. The gardens surround the houses but are mostly sited in front of the houses. The front side of the house is determined by the location of the ancestor's shrine. Within the homegarden are the house, animal pens, fish pond, bee hives, fenced vegetable plots, fruit trees, a concrete paved area for sun-drying crops, and an old-style pit toilet located deep in the garden. The average area of homegardens in this village is almost 3 *sao* or about 1,004 m² (1 *sao* = 360 m², the traditional measurement unit used in the Northern Vietnam region). The 2 smallest homegardens are only 1 *sao*, 6 gardens are 2 *sao*, 4 each are 3 and 4 *sao*, with the largest garden having an area of almost 6 *sao* (2,000 m²).

Livestock include about 60 cattle and buffalo, 100 goats (belonging to 5 households), 300 chickens, Muscovy ducks and geese, and 1 or 2 pigs per household. There are 11 fish ponds belonging to 11 households. Six households have honey bee hives.

Methodology

Selection of Study Site and Study Households

Cao Ngoi village was selected based on discussions with knowledgeable district officers about Cao Lan settlements that maintained their ethnic traditions and met the following criteria: 1) located in rural area, 2) ethnically homogeneous, and 3) the main purpose of their homegardens was production for household consumption. The village was also selected because it was located some distance away from Kinh villages in a remote area in the mountains, and had no recent connections with other Tai groups in Thailand.

Because of the small size of the community, it was not necessary to employ sampling. Instead, all 17 households having homegardens were included in the survey.

Data Collection and Data Analysis

Data collection was carried out for 12 days during September 2012. Data were collected at two levels: 1) community level information on village history and ethnic identity was collected in semi-structured interviews with the village headman and village elders, 2) household level information was collected in semi-structured interviews with garden owners and by making direct observations of their gardens, including measurement of horizontal and vertical dimensions, and enumeration of plant species. Data were collected on homegarden components, functions of individual species, and structural characteristics (horizontal and vertical). These data were recorded on sketch maps, photographs, architectural drawings, and species checklists.

Data on all of the homegardens were entered into an Excel database, which was used to compile tables of characteristics for all gardens of households.

Data analysis employed the classification system for describing the characteristics of homegardens developed by Pijika (2014). This system includes horizontal structural dimensions, vertical dimensions, and measurement of species composition and diversity.

Horizontal dimensions include:

- Shape of planting area or plot: *Geometric* forms include plots or beds with square, rectangular, or circular shapes. *Organic* forms include planting areas with irregular or curvilinear shapes.
- Definition of boundaries of planting areas or plots: Boundaries can be *sharp* and clearly marked or *indeterminate* and ill-defined.
- Arrangement of individual plants within planting areas or beds: Individual plants can be planted in parallel lines (*lineal*) or in multiple clusters of plants, usually including representatives of two or more species (*polycentric*).

- Species composition within each plot: Planting areas or beds can be planted with only a single kind of plant species (*mono-species*) or with a mixture of two or more different species (*multi-species*).

Vertical dimensions include:

- Number of levels of vegetation: Plants of different species have different heights, which were recorded for 5 levels: Level 1 = 1 meter or less, Level 2 = 1.01–5 m, Level 3 = 5.01–10 m, Level 4 = 10.01–15 m, Level 5 = >15 m. All plants in the garden may be of the same height (*single level*) or they may have different heights (*two or more levels*).
- Canopy overlap: The share of the garden area in which the canopies of plants of different heights overlap each other (*non-overlapping*, *<50% overlapping*, *>50% overlapping*).

Species composition and diversity are measured in terms of the:

- Total number of species growing in the garden.
- Species richness, that is the number of species present by using Shannon-Wiener diversity index (H) (Magurran 1988)

$$H = -\sum_{i=1}^S p_i \ln p_i$$

where p_i is proportion of the species relative to the total number of plants, and S is the number of species recorded.

- Species abundance, that is how equally abundant the species are by using Simpson's index (D) (*ibid.*)

$$D = \frac{1}{\sum_{i=1}^S (p_i)^2}$$

where p_i is proportion of the species relative to the total number of plants, and S is the number of species recorded.

Results and Discussion

The Structure of Cao Lan Homegardens

The frequencies with which different structural characteristics of Cao Lan homegardens occur are shown in Table 1. The modal pattern of Cao Lan homegardens is organic shaped planting areas (Fig. 3a) with indeterminate boundaries (Fig. 3c), polycentric plantings (Fig. 3b) of multiple species in the same bed (Figs. 3b and 3d), and having multiple levels (Figs. 3a and 3d) of overlapping canopy layers (Fig. 3a). A large majority of homegardens (72%) have an organic shape of their planting area, 72% have an indeterminate boundary, 78% have a polycentric planting pattern, and 61% have multiple species within the same bed or planting area. All gardens have multiple vegetation levels, with the largest share

Table 1 Modal Pattern of the Cao Lan Homegardens of Cao Ngoi Village, Tuyen Quang Province, Northern Vietnam (n = 17) (Gray shading indicates most common form)

Structural Dimension	Alternatives Forms (%)		Modal Pattern
Horizontal characteristics			
Shape of planting areas	All Geometric	0	Organic
	>50% Geometric	0	
	>50% Organic	28	
	All Organic	72	
Boundary definition of planting area	All Sharp	6	Indeterminate
	>50% Sharp	0	
	>50% Indeterminate	22	
	All Indeterminate	72	
Arrangement of individual plants within planting areas	All Lineal	11	Polycentric
	>50% Lineal	4	
	>50% Polycentric	7	
	All Polycentric	78	
Species composition within planting area	All Mono-species	22	Multi-species
	>50% Mono-species	17	
	>50% Multi-species	0	
	All Multi-species	61	
Vertical characteristics			
No. of vegetation levels	1	0	5 levels
	2	0	
	3	25	
	4	30	
	5	45	
Share of planting area covered by overlapping layers	Non-overlapping	0	Extensive
	<50% Overlap	44	
	>50% Overlap	56	



Fig. 3 Homegardens of the Cao Lan of Cao Ngoi Village; (a) Organic, Multi-level and Overlapping Canopy, (b) Polycentric and Multi-species, (c) Indeterminate Boundary, (d) Multi-level and Multi-species

(88%) having 5 levels. More than half (56%) of the gardens have more than 50% of their planting area covered by overlapping vegetation layers.

A comparative study by Pijika (2014) of homegarden structures of 8 different ethnic groups in Northeastern Thailand and Central and Northern Vietnam, including 6 Tai groups (Phu Tai, Nyaw, Yoy, Lao, Kalaeng, and Cao Lan) and 2 Mon-Khmer groups (Viet and Kinh), identified 3 distinctive types of garden structures. The homegardens of most of the Tai groups (Kalaeng, Lao, Nyaw, Yoy, and Cao Lan) have structures that resemble the tropical forest type (Nair 2001), which is characterized by having an organic shape, indeterminate boundaries of planting areas, polycentric planting patterns, multi-species composition, multiple vegetation levels, and extensive canopy overlap. The homegardens of both of the Vietnamese groups (Viet and Kinh) have a temperate type structure (Niñez 1984), with geometric shapes, sharp boundaries, lineal planting patterns, mono-species composition, only a few levels of vegetation, and relatively limited canopy overlap. Fig. 4 compares, the modal structural pattern of the homegardens of the Cao Lan of Cao Ngoi village to that of the Yoy, a typical Tai minority group in Northeast Thailand, and the Kinh of Central Vietnam. It shows that the structure of the Cao Lan homegardens is very similar to the tropical forest type structure found among ethnically-related Tai groups in Northeast Thailand, but is very different from the temperate type garden structure of their Kinh neighbors in Vietnam.

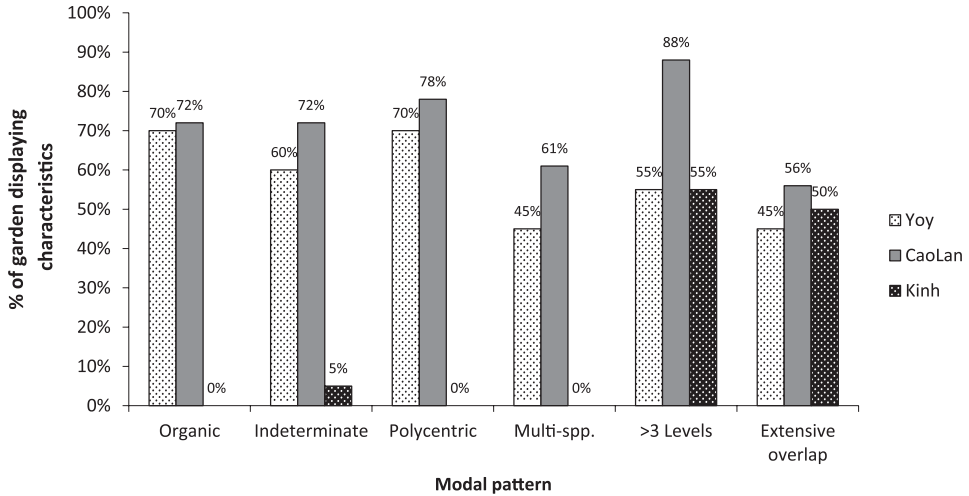


Fig. 4 Comparison of Modal Structural Patterns of Homegardens of Cao Lan with the Yoy, a Related Tai Ethnic Group in Northeast Thailand, and Their Kinh Neighbors in Vietnam (% of gardens of each group displaying characteristics)

Species Composition, Diversity, and Functions

Different plant species are scattered around in different parts of the gardens so as to optimize to their habitats in the different micro-zones of gardens. The total number of plant species found in all 17 gardens was 113. Table 2 presents a detailed list of all species grouped according to their functions. The mean number of species per garden was 25, with a range from 11 to 46 species. Six gardens had 11–20 species, 6 gardens had 21–30 species, 4 gardens had 31–40 species, and only 1 garden had more than 40 plant species.

The most common species are banana (*Musa* spp.) which was found in 15 gardens, ginger (*Zingiber officinale*) and taro (*Colocasia esculenta* Schott.) (14 gardens), guava (*Psidium* sp.) (13 gardens), Ceylon spinach (*Basella albe* L.), sweet potato (*Ipomoea batatas* [L.] Lam) and papaya (*Carica papaya*) (12 gardens), and Indian red wood (*Chukrasia tabularis* A. Juss.) (11 gardens).

Plant species richness was measured using the Shannon-Wiener's index (H), in which the higher the index number, the greater the diversity (Table 3). Species richness in the homegardens ranges from $H = 1.25$ – 3.04 . One homegarden had the highest richness with 35 plant species ($H = 3.04$). The least rich were 2 gardens with 11 species each ($H = 1.25$ and 1.36).

The relative abundance of species was measured using Simpson's index (D) (Table 3). Forty-seven percent of homegardens have the lowest number of plants for each spe-

Table 2 List of Plant Species in Cao Lan Homegardens

Scientific Name	Common English Name	Cao Lan Name	Vietnamese Name	No. and Percentage of Homegardens Having Species (%)
Vegetable:				
<i>Corchorus olitorius</i>	Tossa jute	Phắc rau đay	Rau đay	2 (11.8)
<i>Solanum</i> spp.	Egg plant	Mặc cơ	Cây cà	8 (47.1)
<i>Solanum</i> spp.	Egg plant (purple)	Mặc cơ	Cây cà tím	5 (29.4)
<i>Luffa aegyptiaca</i> Mill.	Gourd loofa	Cơ mặc kéo	Cây mướp	7 (41.2)
<i>Basella albe</i> L.	Ceylon spinach	Cơ mùng toi	Cây mồng toi	12 (70.6)
<i>Brassica juncea</i>	Mustard greens	Phắc cật	Rau cải	10 (58.2)
<i>Perilla frutescens</i> var. <i>Crispa</i>	Shiso	Phắc hòm lằng	Cây tia tở	9 (52.9)
<i>Amaranthus gracilis</i> Desf.	Chinese spinach, Amaranth	Phắc lỏm	Rau dền	5 (29.4)
<i>Sauropus androgynus</i> (L.) Merr.	Pak wan tree, Star gooseberry	Phắc rau ngọt	Cây rau ngọt	6 (35.3)
<i>Piper sarmentosum</i> Roxb.	Wild betel leaf bush	Cơ phắc pat	Lá lốt	4 (23.5)
<i>Vigna unguiculata</i> subsp. <i>sesquipedalis</i> (L.) Verdc.	Yard long bean	Cơ mặc tở	đậu đũa	4 (23.5)
<i>Lactuca indica</i>	Indian lettuce	Phắc bầu	Bồ công anh	3 (17.6)
<i>Artemisia vulgaris</i> L.	Mugwort	Cơ ngải	Cây ngải cứu	6 (35.3)
<i>Persicaria odorata</i>	Vietnamese mint	Cơ phắc lật lẻo	Rau răm	3 (17.6)
<i>Artemisia lactiflora</i> Wall ex. Bess.	Sagebrush	Cơ phắc ngoi	Cây ngải tía	1 (5.9)
<i>Ficus</i> spp.	Ficus	Cơ lá sung	Cây sung	3 (17.6)
<i>Colocasia gigantea</i>	Colocasia	Cơ moong lính	Cây dọc mùng	10 (58.8)
<i>Vigna unguiculata</i> subsp. <i>unguiculata</i>	Cowpea	Mặc tở phùng	Cây đỗ đũa	3 (17.6)
<i>Benincasa hispida</i>	Winter melon	Cơ mặc qua	Cây bí đao	8 (47.1)
<i>Carica papaya</i>	Papaya	Cơ mặc mớ	Cây đu đủ	12 (70.6)
<i>Oroxylum indicum</i> (L.) Kurz	Broken Bones Tree	Cơ núc nác	Cây núc nác	5 (29.4)
<i>Ipomoea batatas</i> (L.) Lam.	Sweet potato	Cơ bảy mền	Cây khoai lang	12 (70.6)
Spice:				
<i>Citrus aurantifolia</i> (Christm.) Swingle.	Lime	Cơ mặc chanh	Cây chanh	9 (52.9)
<i>Zingiber officinale</i> ^{b)}	Ginger	Cơ hằng gừng	Cây gừng	14 (82.4)
<i>Capsicum frutescens</i> L.	Bird pepper	Cơ hằng chiu	Cây ớt	5 (29.4)
<i>Cymbopogon citratus</i> (DC.) Stapf	Lemon grass	Cơ ha hom	Cây sả	7 (41.2)
<i>Curcuma longa</i> ^{b)}	Turmeric	Cơ kinh	Cây nghệ	9 (52.9)
<i>Eryngium foetidum</i> L.	Long coriander	Phắc hòm nằm	Rau mùi tàu	5 (29.4)
<i>Ocimum basilicum</i> L.	Sweet basil	Phắc húng chó	Húng lủi	4 (23.5)
<i>Mentha cordifolia</i> Opiz.	Spearmint	Phắc hòm nhàu	Cây bạc hà	4 (23.5)
<i>Allium tuberosum</i> Rottler.ex Spreng	Chinese chive	Cà cầu sái	Cây hẹ	5 (29.4)
<i>Alpinia galanga</i> (L.) Willd.	Galangal	Cơ nâng lèo	Cây giềng	4 (23.5)
<i>Atalantia citroides</i> Pierre ex Guill.	–	Cơ mặc chanh đông	Cây chanh rừng	2 (11.8)
<i>Garcinia Cowa</i> Roxb.	Garcinia	Cơ mặc lấu xong	Cây tai chua	2 (11.8)
<i>Fortunella japonica</i>	–	Cơ mặc quất	Cây quất	3 (17.6)
<i>Allium fistulosum</i>	Spring onion	Cơ xông	Cây rau hành	3 (17.6)
<i>Melissa officinalis</i> L.	Kitchen mint	Cơ phắc hom	Húng lủi	2 (11.8)
Carbohydrate source:				
<i>Colocasia esculenta</i> Schott.	Taro	Cơ phục	Cây môn sọ	14 (82.4)
<i>Pachyrhizus erosus</i> (L.) Urb.	Yam Bean	Cơ mền cật	Cây củ đậu	5 (29.4)
<i>Maranta arundinacea</i> L.	Arrow root	Cơ miễn tinh	Dong riềng	5 (29.4)
<i>Manihot esculenta</i> L.	Cassava	Cơ miễn mườ	Cây sắn	7 (41.2)
<i>Dioscorea bulbifera</i> L.	Aerial yam	Cơ miễn bần	Cây củ mài	2 (11.8)
<i>Vigna radiata</i>	Mungbean	Đậu nhỏ nhe	Cây đậu xanh	3 (17.6)

Table 2 Continued

Scientific Name	Common English Name	Cao Lan Name	Vietnamese Name	No. and Percentage of Homegardens Having Species (%)
Fruit:				
<i>Averrhoa carambola</i>	Star fruit	Cơ mặc phùng	Cây khế	8 (47.1)
<i>Psidium</i> sp.	Guava	Cơ mặc ổi	Cây ổi	13 (76.5)
<i>Musa</i> spp. ⁹	Banana	Cơ mặc cói toi	Cây chuối tây	10 (58.8)
<i>Musa</i> spp. ⁹	Banana	Cơ mặc cói lừng	Chuối tiêu	8 (47.1)
<i>Musa balbisiana</i> Colla ⁹	Banana	Cơ mặc cói mỏng	Cây chuối hột	15 (88.2)
<i>Prunus armeniaca</i> L.	Apricot	Cơ mây mai	Cây mai	2 (11.8)
<i>Mangifera indica</i> L.	Mango	Cơ mặc xoài	Cây xoài	9 (52.9)
<i>Artocarpus heterophyllus</i> Lamk.	Jack fruit	Cơ mặc mẹt	Cây mít	6 (35.3)
<i>Citrus maxima</i> (Burm.f.) Merr.	Pomelo	Cơ mặc póc	Cây bưởi	10 (58.8)
<i>Prunus persica</i> ⁶	Peach	Cơ mặc đào	Cây đào	4 (23.5)
<i>Zizyphus mauritiana</i> Lamk.	Jujube	Cơ mặc táo	Cây táo	3 (17.6)
<i>Annona squamosa</i> L.	Sugar apple, Castard apple	Cơ mặc na	Cây na	6 (35.3)
<i>Litchi chinensis</i> L.	Lychee	Cơ mặc pai	Cây vải	4 (23.5)
<i>Ananas comosus</i> (L.) Merr.	Pineapple	Cây mắc ló	Cây dứa	3 (17.6)
<i>Syzygium jambos</i> (L.) Alston	Rose apple	Cơ soi	Cây roi	4 (23.5)
<i>Prunus salicina</i>	Plum	Cơ mặc mẩn	Cây mận	4 (23.5)
<i>Dimocarpus longen</i> Lour.	Longan	Cơ mặc nhãn	Cây nhãn	3 (17.6)
<i>Diospyros</i> spp.	Persimmon	Cơ mặc hồng	Cây hồng ngâm	5 (29.4)
<i>Manilkara zapota</i>	Sapodilla	Cơ hồng xiêm	Cây hồng xiêm	2 (11.8)
<i>Lucua mamona</i> Gaerten	Lekima, Egg tree	Mặc lai cay	Cây trứng gà	3 (17.6)
Food dyes:				
<i>Peristrophe bivalvis</i> L.	–	Cơ bay sơn	Cây nhuộm com	2 (11.8)
<i>Momordica cochinchinensis</i> (Lour.) Spreng	Spring bitter cucumber	Cơ mò pít	Cây gấc	5 (29.4)
<i>Boehmeria nivea</i>	Ramie	Cơ bảy dây	Lá gai	6 (35.3)
Medicine:				
<i>Iris domestica</i> (L.) Goldblatt & Mabb.	Blackberry lily	Cơ rê quạt	Cây rê quạt	1 (5.9)
<i>Crinum asiaticum</i> L.	Crinum lily	Cơ cun	Hoa lá náng/Tỏi lợi tía	3 (17.6)
<i>Plantago major</i> L.	Plantain	Cơ mã đề	Cây mã đề	6 (35.3)
<i>Drynaria quercifolia</i> (L.) J. Sm	Basket fern	Et tai thên	Ráng bay	1 (5.9)
<i>Ocimum gratissimum</i> L.	Tree basil	Cơ hương nhu	Cây hương nhu	7 (41.2)
<i>Zingiber cassumunar</i> Roxb.	Cassumunar ginger	Cơ kinh màng	Cây gừng dùng làm thuốc	1 (5.9)
<i>Xanthium</i> spp.	Cocklebur	Cơ phàn pọt	Cây ké	2 (11.8)
<i>Litsea cubeba</i> (Lour.) Pers	May Chang, Aromatic litsea	Mây thu hính	Cây màng tang	2 (11.8)
<i>Crinum asiaticum</i>	Crinum Lily, Cape Lily, Poison Bulb, Spider Lily	Cơ cồn	Cây lá náng	3 (17.6)
<i>Abutilon indicum</i> (L.) Sweet.	Indian mallow	Cơ cối xay	Cây cối xay	4 (23.5)
Stimulants:				
<i>Camellia sinensis</i> (L.) Kuntze	Tea	Cơ xa	Cây chè	2 (11.8)
<i>Areca catechu</i> Le.	Betel nut, Areca palm	Cơ mặc làng	Cây cau	9 (52.9)
<i>Piper betle</i> L. ⁶	Betel	Cơ đau	Trầu không	5 (29.4)
<i>Nicotiana tabacum</i> L.	Tobacco	Cơ xin bay	Cây thuốc lá	2 (11.8)
Aesthetic:				
<i>Celosia argentea</i> L.	Cockcomb, Chinese wool	Hoa lợn cây	Hoa mào gà	4 (23.5)
<i>Gerbera jamesonii</i> Bolus	Gerbera	Va đồng tiền	Hoa đồng tiền	2 (11.8)
<i>Cymbidium aloifolium</i> (L.) Sw.	Aloe-leaved Cymbidium	Phong lan	Hoa phong lan	3 (17.6)
<i>Ficus annulata</i>	Banyan tree	Cơ xì	Cây si	3 (17.6)
<i>Rosa</i> spp.	Rose	Cơ hoa hồng	Hoa hồng	4 (23.5)
<i>Celosia cristata</i> L.	–	Cơ lân cày	Hoa mào gà	3 (17.6)
<i>Eckipja prortraja</i>	–	Cơ mây moong	Cây thực mực	3 (17.6)

Table 2 Continued

Scientific Name	Common English Name	Cao Lan Name	Vietnamese Name	No. and Percentage of Homegardens Having Species (%)
<i>Ficus bengalensis</i>	Banyan tree	Cơ mây lỏng	Cây đa	4 (23.5)
<i>Streblus asper</i> Lour.	Siamese rough bush	Cơ xích xăn	Cây đuối	2 (11.8)
<i>Portulaca grandiflora</i> Hook.	Moss-rose	Cơ mười giờ	Hoa mười giờ	1 (5.9)
<i>Chrysanthemum</i> spp.	Chrysanthemum	Cơ hoa cúc	Cây hoa cúc	2 (11.8)
<i>Rhododendron arboretum</i> Smith	Delavay's Rhododendron	Cơ va hải đường	Cây Hoa hải đường	2 (11.8)
<i>Hura crepitans</i> L.	Monkey's pistol	Cơ vòng	Cây vòng	3 (17.6)
<i>Cyperus papyrus</i> L.	Papyrus	Nhứ	Cây lác dù	1 (5.9)
<i>Alstonia scholaris</i> (L.) R. Br.	Blackboard tree, Indian devil tree, Ditabark, Milkwood pine, White cheesewood and Pulai	Cơ enh chau	Cây Hoa sữa	3 (17.6)
<i>Arfeuillea arborescens</i> Pierre ex Radlk.	–	Cơ độc cây	Cây xương cá	4 (23.5)
<i>Mila</i> sp.	Cactus	Cơ xương rồng	Cây xương rồng	1 (5.9)
Fodder:				
<i>Colocasia esculenta</i> (L.) Schott.	Taro	Cơ moon	Khoai nước	8 (47.1)
<i>Sterculia lanceolate</i> Cav.	Po pha sam	Cơ mời liên	Cây săng	4 (23.5)
<i>Panicum maximum</i>	Elephant grass	Cơ cỏ voi	Cơ voi	3 (17.6)
<i>Diplazium esculentum</i> (Retz.) Sw.	Vegetable fern	Cơ mây lung	Rau đường	3 (17.6)
<i>Morus alba</i> L.	Mulberry	Cơ mây môn	Cây dâu	3 (17.6)
Construction materials:				
<i>Duabanga sonneratioides</i> Ham.	–	Cơ mây tùng	Cây phay	6 (35.3)
<i>Bambusa</i> spp. ^{a)}	Bamboo	Cơ mây tê lung	Cây luồng	5 (29.4)
<i>Bambusa</i> spp. ^{a)}	Bamboo	Cơ mười hóp	Cây tre	4 (23.5)
<i>Azadirachta indica</i> A. Juss.	Quinine	Môi liềm hằm	Cây xoan đầu	9 (52.9)
<i>Caesalpinia pulcherrima</i>	Peacock's Crest	Cơ phượng	Cây hoa phượng	1 (5.9)
<i>Wrightia pubescens</i>	–	Cơ mời mỏng	Cây mức lông mềm	4 (23.5)
<i>Chukrasia tabularis</i> A. Juss.	Indian red wood, Bastard cedar, Chittagong wood, Indian Mahogany, Burmese almond wood, Jamaica cedar	Cơ mai lát	Cây gỗ lát hoa	11 (64.7)
<i>Corypha lecomtei</i> L.	Lan palm	Cơ gui	Cây cọ	4 (23.5)
Food wrapping:				
<i>Stachyphrynium placentarium</i> (Lour.) Clausager & Borchs.	–	Cơ thông chanh	Lá dong	7 (41.2)
Weaving:				
<i>Gossypium hirsutum</i> L.	Cotton	Mây thông tooc	Cây bông bạc	1 (5.9)
Firewood:				
<i>Trema orientalis</i> (L.) Bl.	Poison Peach, Charcoal tree	Cơ tập dết	Cây hu	3 (17.6)

Notes: ^{a)} secondary function as food, ^{b)} as medicine, ^{c)} as pig fodder, ^{d)} aesthetic

cies ranging from 0.01–0.25, followed by 4 homegardens (23.5%) ranging from 0.51–0.75, and 2 homegardens (11.8%) in the range of 0.26–0.50. Only 3 homegardens (17.7%) have the highest frequency of occurrence of each species.

All species were categorized according to their primary use: food and food-related, medicine, aesthetic, stimulants, fodder, construction materials, and other uses (Table 4).

Table 3 Species Composition and Diversity in the Cao Lan Homegardens of Cao Ngoi Village, Tuyen Quang, Northern Vietnam (n = 17)

	Diversity	No. of Homegardens (%)
Richness (Shannon-Wiener index, H)	1.01–1.50	2 (11.8%)
	1.51–2.00	5 (29.4%)
	2.01–2.50	4 (23.5%)
	2.51–3.00	5 (29.4%)
	>3.00	1 (5.9%)
Abundance (Simpson's index, D)	0.01–0.25	8 (47.0%)
	0.26–0.50	2 (11.8%)
	0.51–0.75	4 (23.5%)
	0.76–1.00	3 (17.7%)

Table 4 Primary Functions of Plant Species in the Cao Lan Homegardens (number and percentage)

Functions (no. and % of species)	Type	No. and % of Plant Species (n=113 species)
Food 66 (58.4%)	Vegetable	22 (19.5%)
	Fruit	20 (17.7%)
	Spice	15 (13.3%)
	Carbohydrate source	6 (5.3%)
	Food dye	3 (2.6%)
Aesthetic 17 (15.0%)	Ornamental	17 (15.0%)
Medicine 10 (8.9%)	–	10 (8.9%)
Construction materials 8 (7.1%)	House repair	7 (6.2%)
	Roofing	1 (0.9%)
Fodder 5 (4.4%)	Pig	3 (2.6%)
	Cattle	1 (0.9%)
	Silkworm	1 (0.9%)
Stimulants 4 (3.5%)	–	4 (3.5%)
Other use 3 (2.7%)	Food wrapping	1 (0.9%)
	Weaving	1 (0.9%)
	Firewood	1 (0.9%)

The majority of plant species (58.4%) are used for food, followed by 17 ornamental species (15.0%), 10 medicinal species (8.9%), 8 species for construction (7.1%), 5 species for animal fodder (4.4%), 4 species used as stimulants (3.5%), and 1 species each for other

uses including food wrapping, firewood, and weaving. No species are used for ritual or to sell for cash. Only 7 species serve multiple functions: Ginger is used for spice and medicine, the fruit of three species of banana (*Musa* spp.) are used for human food and the stalks as food for pigs, and bamboo shoots are eaten as human food and the stalks used as construction materials, peach is used for food and serves an aesthetic function, and betel is used as a stimulant and for aesthetic purposes.

A small number of species are used as stimulants (areca nut [*Areca catechu* Le.] and betel leaf [*Piper betle* L.]), as food dye for cooking sticky-rice cake (spring bitter cucumber [*Momordica cochinchinnensis* (Lour.) Spreng], ramie [*Boehmeria nivea*, and *Peristrophe bivalvis* L.]), and as food-wrapping leaves [*Stachyphrynium placentarium* (Lour.) Clausager & Borchs.]. Three households have mulberry trees in their gardens, the leaves of which used to be used to feed silkworms that yielded thread that was formerly used to weave cloth and one household grows cotton, which also used to be used for weaving.

Conclusions

The homegardens of the Cao Lan of Cao Ngoi village are an important component of their agroecosystem. The many different species of plants grown in these gardens provide food and other necessities for the people as well as fodder for their livestock. With a total of 113 species the gardens also contribute to conservation of biodiversity.

Although the Cao Lan of Cao Ngoi village have been geographically isolated from other Tai groups for many centuries, their homegardens display a tropical forest type garden structure that closely resembles that of several Tai groups in Northeast Thailand. This type of homegarden structure is very different from the temperate type structure of the gardens of their Kinh neighbors in Vietnam with whom they share a common environment and are in frequent contact. The persistence of a common structural pattern among these related Tai ethnic groups, despite their inhabiting different environments, and having had no direct contact with each other for a very long time, suggests that culture exerts a very strong influence over agroecosystem structure. This finding provides empirical support for Richard O'Connor's (1995) earlier suggestion that culture and agriculture are tightly linked together to form durable "agro-cultural complexes" that offer a useful key to reconstruction of the cultural history of Southeast Asia.

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A Comparative study of the ecological structures of homegardens of different ethnic groups in Northeast Thailand

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ABSTRACT: Homegardens are an important component of household agroecosystems in Northeast Thailand but little is known about their ecological structure. In this paper we describe the modal horizontal and vertical structures of the homegardens of 7 ethnic groups in Northeast Thailand. Samples of 20 households were selected in villages of each of these groups and detailed information on the ecological structure of their homegardens recorded. Horizontal dimensions included shape of planting area or plot, definition of boundaries of planting areas, and planting pattern and species composition within each plot. Vertical dimensions included the number of levels of vegetation and the extent of canopy overlap. Each of the ethnic groups was found to have a clearly dominant modal characteristic for each of these structural dimensions but they cluster into three types: Type I (Lao, So, Yoy Nyaw, Kalaeng); Type II (Phu Thai), and Type III (Viet). The Type I gardens have organic shape, indeterminate boundaries of planting areas, polycentric planting pattern, multi-species composition, at least 4 vegetation levels, and extensive canopy overlap) while the Type III gardens have geometric shape, sharp boundaries, lineal planting pattern, mono-species composition, only 2 levels of vegetation, and no canopy overlap. The Type II gardens (Phu Thai) occupy an intermediate position between Types I and III but are more similar to Type III. The existence of such distinctive patterns among groups that have resided in close proximity in a quite similar environment for more than 100 years suggests that culture is an important determinant of agricultural patterns.

Keywords: ethnic identity, culture and agriculture, cultural ecology, agroecosystem structure

Introduction

Tropical homegardens have been an important agroecological research topic for over 30 years (Fernandez and Nair, 1986; Niñez, 1987; Kumar and Nair, 2006). However, although homegardens are an important component of household agroecosystems in Northeast Thailand (Grandstaff, 1988), little research has been done on their ecological structure. Therefore, we conducted this comparative study of the horizontal and vertical structures of homegardens of 7 different ethnic groups in the Sakon Nakhon

Basin. In this paper we describe the horizontal and vertical structural characteristics of the homegardens of these different ethnic groups, identify their modal structural patterns, and make a comparative analysis of their similarities and differences.

Material and methods

Selection of study sites and sample households

The homegardens of samples of households in rural communities representing the 7 main ethnic groups in Sakon Nakhon and Nakhon

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Phanom provinces were included in this study. The Nyaw, Phu Thai, Lao, Yoy, and Kalaeng speak Tai languages while the So and the Viet (Thai Vietnamese) speak Mon-Khmer languages. All of the Tai speaking groups, as well as the So, were relocated from Laos by the Siamese army in the early 19th century (Schliesinger, 2001). Most of the Viet fled to the area in the latter part of the 19th century to escape the French occupation of Vietnam (Poole, 1970; Chandavimol, 1998). All of these ethnic groups live under quite similar environmental conditions within the Sakon Nakhon basin, although they commonly occupy ethnically homogeneous villages.

Knowledgeable local researchers and officials were consulted in order to identify all of the villages inhabited by each ethnic group. The study villages were then selected on the basis of being located in a rural area, ethnically homogeneous, and having homegarden production mainly for household consumption, although in the case of the Viet, somewhat more than half of garden production is for sale. The village headmen and other villagers were consulted in order to confirm that the communities actually met the selection criteria. **Table 1** shows the environmental and social characteristics of the study villages.

Maps showing the location of all households in each village were drawn with the assistance of the villagers who then drew a transect line across the center of the settlement area. Starting from the first house at the beginning of the transect line, every house on both sides of the line that met our selection criteria was interviewed until a sample of 20 households (representing from 6 to 17 percent of the total number of households in each village [see Table 1]) was achieved. Sample

households had to meet the following criteria: 1) it had a homegarden, 2) its members identified themselves as belonging to the ethnic group under study, 3) it had been resident in the village for a long period, and 4) an adult member was available, willing to be interviewed, and mentally capable of responding to questions. Although the sampling procedure does not meet the criteria of strict randomness, it minimized the likelihood of unconscious bias on the part of the researchers influencing selection of sample households.

Data collection and analysis

Data were collected between October 2011 to March 2012 using semi-structured interviews with members of sample households and by direct observation and measurement of their gardens. Horizontal structure was recorded on sketch maps and by taking photographs. Vertical structure was recorded by making architectural drawings, with the height of plants measured using either a laser distance meter or hand clinometer depending on light conditions.

Data were recorded in an Excel database which was used to compile comparative tables of garden structural characteristics for all of the groups. Because there are no standardized approaches for classifying many structural dimensions of homegardens, we developed our own analytic system which employs 4 horizontal dimensions (shape of planting area, definition of plot boundaries, and planting patterns and species composition within plots) and 2 vertical dimensions (number of levels of plants, extent of overlap of vegetation layers). The various structural dimensions of each of the gardens of all

sample households belonging to an ethnic group were classified into appropriate categories (e.g., planting areas predominantly geometric or organic in shape, planted in lines or in clusters, with or without overlapping layers of vegetation) and the total number of gardens assigned to each category computed. In order to analyze the data in a way that would both identify central tenden-

cies and display the range of variation within each group, we employed a method originally devised by anthropologists to describe the modal personality structures of different ethnic groups (Wallace, 1952). Modal structural characteristics are those characteristics that were found in the largest share of gardens of sample households belonging to each of the ethnic groups. Cluster analysis was done using SPSS 11.5.

Table 1 Characteristics of study villages of different ethnic groups .

Ethnic group	Location (province, district, sub-district)	Geographic coordinates ¹	Land suitability ²	Population ³	No. of house holds ³	Main purpose of homegardens ⁴
Yoy	Sakon Nakhon, Akat Umnuaay, Akat Umnuaay	17° 36.00.83»N 103° 58.42.81» E	Loamy sand, infertile soil	510	118	100% subsistence
Phu Thai	Sakon Nakhon, Waritchaphum, Waritchaphum	17° 16.52.06» N 103° 39.11.81» E	Loamy sand, infertile soil	1,058	335	55% subsistence, 45% commercial
Nyaw	Sakon Nakhon, Ponnakaew, Baan Paen	17° 11.41.83» N 104° 13.20.76» E	Loamy sand, infertile soil	556	189	100% subsistence
Lao	Sakon Nakhon, Song Dao, Tha Sila	17° 14.38.03» N 103° 21.57.94» E	Sandy loam, infertile soil	655	198	95% subsistence, 5% commercial
Kalaeng	Sakon Nakhon, Kud Bak, Kud Bak	17° 04.09.34» N 103° 47.00.40» E	Loamy sand, infertile soil	788	218	100% subsistence
So	Sakon Nakhon, Kusuman, Phothi Phaisan	17° 22.12.80» N 104° 21.41.03» E	Loamy sand, infertile soil	914	214	100% subsistence
Viet	Nakhon Panom, Muang Nakhon Panom, Nong Yat	17° 22.38.09» N 104° 45.45.10» E	Sandy loam or sandy clay loam, low to moderate infertile soil	520	118	40% subsistence, 60% commercial

Sources: ¹ GPS records of author; ² Land Development Department (<http://giswebldd.ldd.go.th/>); ³ Village headman; ⁴ Samples of 20 homegardens in each village

Table 2 Comparison of modal horizontal and vertical structural characteristics of homegardens of different ethnic groups in the Sakon Nakhon Basin (% of gardens displaying characteristic).

Structural dimension	Alternatives (%)	Tai					Mon-Khmer	
		Yoy	PhuThai	Nyaw	Lao	Kalaeng	So	Viet
Shape of planting areas	All Geometric	15	45	10	15	25	20	70
	>50% Geometric	0	20	5	5	0	5	15
	>50% Organic	15	15	30	5	0	10	0
	All Organic	70	20	55	75	75	65	15
Boundary definition of planting areas	All Sharp	20	50	15	15	0	40	95
	>50% Sharp	5	25	20	5	40	0	0
	>50% Indeterminate	15	5	40	5	0	5	0
	All Indeterminate	60	20	25	75	60	55	5
Arrangement of individual plants within planting areas	All Lineal	15	5	15	15	25	10	75
	>50% Lineal	15	65	5	20	0	15	5
	>50% Polycentric	0	0	15	0	0	0	5
	All Polycentric	70	30	65	65	75	75	15
Species composition within planting area	All Mono-species	45	55	35	45	35	45	95
	>50% Mono-species	10	30	0	5	0	5	0
	>50% Multi-species	0	5	10	0	0	0	0
	All Multi-species	45	10	55	50	65	50	5
No. of vegetation levels	1	0	0	0	5	5	0	0
	2	5	0	0	0	0	5	55
	3	40	10	20	15	15	40	10
	4	45	55	45	65	55	45	20
	5	10	35	35	15	25	10	15
Share of planting area covered by overlapping layers	Non-overlapping	0	0	5	5	5	0	50
	<50% overlapping	55	55	30	75	45	60	45
	>50% overlapping	45	45	65	20	50	40	5

Note: Bold italic numbers indicate modal characteristic. Bold underlined numbers indicate dual modes for that dimension.

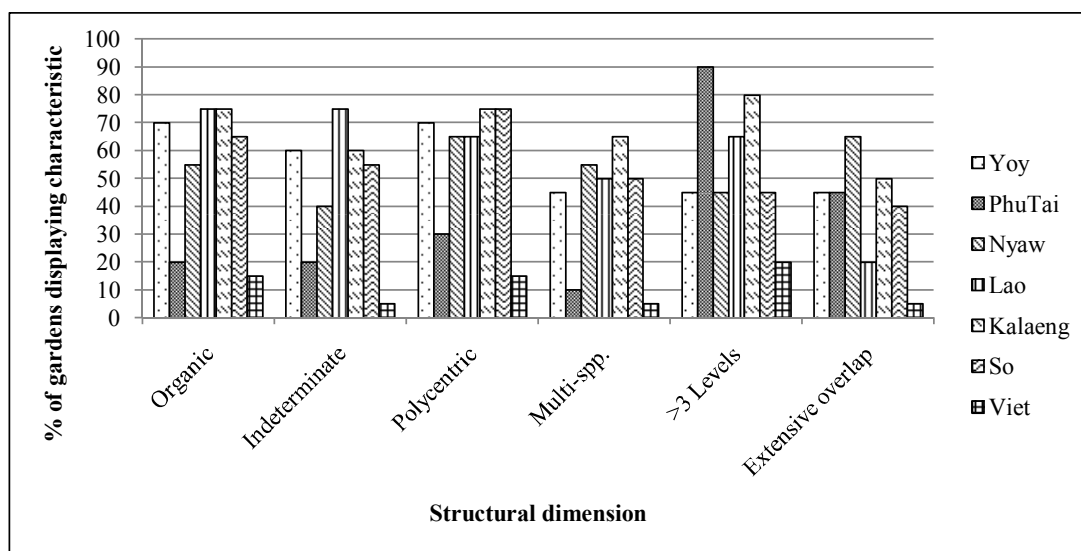


Figure 1 Comparison of modal structural patterns of homegardens of different ethnic groups in the Sakon Nakhon Basin, Northeast Thailand.

Results and Discussion

Each ethnic group has a clearly dominant modal characteristic for each of the 6 structural dimensions (with the sole exception of the Yoy, for which equal shares [45%] of gardens have mono-species and multi-species planting patterns within beds) (Table 2). Although some characteristics are widely shared among the different ethnic groups (e.g., 6 out of 7 groups have 4 levels of vegetation as a modal characteristic), each of the groups displays a somewhat distinctive overall modal structural pattern and no two groups have completely identical modal patterns to each other. A hierarchical cluster analysis of the homegarden structures of the 7 ethnic groups revealed 3 groupings: Type 1 (Lao, So, Yoy, Nyaw, Kalaeng); Type II (Phu Thai), and Type III (Viet). Type I gardens have organic shape, indeterminate boundaries of planting areas, polycentric planting

pattern, multi-species composition, at least 4 vegetation levels, and extensive canopy overlap, while Type III gardens have geometric shape, sharp boundaries, lineal planting pattern, mono-species composition, only 2 levels of vegetation, and no canopy overlap. Type II gardens (Phu Thai) occupy an intermediate position between Types I and III, although they are closer to Type III (Figure 1).

Conclusions

It is noteworthy that there are 3 distinct types of homegarden structure despite the fact that all of these groups have lived in close proximity to each other under quite similar environmental conditions for multiple generations. This should have allowed sufficient time for them to converge on a common modal structure if agroecosystem structure is mainly determined by environmental

selective forces and/or acculturative pressures. That the different groups retain their own distinctive garden structures suggests that culture is an important determinant of homegarden structure. This interpretation is supported by earlier ethno-historical research in Southeast Asia which has found that culture and agriculture are tightly bound together into highly durable "agro-cultural complexes" (O'Conner, 1995) which tend to persist even when ethnic groups move into different environments and encounter strong acculturative pressures from ethnically distinct neighboring populations

This finding has important implications for agricultural research, which has been largely guided by the assumption that farmers, regardless of their ethnic identity, will always tend to adopt innovations that provide optimum economic returns (Salamon, 1985). The existence of the close relationship between culture and homegarden structure identified in our study suggests, however, that culture may be a more important determinant of agricultural patterns and practices than is commonly recognized. Therefore, cultural influence on agriculture deserves increased attention from researchers and policymakers concerned with the agricultural development.

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RESEARCH ARTICLE

The Influence of Culture on Agroecosystem Structure: A Comparison of the Spatial Patterns of Homegardens of Different Ethnic Groups in Thailand and Vietnam

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Data Availability Statement: All relevant data are within the paper and its Supporting Information files. Because making the original data publicly available would potentially reveal the identity of the farmers who permitted us to observe and measure their homegardens we do not think it is permissible for us to deposit them in a public repository. However, if any legitimate researcher requests to see the maps and diagrams on which this analysis is based we would be willing to make them available after removal of identifying information about the garden owners. Contact Dr. Pijika Timsuksai at pijika_timsuksai@hotmail.com.

Abstract

Different ethnic groups have evolved distinctive cultural models which guide their interactions with the environment, including their agroecosystems. Although it is probable that variations in the structures of homegardens among separate ethnic groups reflect differences in the cultural models of the farmers, empirical support for this assumption is limited. In this paper the modal horizontal structural patterns of the homegardens of 8 ethnic groups in Northeast Thailand and Vietnam are described. Six of these groups (5 speaking Tai languages and 1 speaking Vietnamese) live in close proximity to each other in separate villages in Northeast Thailand, and 2 of the groups (one Tai-speaking and one Vietnamese-speaking) live in different parts of Vietnam. Detailed information on the horizontal structure of homegardens was collected from samples of households belonging to each group. Although each ethnic group has a somewhat distinctive modal structure, the groups cluster into 2 different types. The Tai speaking Cao Lan, Kalaeng, Lao, Nyaw, and Yoy make up Type I while both of the Vietnamese groups, along with the Tai speaking Phu Thai, belong to Type II. Type I gardens have predominantly organic shapes, indeterminate boundaries, polycentric planting patterns, and multi-species composition within planting areas. Type II homegardens have geometric shapes, sharp boundaries, lineal planting patterns, and mono-species composition of planting areas. That the homegardens of most of the Tai ethnic groups share a relatively similar horizontal structural pattern that is quite different from the pattern shared by both of the Vietnamese groups suggests that the spatial layout of homegardens is strongly influenced by their different cultural models.

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Introduction

A great deal of ethnoecological research has revealed that farmers belonging to different cultures have varying perceptions of the natural world, including the structure and functioning of their agricultural ecosystems [1]. Based on long-term trial and error experimentation by farmers, different ethnic groups have evolved distinctive cultural models of appropriate agroecosystem structures. These cultural models help guide their management decisions and interactions with the soil, water, plants and animals that make up their agroecosystems. Often these farmer models closely approximate the models developed by agricultural scientists. Sometimes the farmer models are superior to the scientific ones, but in other cases they are empirically deficient in varying ways [2]. Describing and understanding the cultural models of agroecosystems, including homegardens, of farmers belonging to different ethnic groups remains a major concern of ethnoecological investigations of agriculture, especially in developing countries in the tropics.

Homegardens occur on farmsteads in many parts of the tropical and temperate regions of the world. They are commonly, but not always, a relatively small subsidiary component of larger and more complex farm-level agroecosystems that may also include irrigated and/or dry-land staple crop fields, pastures, and forest plots. Homegardens are most commonly used to produce food and other materials for household consumption (although they sometimes are also used to produce crops for the market, as in the case of the Viet ethnic group in this study).

Although it is highly probable that variances in the horizontal structure of homegardens among ethnic groups reflect differences in farmers' cultural models, there is limited empirical evidence to support this assumption. Only a few systematic comparative studies of the homegardens of different ethnic groups have been published [1–9]. Moreover, the dimensions that are most commonly used to describe homegarden structure (surface area, vertical architecture, and species composition and diversity) [10–12] may not be reliable indicators of ethnic identity because they can be influenced by environmental and economic factors, rather than reflecting the traditional cultural models of the farmers. For example, the surface area of gardens is strongly influenced by population density and availability of land and gardens with small areas do not have enough space to grow tall trees. Species composition and diversity have also been shown to be influenced by both garden area and extent of commercial orientation [13]. The horizontal plans or layouts of gardens (e.g., shape of planting areas, definition of boundaries of plots within gardens, and planting patterns within plots), which are less subject to exogenous influences, and thus more likely to reflect the cultural models of the farmers, would seem to be more reliable markers of ethnicity. However, horizontal structure has received almost no attention in earlier research on homegardens anywhere in the world, and, in contrast to well-developed systems for describing vertical structure and species composition and diversity, there are no standard ways of describing horizontal structure.

In order to assess the extent to which different horizontal structural patterns of homegardens are associated with different ethnic groups, we carried out this comparative research on the homegardens of eight ethnic groups belonging to two different language families in Thailand and Vietnam. Six of these groups (5 belonging to the Tai language family and 1 belonging to the Vietnamese branch of the Mon Khmer language family) live in close proximity to each other in separate villages within the Sakon Nakhon Basin in Northeast Thailand and 2 of the groups (one Tai-speaking and one Vietnamese-speaking) live in different parts of Vietnam. We hypothesized that all culturally-related ethnic groups would have homegardens with broadly similar horizontal structural patterns, regardless of differences in their respective environments or exposure to neighboring groups with different garden structures. Thus, we anticipated that the homegardens of all of the Tai groups, regardless of whether they were in Northeast Thailand or in Vietnam, would have similar modal patterns and that the same

would be the case for the Vietnamese groups. In this paper we present a system for classifying the key horizontal structural characteristics of homegardens, describe the modal horizontal structural characteristics of the homegardens of each of these ethnic groups, make a systematic comparative analysis of similarities and differences in the homegarden structures of the different ethnic groups, and relate these structural differences to differences in the general cultural patterns of the different groups.

Methods

Research approach

This study was designed to collect systematic data on the horizontal structure of homegardens of samples of households in rural communities representing the 8 ethnic groups included in this study. Because our preliminary observations revealed considerable variation in the structural characteristics of the homegardens of different households within the same ethnic community, we sought to analyze the data in such a way that would identify central tendencies without losing sight of the range of variation within each group. Therefore we employed a method devised by anthropologists to describe the modal personality structures of different cultures [14, 15]. Modal personality structure has been defined as "...the body of character traits that occur with the highest frequency in a culturally-bounded population. Modal personality is a statistical concept rather than the personality of an average person in a particular society" [16]. This approach is suitable for identification of central tendencies in populations that are internally heterogeneous. When applied to the study of homegardens, the goal is to identify those structural characteristics (e.g., organic or geometric form, lineal or polycentric planting patterns) that are found in the largest share of gardens of sample households belonging to each of the ethnic groups. Although our focus is on identification of modal tendencies, the frequencies with which alternative characteristics occur in each ethnic group sample are also shown.

Selection of ethnic groups

The northeastern region of Thailand is ethnically relatively homogeneous with members of the Thai Lao ethnolinguistic group (commonly referred to simply as "Lao") forming the majority of the population [17]. However, the Sakon Nakhon Basin in the northern part of the region where we did this study has unusual ethnic diversity. The Lao, along with the Kalaeng, Nyaw, and Phu Thai, belong to the Southwestern group, the Yoy to the Northern group of the Tai language family, and the Viet (Thai Vietnamese) belong to the Vietnamese branch of the Mon-Khmer language family (Fig 1). The Cao Lan are a Tai speaking group in the Midlands of northern Vietnam who belong to the Central group of the Tai language family. They have had little or no contact with the Tai communities in Thailand for several hundred years. The Kinh (ethnic Vietnamese) in central Vietnam are the ancestral population of the Viet group in Northeast Thailand from whom they have been geographically isolated for more than a century.

There has been relatively little ethnographic research on most of the Tai groups. All of the Tai speaking groups are believed to have settled in the Sakon Nakhon Basin in the early nineteenth century after the Siamese army forcibly relocated them there from their homes in Laos [18]. Most of the Viet came to the area in the latter half of the nineteenth century, first fleeing the persecution of Catholic converts by the Vietnamese emperor Minh Mang and then escaping from the French colonial occupation of their homeland in central Vietnam. Later they were joined by refugees from the Indochina War in the late 1940s and after 1975 [19, 20]. The Cao Lan migrated into northern Vietnam from southern China several centuries ago [21, 22] and the Kinh (ethnic Vietnamese) are indigenous to central Vietnam.

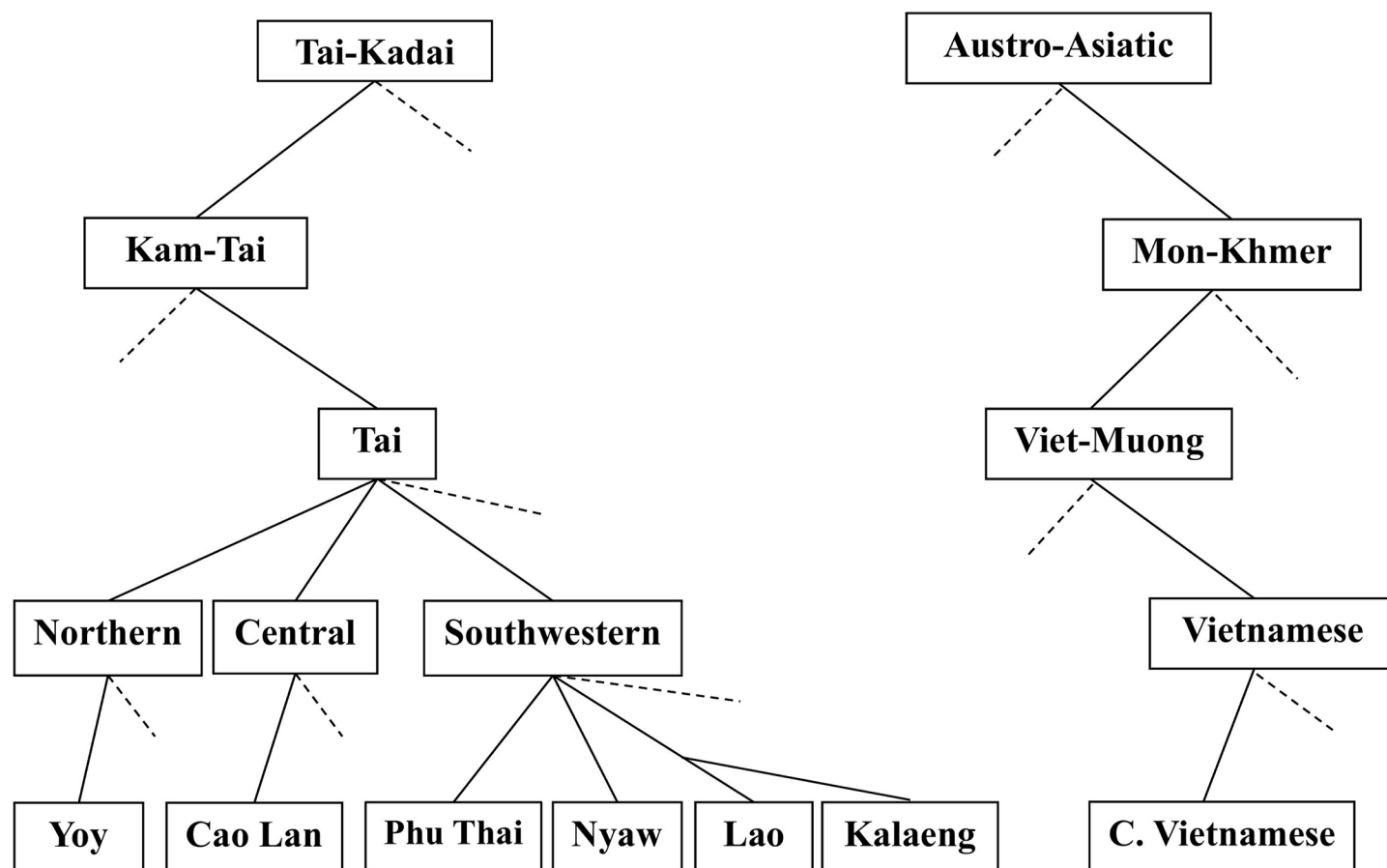


Fig 1. Ethnolinguistic taxonomy of groups in Northeast Thailand and Vietnam [44].

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Selection of study sites

The study sites in Northeast Thailand were selected from rural villages representing the 5 Tai groups (Kalaeng, Lao, Nyaw, Phu Thai, and Yoy) and the Viet, all found within a relatively small area within the Sakon Nakhon Basin. In Vietnam, a Cao Lan village in a remote part of Tuyen Quang province was selected for study [23] along with a Kinh village in the district in Ha Tinh province from which the Viet living in Northeast Thailand had originally come. Knowledgeable local researchers and government officials were consulted in order to identify all of the villages inhabited by each ethnic group. The study villages were then selected on the basis of being located in a rural area, ethnically homogeneous, and having homegarden production mainly for household consumption. Semi-structured interviews were then conducted with village headmen and other villagers in order to confirm that the communities actually met the selection criteria. The locations of the study villages are shown in Fig 2. Table 1 presents information on the environmental and social characteristics of the study communities.

Selection of sample households in each community

Maps showing the location of all households in each village were drawn with the assistance of the village headman and/or village members who then drew a transect line across the center of the settlement area in order to provide a basis for sampling representative households. Starting from the first house at the beginning of the transect line, every house on both sides of the line

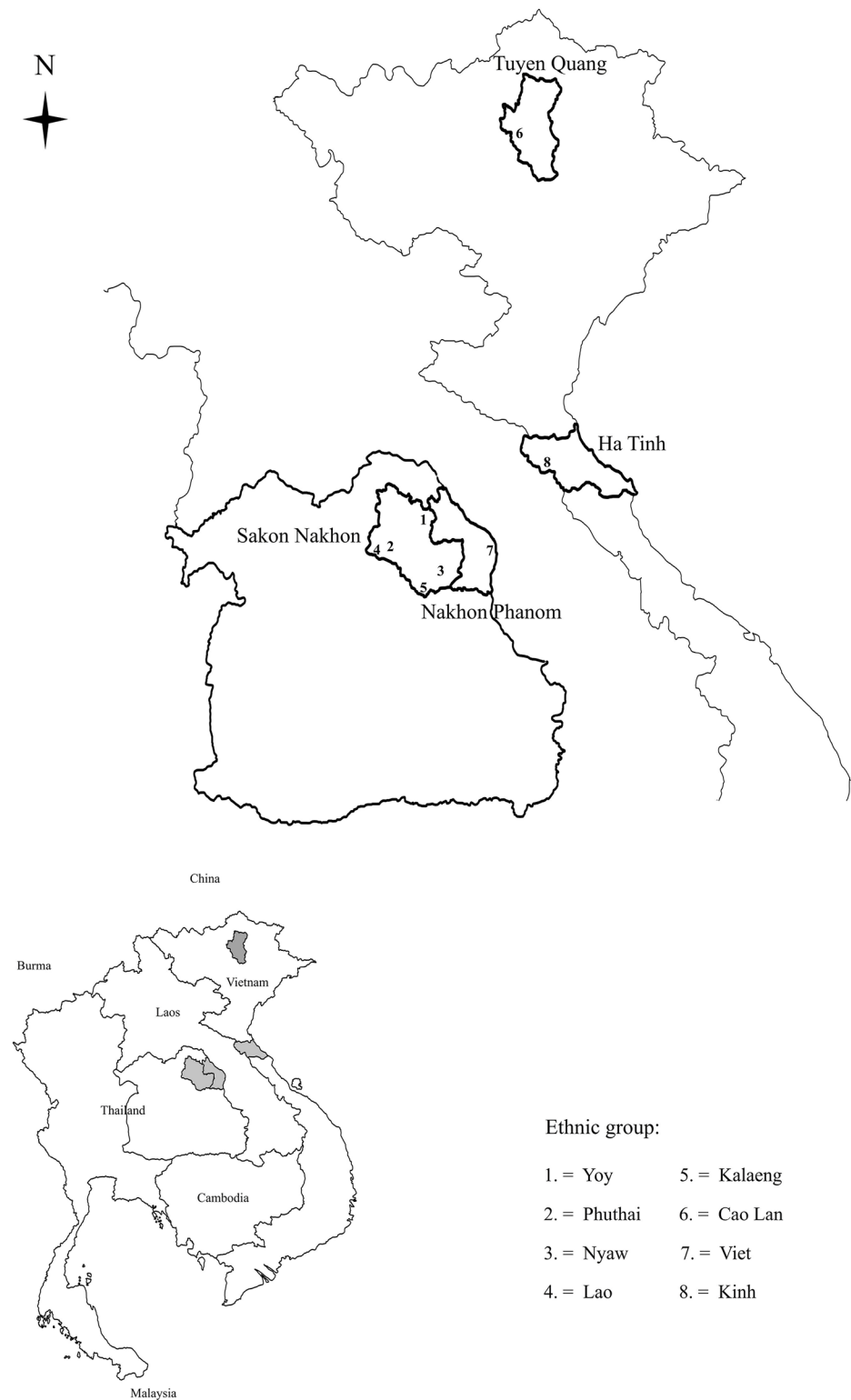


Fig 2. Map showing location of study villages in Northeast Thailand and Vietnam.

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Table 1. Characteristics of study villages of different ethnic groups.

Ethnic group	Yoy	Phu Thai	Nyaw	Lao	Kalaeng	Cao Lan	Viet	Kinh
Location (province, district, sub-district)	Sakon Nakhon, Akat Umuay, Akat Umuay	Sakon Nakhon, Waritchaphum, Waritchaphum	Sakon Nakhon, Ponnakaew, Baan Paen	Sakon Nakhon, Song Dao, Tha Sila	Sakon Nakhon, Kud Bak, Kud Bak	Tuyen Quang, Son Duong, Dong Loi	Nakhon Panom, Muang Nakhon Panom, Nong Yat	Ha Tinh, Huong Khe, Huong Lien
Geographic coordinates ¹	17° 36'00.83"N 103° 58'42.81" E	17° 16'52.06" N 103° 39'11.81" E	17° 11'41.83" N 104° 13'20.76" E	17° 14'38.03" N 103° 21'57.94" E	17° 04'09.34" N 103° 47'00.40" E	17° 22'12.80" N 104° 21'41.03" E	17° 22'38.09" N 104° 45'45.10" E	18° 03'46.04" N 105° 45'21.94" E
Elevation (m amsl) ¹	152	193	166	214	212	169	156	83
Topographical setting ²	River bank	Hilly	Gently slopping	Hilly	Hilly	Mountain valley	Gently slopping	Mountain valley
Land suitability ³	Loamy sand, infertile soil, good drainage	Loamy sand, infertile soil, good drainage,	Loamy sand, infertile soil, poor drainage	Sandy loam, infertile soil, moderately well drained	Loamy sand, infertile soil, good drainage,	Clay loam, infertile soil, well drained	Sandy loam or sandy clay loam, low to moderate infertile soil, poor drainage	Clay loam, infertile soil, well drained
Area (ha) ⁴	50	488	760	536	800	120	202	40
Population ⁴	510	1,058	556	655	788	76	520	376
Population density (no. of people/km²)	1,020	220	70	122	100	63	260	940
No. of households ⁴	118	335	189	198	218	20	118	102
Main purpose of homegardens ⁵	100% subsistence	55% subsistence, 45% commercial	100% subsistence	95% subsistence, 5% commercial	100% subsistence	100% subsistence	40% subsistence, 60% commercial	100% subsistence

Sources:

¹GPS records of author;

²Observation by author;

³ Land Development Department (<http://giswebldd.ddd.go.th/>)(except for Cao Lan and Kinh groups from <http://www.fao.org/ag/Agp/AGPC/doc/Counprof/vietnam/vietnam.htm>);

⁴Village headman;

⁵ Samples of 20 homegardens(17 for the Cao Lan) in each village

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that met our selection criteria was selected until a sample of 20 households (17 in the Cao Lan village) was achieved. For a household to be included in the sample, it had to meet the following criteria: 1) it had a homegarden, 2) its members belonged to the ethnic group under study, 3) it had been resident in the village for a minimum of two generations, and 4) an adult member granted us permission to observe and measure their homegarden. This work was done in accordance with the principles outlined in the Declaration of Helsinki. Although the Thai university agricultural faculties with which the authors are affiliated do not require human subjects review of non-medical research of this type, the research protocol was reviewed by the ethics board office of the Research and Development Institute of the first author's university and classified as exempt due to low risk to human subjects. In the case of our study, no sensitive personal information was collected. Before we began data collection, the research was explained to the village head and his permission obtained to do the study in the village. At each of the sample households, the purpose of the research was explained to the farmers and their verbal permission obtained to observe and measure their gardens. It was explained that their participation was voluntary and they could opt out of the study at any time. All data in the

paper are anonymous and cannot be traced to any particular individual informants. Although the sampling procedure does not meet the criteria of strict randomness, it did minimize the likelihood of unconscious bias on the part of the researchers influencing selection of sample households.

Data collection and recording

Data were collected by means of direct observation and measurement of structural characteristics. Horizontal structure was recorded on sketch maps and by taking photographs. Data for the structural characteristics of all sample homegardens for each community were recorded in an Excel database which was used to compile comparative tables of garden structural characteristics for all of the study sites.

Data analysis

Because there are no standardized approaches for classifying horizontal structural dimensions of homegardens, we were compelled to develop our own analytic system. This system includes four different horizontal structural dimensions ([Fig 3](#)):

- Shape of planting areas or plots: *Geometric* forms include plots or beds with square, rectangular, or circular shapes. *Organic* forms include planting areas with irregular or curvilinear shapes.
- Definition of the boundary of the planting areas or plots: Boundaries can be *sharp* and clearly marked or *indeterminate* and ill-defined.
- Arrangement of individual plants within planting areas or beds: Individual plants can be planted in parallel lines (*lineal*) or in multiple clusters of plants (*polycentric*).
- Species composition within each plot: Planting areas or beds can be planted with only a single kind of plant species (*mono-species*) or with a mixture of two or more different species (*multi-species*).

Each homegarden of all of the sample households from each ethnic group was classified by a single researcher (the first author) in terms of the extent to which it manifested the alternative characteristics for each structural dimension. For example, the shapes of all of the planting areas within a garden were classified as being either geometric or organic and the surface area covered by each of these forms calculated. The garden was then categorized as to whether it was all geometric, >50% geometric, >50% organic, or all organic. The characteristic (e.g., all or mostly geometric) that was found to occupy more than 50% of the area in the largest number of gardens was selected as being modal for that structural dimension for that ethnic group. These data were then used to make a cluster analysis using the SPSS statistical package version 16.0 (SPSS Inc. Released 2007. SPSS for Windows, Chicago, SPSS).

Results

Detailed information on the frequency of occurrence of different characteristics for each of the 4 horizontal structural dimensions for the sample of homegardens of each of the ethnic groups is presented in [Table 2](#). Each of the ethnic groups has a single clearly dominant characteristic for each of the 4 structural dimensions (with the exception of the Yoy, for which equal shares [45%] of gardens have all mono-species and all multi-species planting patterns within beds). [Table 3](#) presents the modal structural characteristics for each group.

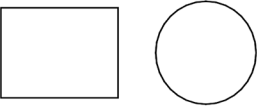
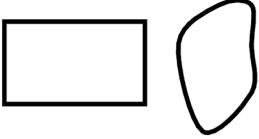
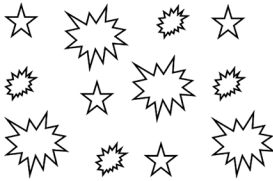
Dimensions	Alternative characteristics	
Shape of planting area	Geometric 	Organic 
Boundary definition	Sharp 	Indeterminate 
Arrangement of individual plants within plot	Lineal 	Polycentric 
Species composition within plot	Mono-species 	Multi-species 

Fig 3. Classification system of horizontal structural characteristics of homegardens.

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Organic shaped planting areas, indeterminate boundaries, and polycentric planting patterns are modal for the Cao Lan, Kalaeng, Lao, Nyaw, and Yoy, while for the Phu Thai, Kinh, and Viet geometric forms with sharp boundaries and lineal planting patterns are modal (although a sizable minority of Phu Thai gardens have organic or mostly organic shapes, indeterminate or mostly indeterminate borders, and polycentric planting patterns). Planting of multiple species in the same planting area is modal for the Cao Lan, Kalaeng, and Nyaw, and while the Phu Thai, Kinh, and Viet have mono-species planting areas and the Yoy and Lao have equal shares of gardens with mono- and multi-species beds.

Fig 4 is a graphic comparison of the modal patterns of each of the groups. The patterns of all Tai groups, with the exception of the Phu Thai, are quite similar to one another, although the Cao Lan pattern is the most distinct and does not fully overlap with the other Tai patterns. The Kinh and the Viet patterns are almost identical while the Phu Tai pattern is closer to that of the Vietnamese groups than it is to the other Tai groups.

Table 2. Comparison of horizontal structural characteristics of homegardens of different ethnic groups in Northeast Thailand and Vietnam (% of gardens displaying characteristic) (n = 20, except 17 for Cao Lan).

Structural dimension	Alternatives (%)	Tai groups						Vietnamese groups	
		Yoy	Phu Tai	Nyaw	Lao	Kalaeng	Cao Lan	Viet	Kinh
Shape of planting areas	All Geometric	15	45	10	15	25	0	70	60
	>50% Geometric	0	20	5	5	0	0	15	25
	>50% Organic	15	15	30	5	0	28	0	15
Boundary definition of planting area	All Organic	70	20	55	75	75	72	15	0
	All Sharp	20	50	15	15	0	6	95	75
	>50% Sharp	5	25	20	5	40	0	0	10
	>50% Indeterminate	15	5	40	5	0	22	0	10
Arrangement of individual plants within planting areas	All Indeterminate	60	20	25	75	60	72	5	5
	All Lineal	15	5	15	15	25	11	75	55
	>50% Lineal	15	65	5	20	0	4	5	45
	>50% Polycentric	0	0	15	0	0	7	5	0
Species composition within planting area	All Polycentric	70	30	65	65	75	78	15	0
	All Mono-species	45	55	35	45	35	22	95	90
	>50% Mono-species	10	30	0	5	0	17	0	10
	>50% Multi-species	0	5	10	0	0	0	0	0
	All Multi-species	45	10	55	50	65	61	5	0

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Fig 5 presents a hierarchical cluster analysis of the modal structural characteristics of the homegardens of the 8 ethnic groups. They cluster into two main types: Type I (Cao Lan, Kalaeng, Lao, Nyaw, and Yoy) and Type II (Phu Thai, Kinh and Viet). Within Type I, the Cao Lan are a separate sub-type while the Phu Thai are a separate subtype within Type II. Homegardens of Type I are characterized by having predominantly organic shapes, indeterminate boundaries of planting areas, polycentric planting patterns, and multi-species composition within planting areas. Homegardens of Type II have geometric shapes, sharp boundaries, lineal planting patterns, and mono-species composition of planting areas. However, the Phu Thai homegardens, although they belong to Type II, are less homogenous than those of the Vietnamese groups and show resemblance to Type I in some regards. Thus, although geometric shapes, sharp boundaries, lineal planting patterns, and mono-species composition are modal, organic shapes, indeterminate boundaries of planting areas, and polycentric planting patterns are also encountered in a considerable minority of their gardens.

Table 3. Comparison of modal structural characteristics of homegardens of different ethnic groups in Northeast Thailand and Vietnam (% of homegardens with all or >50% of their area displaying each characteristic) (n = 20, except 17 for Cao Lan).

Dimension	Tai groups						Vietnamese groups	
	Yoy	Phu Thai	Nyaw	Lao	Kalaeng	Cao Lan	Viet	Kinh
Shape of planting area	Organic (85%)	Geometric (65%)	Organic (85%)	Organic (80%)	Organic (75%)	Organic (100%)	Geometric (85%)	Geometric (85%)
Boundary definition of planting areas	Indeterminate (75%)	Sharp (75%)	Indeterminate (65%)	Indeterminate (80%)	Indeterminate (60%)	Indeterminate (94%)	Sharp (95%)	Sharp (85%)
Arrangement of individual plants within planting area	Polycentric (70%)	Lineal (70%)	Polycentric (80%)	Polycentric (65%)	Polycentric (75%)	Polycentric (85%)	Lineal (80%)	Lineal (100%)
Species composition within planting area	Mono-species (55%)	Mono-species (85%)	Multi-species (65%)	Mono-species (50%) Multi-species (50%)	Multi-species (65%)	Multi-species (61%)	Mono-species (95%)	Mono-species (100%)

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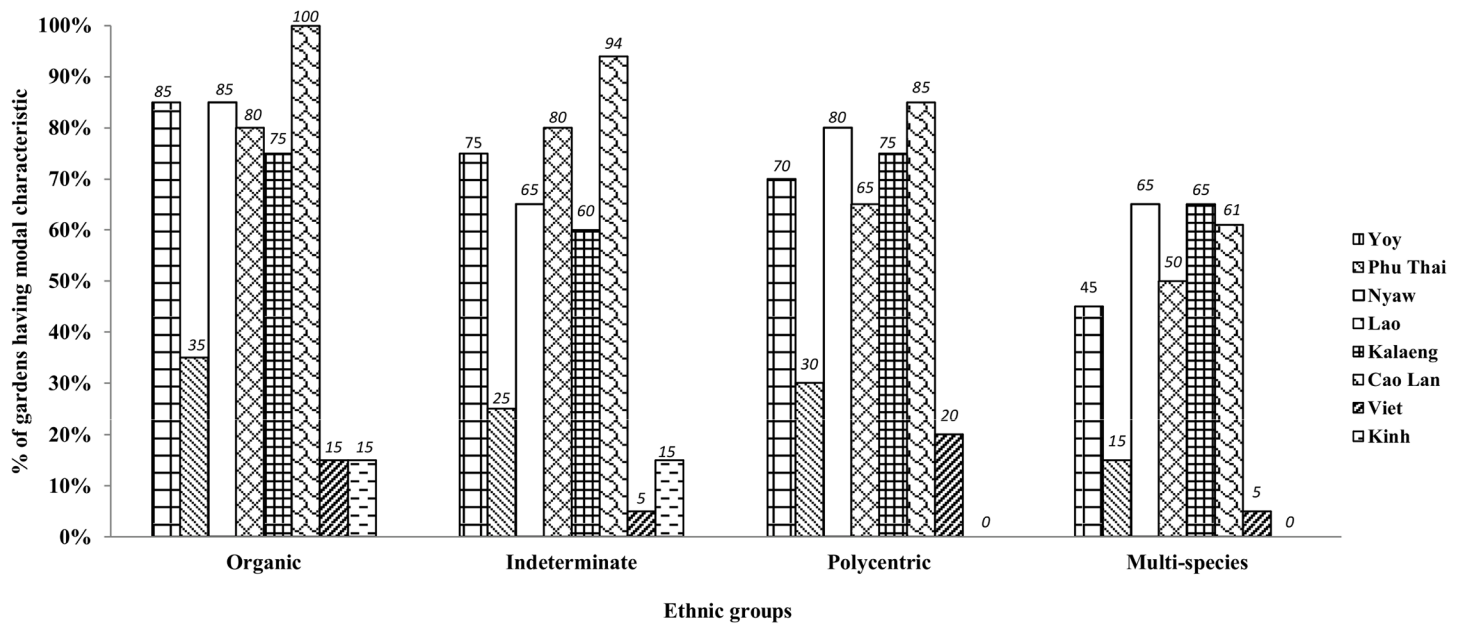


Fig 4. Comparison of modal structural patterns of homegardens of different ethnic groups in Northeast Thailand and Vietnam (% of gardens having characteristic).

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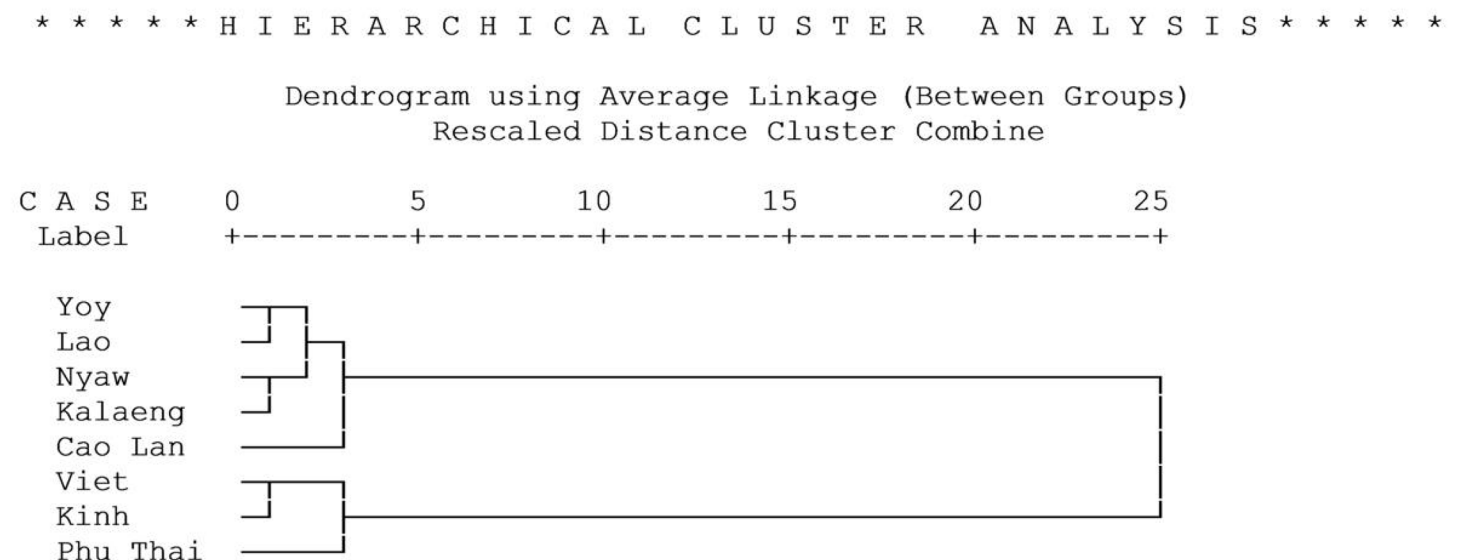


Fig 5. Hierarchical cluster analysis based on percentages of modal characteristics of structural dimensions of homegardens of ethnic groups in Northeast Thailand and Vietnam.

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Discussion

There is a strong association between ethnicity and the horizontal structure of homegardens. The homegardens of most of the Tai ethnic groups share a relatively similar horizontal structural pattern, one that is quite different than the pattern shared by both of the Vietnamese groups. Although we are well aware of the axiom that correlation does not equal causation, we believe that it is legitimate in this case to infer that the spatial layout of homegardens is strongly

influenced by the cultural models of the different ethnic groups and not the reverse. The Tai groups in Northeastern Thailand have had no direct contact with the Cao Lan in Vietnam for many centuries and yet their gardens display very similar horizontal structural patterns. At the same time, the structural pattern of the homegardens of the Viet in Northeastern Thailand is virtually identical to that of the Kinh in Vietnam from whom they have been separated for more than 100 years. The persistence of this common pattern, despite the fact that the Viet have lived in close proximity with neighboring Tai groups in Northeastern Thailand for several generations, is remarkable since there should have been sufficient time for convergence on a common modal pattern to have occurred if environmental selective forces and/or acculturative pressures were the main determinants of agroecosystem structure. Studies of the homegardens of immigrant minority groups in other parts of the world have also found that they commonly replicate the garden patterns of their homelands rather than adopting the pattern of the majority populations of the countries where they have resettled. For example, the vegetable gardens of Vietnamese refugees living in New Orleans in the United States have similar planting patterns and species composition to homegardens in Vietnam [24]. The widespread persistence of distinctive agricultural patterns in immigrant communities in new environmental circumstances [25–27] provides further evidence that culture is an important determinant of agroecosystem structure.

Although not amenable to quantitative analysis, it appears that the structural patterns of the homegardens of the Tai ethnic groups are highly congruent with the other Tai cultural patterns while the structural patterns of the Vietnamese gardens are congruent with broader Vietnamese cultural patterns. In particular, we would suggest that differences between the Tai and Vietnamese gardens in the spatial arrangement of plants within the gardens and the extent to which planting areas are clearly delineated reflect important differences in basic Tai and Vietnamese cultural patterns. The Tai gardens, which are polycentric and mix together many different species in the same organically shaped planting areas, may seem to an outside observer to be unplanned and lacking in order in comparison to the straight rows of plants of a single species in the neatly laid out geometric beds of the Vietnamese gardens. The same seeming lack of order has often been noted as a general characteristic of Thailand's society, which was famously characterized by John Embree [28] as being "loosely structured." Embree, an American anthropologist who had done extended ethnographic research in Japan before coming to Thailand, was struck by the seeming lack of order in Thai social life in comparison to the highly codified patterns of Japanese society. Of course, although Embree failed to perceive it, there is an underlying order in Thai society [29], but it is of a very different nature than the more rigidly defined social order in Chinese-influenced cultures such as Japan and Vietnam [30]. Differences in the sharpness with which the boundaries of planting areas are defined in Tai and Vietnamese gardens may also reflect more general cultural patterns of these societies. In comparison to the sharp borders of Vietnamese garden beds, the planting areas of the Tai gardens lack clearly demarcated edges or borders. This is congruent with a more general lack of concern in Tai culture with demarcating territorial boundaries. It was only in the mid-nineteenth century when, under pressure from the British and French, the Kingdom of Siam first began to map its territorial borders [31]. Only in the 1960s, encouraged by government rural development workers, did Northeastern Thai villagers begin to build fences to mark the borders of their house plots [32]. In contrast Vietnamese culture strongly emphasizes the delineation of clear boundaries, including of the borders of the national territory, of individual villages, which were traditionally surrounded by a bamboo hedge or earthen wall and of individual house plots within villages [33].

The finding that the homegardens of the Phu Thai have a structural pattern that is closer to the Vietnamese pattern than that of the other Tai groups does not fit with our initial hypothesis

and is difficult to explain using the very limited available historical and ethnographic information about the Tai ethnic groups in Northeast Thailand. However, the Phu Thai are commonly recognized as being culturally quite distinct from other Tai groups. After they were resettled in Thailand in the 1800s, they lived in a largely autonomous ethnic enclave with their own ruler and had very limited contact with other Tai groups in the area. At present they have a reputation among other Tai for being hard-working and innovative. Their economy is more productive, and they have been very quick to diversify their agriculture into production of a variety of cash crops [34]. We observed that their village was better organized and exhibited greater social cohesion than the other Tai communities included in our study.

The continuing coexistence within the same geographical area of homegardens with two quite different structural patterns raises questions about the extent to which agroecosystem structure is determined by environmental factors as is often assumed to be the case [35, 36]. The Type I homegardens of the Tai groups resemble the tropical forest model of homegardens first proposed by Terra [3–5] and later elaborated by Soemarwoto [37] and researchers associated with the International Center for Research in Agroforestry (ICRAF) (e.g., 10–12). In gardens of this type, the planting pattern has been variously characterized as having uneven or random spacing, or even as being in “disarray,” with individual plants of different species scattered at seemingly random intervals within the garden area [38]. The structure of Type II gardens of the Phu Thai and both of the Vietnamese groups resembles the “temperate type” homegardens described by Niñez [39]. Temperate type gardens are characterized by neatly arranged plantings of mostly annual crops of uniform height in mono-specific rectangular beds. Tropical type homegardens are indigenous to Southeast Asia [3–5] while the temperate type of homegardens probably originated in China [40]. The latter type subsequently spread to Southeast Asia, first to Vietnam, while it was under Chinese political domination, and subsequently, during the European colonial era to Malaya and other colonies where it was introduced by Chinese migrants [41]. The fact that temperate type homegardens function successfully in both Northeast Thailand and central Vietnam, which have tropical climates, suggests that environmental selection is not very rigorous and that both types are essentially equally well-adapted to tropical conditions.

Conclusions

Study findings suggest a close linkage between ethnicity and the structure of homegarden agroecosystems. Most of the Tai groups share a common structural pattern for their homegardens while both of the Vietnamese groups share their own common structural pattern. This close association between ethnicity and agroecosystem structure represents what Richard O’Conner [42], in his study of ethnic competition in the history of Southeast Asia, has referred to as an “agro-cultural complex.” These complexes have persisted through time and space and retained their integrity, even when the ethnic groups on which they are based have migrated into different environments and encountered strong acculturative pressures from neighboring populations having different ethnic identities and distinctive agroecosystem models.

The existence of such strong and durable links between ethnic identity and agroecosystem structure has important implications for research on agricultural development. Agricultural research has been heavily dominated by economic and technological concerns, reflecting the assumption of agricultural scientists and government policymakers that farmers, regardless of their ethnic identity, will always tend to adopt agricultural structures and practices that provide optimum economic returns [27]. To the extent, however, that agroecosystem structures reflect the cultural models of the farmers, adoption of improved technology may be constrained by its compatibility with these models. It is possible, of course, that homegardens, which are mostly

small plots used to meet household subsistence needs, are more likely to conserve traditional cultural patterns because they are less subject to market pressures to maximize productivity than cash-cropping components of agroecosystems. However, this is not necessarily the case since we know that even modern American commercial farmers are influenced by cultural factors, as shown, for example, by their initial resistance to adoption of economically beneficial sustainable agriculture partly because this system was associated in the popular imagination with “hippies” [43]. Therefore, assessing the ways in which the cultural beliefs and values of farmers from different ethnic groups influence their choice of appropriate agricultural structures and practices should have an important place on the research agenda of agricultural researchers and policymakers in developing countries.

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Author Contributions

Conceived and designed the experiments: ATR PT. Performed the experiments: PT. Analyzed the data: PT ATR. Contributed reagents/materials/analysis tools: ATR PT. Wrote the paper: ATR PT.

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Cost-Benefit Analysis of Vegetable Production in Thai-Vietnamese Homegardens in Northeast Thailand

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ABSTRACT: Homegardens have been widely promoted as highly sustainable low input agroecosystems that provide food, materials, cash income, and ecological services to poor rural households. However, there have been only a few attempts to assess their productive efficiency by measuring inputs of labor, cash and materials and outputs of food and other products. This study was designed to record all inputs and outputs for a period of 10 days of a sample of 9 homegardens of Thai-Vietnamese farmers in a village in Northeast Thailand. Short production cycle crops, e.g., lettuce, edible morning glory, and sweet corn, were the most commonly grown crops. Most garden produce is sold in the market but some is consumed by the farm households. The imputed cost of family labor accounted for 85% of total input costs while electricity used to power the pumps for irrigating the homegardens and manure each accounted for 6.8% of total input costs. Expenditures on fuel for hand tillers, chemical insecticides, and seed were small. The output values of the homegardens depended on the kinds of vegetables grown and their yields. On average, each household obtained gross income of 852 Baht (USD 26.4) and net return of 619 Baht/day. Productive efficiency was high with an average net return on input cost (net benefit - cost ratio) of 2.7:1, which is much higher than for rainfed rice, which is the main alternative agricultural system in the area. Productivity per labor hour was high with an average net return per labor hour of 117 Baht. Net benefits per unit area were also quite high with an average net return of 1.3 Baht/m² of planted area per day. Not surprisingly, the Thai-Vietnamese farmers have largely abandoned cultivating rainfed rice in order to concentrate on their much more productive homegardens.

Keywords: productive efficiency, vegetable gardening, tropical homegardens, input-output analysis, agricultural intensification

Introduction

Homegardens have been widely promoted as highly sustainable low input agroecosystems that provide food, materials, cash income, and ecological services to rural households in developing countries (Stoler, 1981; Soemarwoto, 1987; Gajaseni and Gajaseni, 1999; Trinh et al., 2003; Kumar and Nair, 2004; Galhena et al., 2013). However, because of severe methodological constraints, there have been only a few attempts to actually assess the productive efficiency of these systems by measuring inputs of labor, cash

and materials and outputs of food and other products. Most existing studies on the economic value and yield of homegardens have been done in temperate home vegetable gardens in the United States (e.g., Stall 1979; Stephens et al. 1980; Cleveland et al. 1985). There have been only a few input-output studies of tropical homegardens: Stoler (1981) reported a range of cash values of production per hectare and the average return per labor hour for homegardens in Java, Indonesia; Pandey et al. (2007) described the gross annual income per total cost of inputs of homegardens in the Andaman and Nicobar

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islands of India; Mohan (2004) presented estimates of the annual mean value/m² of all products harvested from homegardens in Kerala, India; Alam (2012) estimated the total annual benefits and costs of agroforestry gardens in Bangladesh; and Cuanalo de la Cerdo and Mukul (2008) made estimates of the annual value of inputs and outputs for producing different kinds of crops and livestock in Maya homegardens in Yucatan, Mexico. Most previous studies of productive efficiency have been based on recall interviewing of farmers about the value of products and costs of inputs in the preceding year so are necessarily rough approximations at best. We have been unable to find any detailed analyses based on daily record keeping of the value of all of the inputs and outputs of homegardens in either the tropics or the temperate zone. Therefore, we conducted a detailed field study to record all inputs to and outputs from a sample of homegardens of the Thai-Vietnamese farmers in Najok village in Northeast Thailand. In this paper we present an analysis of all inputs and outputs and assessment of the productive efficiency of vegetables and other short cycle crops produced in these gardens

Homegardens are found in virtually all of the world's cultivable regions, including both tropical and temperate zones (Niñez, 1987). They are seen as being a highly sustainable component of the farming systems of smallholders that conserve soil and water resources and protect biodiversity (Soemarwoto, 1987; Karyono, 1990; Torquebiau, 1992; Gajaseneni and Gajaseneni, 1999; Trinh et al., 2003; Kehlenbeck and Maass, 2004; Mohri et al., 2013). In general, homegardens are located in the immediate vicinity of the farmers' houses. They

commonly incorporate a mixture of annual and perennial agricultural crops and livestock that provide food, services and income to the households. Homegardens are managed with the part-time labor of family members and are characterized by having low inputs and outputs (Fernandes and Nair, 1986; Niñez, 1987; Hoogerbrugge and Fresco, 1993; Landreth and Saito, 2014). There have been many studies conducted on homegarden systems in various parts of the world that have generally concluded that the main benefits of homegardens are to ensure and enhance household nutrition and food security and provide some ecosystem services (Huai and Hamilton, 2008; Mohri et al., 2013; Galhena et al., 2013). Homegardens usually only provide a supplementary source of food and income but in some cases they are a main source of household income.

Materials and Methods

The 9 sample households used in this study were selected from a larger sample of 20 households in Najok village in Nakhon Phanom province. The ecological structure of these gardens had previously been studied by Timsuksai (2014). This sample was used because of the availability of detailed information about the ecological structure and functioning of their gardens (Timsuksai 2014; Timsuksai and Rambo 2015; 2016). These 9 households were the only ones from the initial sample of 20 that had continued to actively cultivate vegetables in their homegardens and were willing and able to be interviewed.

Data collection was done using questionnaires, semi-structured interviews and informal discussions with farmers about their household economies and their homegardens. Information about gardening inputs and outputs was gathered by having each household complete a daily record sheet. The record sheets included information on: 1) Type of activities in homegardens and who performed them for how long; 2) Type, amount and cash value of material inputs (e.g., manure, fertilizer, fuel) used in homegardens; 3) Amount and cash value of products produced for daily household consumption; 4) Amount and cash value of products produced for sale. Because this study is focused on analysis of inputs and outputs in the production of short cycle vegetable and flower crops, long production cycle crops such as fruit trees (e.g., dragon fruit, jackfruit, banana, and pomelo) and spices are not included in this analysis.

Record sheets were kept by all sample households for 10 days from 26 March to 5 April, 2014. Although 10 days is a relatively short period, because all of the households had many beds in their gardens in various stages of the production cycle, all of the various activities involved in garden cultivation, including land preparation, cultivation (seeding, transplanting, weeding and irrigating) and harvesting were performed in all of the sample gardens during this period.

Data were entered into an Excel database and were analyzed using standard descriptive statistic. The calculation of the cash value of inputs and outputs in these homegardens was based on the following factors:

1) The cost of hired labor equals 300 Baht/day (8 hours).

2) The cost of irrigation was based on calculating the cost of the number of kWh of electricity used to power the pump used for watering the homegarden.

3) Food produced for home consumption was assigned a cash value based on the market price of the relevant items on the recorded day.

4) The cash value of products for sale was calculated based on the market price of the specific items on the recorded day.

The returns on production in homegardens were calculated using the following formulas:

$$\begin{aligned} \text{- Return on input cost} &= \frac{\text{Net return}}{\text{Total variable cost}} \\ \text{- Return on planted area (Baht/m}^2\text{)} &= \frac{\text{Net return}}{\text{unit planted area of land}} \\ \text{- Return on labor (Baht/labor hour)} &= \frac{\text{Net return}}{\text{Labor input}} \end{aligned}$$

Results

Study site

The study was conducted in Najok village, Muang district, Nakhon Phanom province in Northeast Thailand (17°22'38.09"N and 104°45'45.10"E) (**Figure 1**). This village was settled by immigrants from Central Vietnam beginning in the 1880s (Timsuksai, 2014). Although the inhabitants are now Thai citizens, they maintain many aspects of Vietnamese culture, including speaking Vietnamese within their homes.

The total surface area of the village is 116 ha with a population of 303 people. The terrain is mostly a gently sloping plain with an average elevation of 156 m above mean sea level. The

dominant soil in the village is silt with low to moderate fertility and good to moderate drainage. The area has a tropical savanna climate. The mean temperature varies from 21.8°C to 31.8°C, with the minimum in December and the maximum in April. Average annual rainfall is 2,347 mm. Most of the rainfall (95%) falls between April and October, whereas the four months from November to February are relatively dry. Relative humidity ranges from 67% to 88% with the lowest level in the dry season (Thai Meteorological Department, 2014).

The Thai-Vietnamese living in Najok village have a long tradition of cultivating homegardens.

Until recently their homegardens were an integral component of a complex farming system that included paddy fields, upland crops fields, and livestock, but in 2012 most households stopped engaging in other agricultural activities in order to concentrate on homegarden production. Their gardens are mostly devoted to growing of high value short cycle crops including vegetables, sweet corn, and flowers. Some of these crops are consumed by the households themselves but sale of garden produce in the market has become the main source of household income.

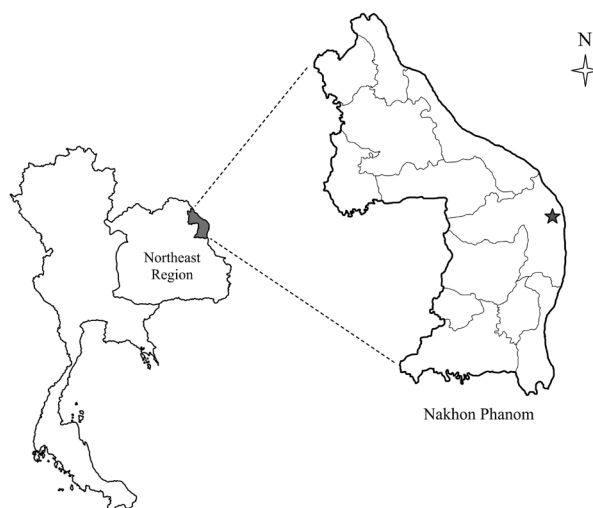


Figure 1 Map showing location of study site

Area of homegardens, number of planting beds, and labor force

The average area of the homegardens was 3,168 m², with a range from 1,600 to 7,200 m². Most of the areas in front of the houses, which accounted for 27% of the total homegarden area, were used for production of short cycle crops including leafy vegetables, sweet corn, beans and

flowers. The mean area planted to short cycle crops throughout the whole year was 2,448 m², ranging from 1,230 m² to 3,970 m².

On average, a household had 2 beds undergoing land preparation; 9 beds under cultivation; 7 beds being harvested; and 7 beds in fallow after harvesting (Table 1).

Table 1 Activities being conducted in the different vegetable beds in the sample homegardens in the Thai-Vietnamese homegardens in Najok village (n=9 homegardens for 10 days)

Household	Total no of beds in garden	Land Preparation	Cultivation	Harvesting	Fallowed
1	29	4	15	3	7
2	36	4	10	16	6
3	20	2	7	4	7
4	29	2	13	7	7
5	19	0	4	8	7
6	26	3	12	7	4
7	16	0	3	3	10
8	14	2	4	4	4
9	32	4	10	10	8
Mean	25	2	9	7	7
Total	221	21	78	62	60

The average of number of laborers per household was 2, ranging from 1 to 4 laborers.

The vegetable production cycle

Table 2 shows the major types of vegetables planted in the gardens, the months when they are

grown, and the number of production cycles per planting season. The kind of vegetables grown depends on market demand and the season. Most kinds are grown from late August until early April but some are grown all year round.

Table 2 Short cycle crops planted in Vietnamese homegardens in Najok village (n=9 homegardens)

Common English name	Scientific name	Vietnamese name	Planted area (m ²) in 9 sample gardens		Percent of total vegetable area (%)	Cultivation period	No of Cycles/ year
			Mean	Range			
Lettuce	<i>Lactuca sativa</i> L.	Xà lách	1245.0	0-2650	50.9	September-April	4-5
Morning glory	<i>Ipomoea aquatic</i> L.	Muống	536.7	0-2160	21.9	August-September; March-April	1-2
Sweet corn	<i>Zea mays</i> subsp. <i>saccharata</i>	Ngô ngọt	474.4	0-800	19.4	May - mid-July	1
Other vegetables	-	-	192.2	0-370	7.9	September-April; Whole year	1-4

During the period of study in March-April, lettuce (*Lactuca sativa*) occupied half of the total area planted to vegetables, with an average area of 1,245 m²/garden. Lettuce was grown in all of the homegardens because of high market demand, good price, and especially because it

is well adapted to the climatic conditions in the area between September and April. The full cultivation cycle for lettuce lasts for about two months (one month for growing the seedlings is a special nursery bed and around one more month after the seedlings are transplanted into

one of the main beds until they are harvested). The farmers all have multiple vegetable beds in their gardens so they use one bed to raise seedlings during the whole season. When they are ready, seedlings are transplanted into whatever bed is available at the time. By using this staggered planting of different beds, farmers ensure a steady flow of production throughout the growing season.

Edible morning glory or water spinach (*Ipomoea aquatic*) was the second most important kind of vegetable with an average planted area of 537 m²/household, accounting for about 22 percent of the total planted area. The area was smaller than that of lettuce because of the season when the survey was done. Morning glory does better in hot weather (from August to September and from March to April). Although the production cycle of morning glory is shorter than that of lettuce (25-30 days), most households grow only 1 or 2 cycles/year, although there was one household that grew edible morning glory throughout the rainy season.

The planted areas of Chinese spinach, jute mallow, cabbage, broccoli, mustard greens and other vegetables and flowers were all small (less than 1 percent each of the total area of vegetables) because these vegetables can only be grown in certain limited periods during the year. For example, jute mallow and Chinese spinach can be grown only in the hot season and cabbage and garland chrysanthemum only in the cool dry season. Also, market demand for these crops was not high so that only a few farmers planted them and they were grown for only one cycle/year. Black gram and yard-long beans were grown on small areas in some homegardens, but were not popular crops in this village.

In the rainy season, almost all of the plots which had been used for vegetable production in the preceding dry season were used to grow sweet corn from late April to the end of July. During this season, households planted only small vegetable plots for family consumption.

Input costs

Table 3 shows the costs per day of all inputs used for growing vegetables and other short cycle crops. The imputed cost of family labor accounted for 85% of total input costs. Household spent on average 5.3 hours /day, ranging from 1.5 hours to 10 hours/day, working in their gardens (Table 4). Labor was expended on land preparation, planting, applying manure, watering, erecting shade cloth, weeding, and harvesting. During the period of data collection, many of the vegetable crops in their homegardens were ready to be harvested, and all households engaged in harvesting activities, so that this activity accounted for 43% of labor costs. Because it was the dry season, watering accounted for the second greatest amount of labor costs (35%). There were 7 households doing land preparation, applying manure and planting, but only in small plots, so preparing land (5%), applying fertilizer (2%), planting (4%), and erecting shading for vegetable beds (1%) represented only small shares of total labor input costs.

Electricity used to power the pumps for irrigating the homegardens accounted for 6.8% of total input costs. Because it was the dry season, the vegetables needed to be watered every day (for an average of 1.8 hours/day). Manure represented 6.8% of input costs. Because manure was the main fertilizer used in these gardens there was almost no expenditure on chemical fertilizer. Expenditures on chemical insecticides were also

small. Expenditures on seed and fuel (diesel for hand tillers) represented the smallest share of input costs. Most of the seeds used in these gardens were saved by the farmers from previous crops, or bought cheaply from the local shops in their village. The fuel cost was low because almost

all of the activities in the gardens were done by human labor. Farmers only used two-wheeled tractors once each year when they started preparing land for the new planting season. For subsequent crops they used hoes to cultivate the soil.

Table 3 Input costs (Baht/day) for all types of short cycle crops produced in Thai-Vietnamese homegardens in Najok village (n=9 homegardens)

Kind of inputs	Daily mean	Daily minimum	Daily maximum
Manure	15.8 (6.8%)	0.0	40.0
Seed	1.6 (0.7%)	0.0	12.5
Fuel	1.4 (0.6%)	0.0	9.0
Irrigation (electricity to run pumps)	15.9 (6.8%)	2.2	42.0
Labor	198.6 (85.2%)	55.3	376.9
Input cost/100 m ² planted area	49	21	78

Table 4 Labor expenditure (hours) per day in Thai-Vietnamese homegardens in Najok village (n=9 homegardens)

Activities	Mean	Min	Max
Land preparation	0.3 (5%)	0.0	0.7
Fertilizer Application	0.1 (2%)	0.0	0.3
Planting	0.2 (4%)	0.0	0.8
Erecting shade cloth	0.1 (1%)	0.0	0.1
Watering	1.8 (35%)	0.8	4.0
Weeding	0.5 (10%)	0.0	1.7
Harvesting	2.3 (43%)	0.4	6.2
Total	5.3 (100%)	1.5	10.0

Output values

The output values of homegardens depended on the kinds of crops grown and their yields. On average, each household obtained gross income of 852 Baht/day, and an estimated 125,652 Baht/year. Average input costs/year, not including value of household labor, were estimated by farmers at 29,761 Baht. The daily mean cash value of outputs/100 m² of planted area was 179 Baht, ranging from 69 to 313 Baht (**Table 5**).

The output value of vegetables was calculated by first multiplying the quantity produced of each species by its market price and

then adding together the values of all different types of vegetables to get the total value of vegetable production. Because they had good yields and prices, vegetables had the highest output value of all garden crops, accounting for 89% of the total output value of homegardens. The daily output value of vegetables /100 square meters of planted area was also the highest, with an average value of 190 Baht, ranging from 37 to 351 Baht. The output values of sweet corn and other crops were not very high because they were grown on much smaller areas and their prices were lower than for vegetables.

Table 5 Gross output values of short cycle crops in Thai-Vietnamese homegardens in Najok village (n=9 homegardens)

Components	Mean	Minimum	Maximum	Total for 9 gardens
<i>Output values (Baht/day)</i>				
Vegetables	762.3 (89%)	140.0	1752.5	6860.5
Sweet corn	76.1 (9%)	0.0	640.0	685.0
Others	13.8 (2%)	0.0	124.0	124.0
Total product value	852.2 (100%)	142.0	1752.5	7669.5
<i>Product value (Baht/100m²/day)</i>				
Vegetables	190.0	37.0	351.0	1,710
Sweet corn	117.0	0.0	180.0	1,053
Others	64.0	0.0	124.0	576
Whole garden	179.0	69.0	313.0	1,611

The costs and returns of the homegardens

Although input costs are high because of high labor costs, the net return of homegardens was also high. On average, the net return of the homegardens was 619 Baht/day, with a range from 40 to 1,325 Baht/day during the 10 days that were recorded (Table 6). Although the input costs

to the homegardens were also quite high, the overall average net return on input cost (net benefit - cost ratio) was positive at 2.7:1. Productivity per labor hour was high with an average net return per labor hour of 117 Baht. Net benefits per unit area were also quite high with an average daily net return of 1.3 Baht/m² of planted area.

Table 6 Input costs and output values of Thai-Vietnamese homegardens in Najok village (n=9 homegardens)

Productive efficiency	Unit	Mean value	Minimum	Maximum
Total input costs/day	Baht	233.3	57.9	426.8
Total product value/day	Baht	852.2	142.0	1752.5
Net return/day	Baht	618.9	40.0	1325.7
Net return per planted area/day (Total area 476.2 m ²)	Baht/m ² /day	1.3	0.3	2.4
Net return per labor hour (Total labor time =5.3 hours/day)	Baht/hour	116.8	21.1	281.4
Ratio of net return/input cost		2.7	0.4	7.2

Discussion

The homegardens of the Thai-Vietnamese farmers of Najok village are highly productive and enjoy a very favorable ratio of inputs to outputs. Labor represented by far the highest input cost of homegarden production, confirming the findings of previous studies of homegardens

elsewhere in the world. For example, Jacob and Alles (1987) reported that in Sri Lanka 87.8 percent of total cash inputs were for labor while Stephens et al. (1980) found that in vegetable production in homegardens in North Florida in the USA, labor costs accounted for more than 50 percent of total input costs. However, farmers in Najok village, probably because they sold most

of their produce for cash, expended many more hours in total than is typical for homegarden production elsewhere in the world. On average, the households spent 5.3 hours/day for vegetable production in their gardens, compared to the one hour or less/day that Hoogerbrugge and Fresco (1993) reported in their review of research on labor inputs in homegardens in different parts of the world.

The net return to labor of the Thai-Vietnamese homegardens was 117 Baht/hour, which is much higher than the net returns per labor hour of commercial vegetable farms in Chiang Mai in northern Thailand that obtained only 54 to 109 Baht/labor-day (Kawasaki and Fujimoto, 2009). The net benefit-cost ratio of the Thai-Vietnamese homegardens, which averaged 2.7:1, ranging from 0.4 to 7.2, was also much higher than for other systems, such as commercial vegetable production in Northern Thailand which ranged from 0.1:1 to 0.9:1, depending on species grown and production technology used (Kawasaki and Fujimoto, 2009). It was also much higher than for other small-holder agricultural systems commonly found in Northeast Thailand, such as the rainfed rice production system which had an estimated net benefit-cost ratio of only 0.15:1 (Arayaphong, 2012).

Conclusions

Although tropical homegardens are commonly considered to be low input-low output systems, requiring minimal investment of labor and material inputs in their cultivation but also having relatively low yields, the Thai-Vietnamese homegardens in Najok village have both high inputs and high outputs. Despite having high input costs, they have much higher costs and returns than rainfed rice, which is the main alternative

agricultural system in this locality. Consequently, it is not surprising that most the Thai-Vietnamese farmers in Najok village have recently abandoned cultivation of rainfed rice in order to concentrate their limited household labor supply on much more profitable homegarden production. Despite these advantages, however, the area of homegardens cultivated by these farmers is relatively small. Further expansion of this system appears to be constrained by the limited supply of household labor and the high cost of employing hired laborers. Finding ways to reduce the labor time needed to manage the homegardens might allow households to expand production and increase their incomes.

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AFTERWORD

Swidden agriculture in retrospect

*A. Terry Rambo**

It is more than 50 years since I first became involved in research on swidden agriculture, during my first field trip to Central America in the early 1960s. Since then, I have been fortunate to have been able to observe many different types of swiddens in different countries and different environments. I have also witnessed the general downward trajectory followed by swidden agriculture in Southeast Asia and have directly observed some of the key factors leading to that decline. Therefore, in this short autobiographical essay, I will recount some key points on my personal timeline of observing swiddening in different times and at different places (figure 1) in order to illustrate some of the important conclusions that can be drawn from recent research on swidden agriculture presented in some of the chapters in this volume.

November 1962: A Kekchi Maya village, Rio Blanco, Toledo district, British Honduras

I was a 22-year-old undergraduate student of anthropology doing my first extended fieldwork in a Kekchi Maya village, deep in the undisturbed rainforest of southern British Honduras (now independent Belize). Taking participation-observation to an extreme, I found myself standing on a tall, flimsy platform built above the buttresses of a gigantic tree in a new *milpa* (swidden) that the villagers were clearing in the rain forest. I swung an axe against the huge hardwood trunk and tried desperately to maintain a shaky balance, but it quickly became clear to all concerned, especially me,

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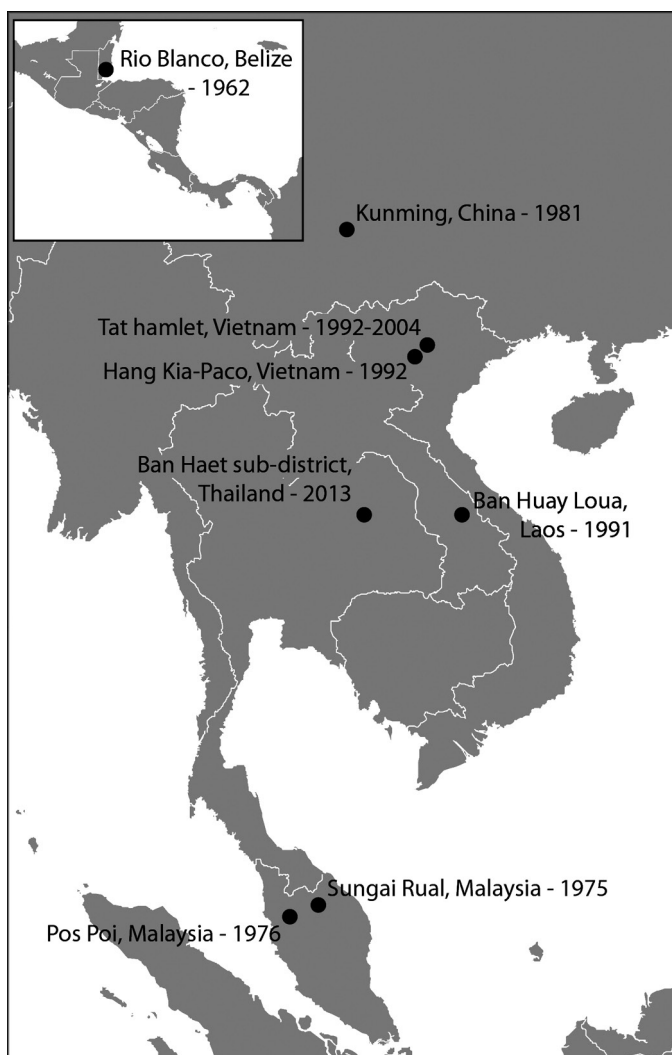


FIGURE 1 Location of the study areas

that I lacked the skills to carry on. I was demoted to helping the women and older men to slash the smaller vegetation on the forest floor with machetes. The work was hard, but often exhilarating as the villagers let out whoops of excitement every time a giant tree fell to the ground with a resounding crash. Months later, I found a similar sense of exhilaration when the dry vegetation was burned to clear the field for planting. The fireworks were spectacular, with flames soaring heavenward beneath a huge column of smoke and ash. The excited shouts of the young men who ran around with burning torches to ignite the dried vegetation were almost drowned out by the roar of the fire and the maniacal screeching sounds coming from the burning trees. That was the moment, I must confess, when I became hooked on swiddening.

The Kekchi villagers were not indigenous to British Honduras, but were recent migrants to the country's vast empty rain forest. The interior of southern British Honduras had remained virtually uninhabited since the Spanish conquest in the 1600s. Earlier, it had been the site of huge, ancient Mayan cities. Only a few abandoned logging roads, built to extract mahogany in the 1920s, penetrated the interior. Beginning in the 1940s, the Kekchi had begun migrating to British Honduras from the over-crowded highlands of Alta Verapaz in Guatemala, seeking both land and safety from the endemic insecurity in their homeland. They were true pioneer shifting cultivators. They cut very large swiddens from the mature forest every year and grew maize and hill rice. The maize was partly for their own consumption, but mostly to feed pigs that were driven to the market in the district capital on the coast, and the rice was wholly a cash crop. Although the forest looked lush, the soils were mostly very infertile, so they cropped their *milpas* for only one year, then abandoned them and cleared a new patch of forest. Because of the large area cleared each year and the very slow regeneration of the fallowed land, the Kekchi were finding it increasingly difficult to find good patches of mature forest near the village in which to clear new fields, and some families had begun to move away in search of new areas of forest.

Much later, many years after I left Rio Blanco, the area around the village was incorporated into a new national park. Now, swiddening is prohibited in the slowly regenerating secondary forest and the plot I once so ineffectually helped to clear is silent except for the chattering of visiting groups of foreign ecotourists.

August 1975: A Jahai Semang resettlement site at Sungai Rual, Kelantan state, west Malaysia

At this time I was a 35-year-old lecturer in anthropology at the University of Malaya. I led a group of my students to study the Jahai Semang, a group of 'Negrito' hunter-gatherers living deep in the rain forest near the Malaysian–Thai border. Six Jahai 'bands' had been resettled together at Sungai Rual by the Malaysian Government's Aboriginal Affairs Department (JOA), as part of an ill-conceived effort to convert the nomadic forest foragers into settled farmers. The JOA was providing free food rations to the Jahai to get them to clear a communal swidden in the mature rainforest surrounding the settlement. For the first time since I left Rio Blanco 13 years before, I heard axes ringing against hardwood trunks. This time, I limited my participation to taking photos of the men swinging their axes from tall platforms built to elevate them above the huge buttresses of the forest trees (figure 2). On the ground, women and less-agile men used jungle knives to cut down smaller trees, just as I had done in Rio Blanco. Once again, I felt the shared sense of excitement every time a giant tree crashed to the forest floor.

The following year I returned to Kelantan state in time to witness the destruction of the vast area of rain forest that surrounded Sungai Rual. A logging company had bought the timber rights to the whole area from the Kelantan state government, which

denied that the aboriginal people had any rights to the land they had occupied for centuries. Huge bulldozers were slashing roads through the forest while Malaysian Chinese loggers using chain saws were cutting down all the valuable timber trees. The Jahai had mostly given up trying to farm their swiddens, after exhausting the government food rations, and had resumed their nomadic collection of wild products to trade for rice. They periodically returned to Sungai Rual so that their children could take part in the school lunch programme for a few days. The children would receive food at school, but would take it home to share with their families (Rambo, 1985).



FIGURE 2 A Jahai man cutting down a tree to clear a swidden in mature rainforest at Sungai Rual, Kelantan, Malaysia.

Photo: A. Terry Rambo

September 1976: Pos Poi, a Temiar village in the mountains of Perak state, west Malaysia

This time, I took my students on a field trip to observe the way of life in a remote Temiar Senoi village located high in the mountains of the Main Range of West Malaysia. All of the households had joined together to clear a single *ladang* (swidden), although each household was responsible for planting its own part of the field. It was the first swidden I had seen that resembled the multi-layered tropical-forest model made famous by Geertz (1963). Interspersed among the rice plants were occasional hills of maize and newly sprouted stems of cassava, while cucumbers and squash vines crept along the ground. Few weeds were visible, but many new saplings had emerged from the stumps of felled forest trees. Close to the new rice swidden was a *ladang* that had been cleared the previous year and was densely covered with cassava. Next to that was a fallowed swidden that was completely covered by wild bananas and emergent tree seedlings. Other plots on the slopes surrounding the settlement were covered with secondary forest in various stages of succession. This was swiddening as I had always imagined it to be: an apparently sustainable subsistence system practised by an isolated and autonomous indigenous people. I would have liked to do more detailed research on the system, but never had the opportunity to return.

September 1981: A conference on agroecological research in Kunming, Yunnan province, China

I had become a researcher at the East-West Center, in Honolulu, and was the leader of the first delegation of foreign scientists allowed to visit China's Yunnan province following the end of the Cultural Revolution. Our group, which was made up of agroecosystem researchers from Indonesia, the Philippines, Thailand and the United States, had been invited by China's national environmental agency to hold a workshop together with leading Chinese agroecology researchers. In one of the discussion sessions, Percy Sajise, an ecologist on the faculty of the University of the Philippines at Los Baños, and I used the example of swidden agriculture to illustrate the systems approach being developed within our group. We were suddenly interrupted by a senior Communist Party official who began to harangue the Chinese scientists in rapid-fire Mandarin. The interpreters fell silent, but a member of our group who was fluent in Chinese provided us with a running account of what was being said. The party official was ordering the Chinese scientists to ignore everything we said about well-managed rotational swiddening being both sustainable and meeting the needs of farmers. He asserted that swiddening was a backward, feudalistic system that destroyed the country's precious forest resources. After the Party cadre finally wound down, Pei Sheng-jie, a Chinese ethnobotanist who had spent many years working with ethnic minorities in Yunnan, stood up and said he thought it was worth listening carefully to what the foreign scientists said, because it was also his view that swiddening was not always a bad system. With that, the meeting was abruptly adjourned. The next day, Pei did not appear for the scheduled discussion. We later learned that he had been subjected to a long 'struggle session', in which he had been harshly criticized for daring to publicly contradict party dogma and had been forbidden to attend the rest of the workshop. However, a senior provincial government leader who had listened to our discussion later invited Pei to write a position paper on swiddening. He told Pei that he had been on the point of ordering some swidden farmers to be shot, to make an example of them, but had rethought his position and no longer saw swiddening as an evil system. Chinese researchers later renamed swiddening 'regenerative rotational agriculture', and in that guise it became politically more acceptable.

June 1991: Ban Huay Loua, Xepone district, Savannakhet province, Laos

I was pacing out the boundary of a rice swidden near a village of the Tri-ethnic minority people, located in mountains beside Route 9, near the border between Laos and Vietnam (Rambo and Lovelace, 1992). The field was located close to the route of the Ho Chi Minh Trail, and was one of the most heavily bombed areas on Earth. Suddenly, the local guide grabbed my shoulder to stop me. Only one metre in front of me, lying on the ground, was an unexploded cluster bomb (a 'bom-bi', as the locals called them). I broke out in a sweat, but gathered my nerve and sat down gently, took out my camera and photographed the 'bom-bi' before making a hasty retreat (figure 3). The presence of so many unexploded bombs in the area was one reason that

people continued to make swiddens in the extremely degraded secondary scrub forest, despite the appallingly low yields they obtained. When they burnt their fields, the heat from the fire cooked off the more sensitive buried ordinance (Nicholas Menzies, a member of our research team, labelled it 'slash-and-boom agriculture'). This allowed the farmers to safely plant crops using wooden dibble sticks. Attempts to construct paddy fields had largely been abandoned because of the calamitous consequences of a metal hoe striking a buried bomb.

In another swidden near the same village I saw a woman squatting in a dense growth of weeds that was smothering her rice crop. She was using a bush knife to dig out weeds that almost hid her from view. She said the weeds were very thick because the fire had not been hot enough to kill them and she lacked sufficient labour to remove them from much of her plot. She expected her rice yield would be very low that year.

January 1992: The H'mong village of Hang Kia-Paco, Mai Chau district, Hoa Binh province, northwestern Vietnam

I was driving with my Vietnamese colleagues Le Trong Cuc and Tran Duc Vien along National Route 6, the main highway from Hanoi into the northwestern mountains. In the H'mong settlement of Hang Kia-Paco, the swidden fields planted in full view of our old Land Rover were covered with beautiful poppy flowers. Cleared on badly degraded



FIGURE 3 An unexploded cluster bomblet on the surface of a swidden in Xepon, Laos

Photo: A. Terry Rambo



FIGURE 4 A Lao Theung woman struggles with weeds in her poor-looking swidden crop of rice.

Photo: A. Terry Rambo (1991)

land covered with low scrub, these swiddens were too infertile to grow rice. The Hmong farmers sold their opium crop to obtain cash to buy motorcycles that they used to travel across the border into Laos, where they could still find good forest in which to clear swiddens to grow hill rice for their own consumption. A couple of years later, when I next passed through the area, there were no opium poppies to be seen; the abandoned swiddens were covered with sparse scrub. The Vietnamese government had implemented and enforced a very strict campaign to suppress opium cultivation, so the Hmong had to abandon their most profitable cash crop – at least in fields that could be seen from the road.

The years from 1992 to 2004: Tat hamlet, Da Bac district, Hoa Binh province, northwestern Vietnam

When Cuc, Vien and I first saw Tat hamlet, a long established community of Da Bac Tay composite swiddeners in a narrow mountain valley in Hoa Binh province, the upper slopes of the mountains that surrounded the village houses and paddy fields were covered with mature forest. Rice swiddens (called *hai* in the Tay language) on the slopes were still giving reasonably good yields for one or two crops before being fallowed for 8 to 10 years, allowing sufficient time for forest regeneration. We were delighted to have found a distinct type of swidden system (that I later labelled ‘composite swiddening’) that appeared to be highly sustainable. Subsequently, we established a long-term research project in Tat hamlet and made detailed studies of many aspects of the system (Vien et al, 2009). However, shortly after we began our research, the system entered a period of very rapid change. First, a state logging enterprise cut down most of the large trees to make chopsticks to sell to Japan. Then the villagers, who had formerly cleared swiddens mostly for subsistence purposes, began to rapidly expand their production of cassava as a cash crop. After the rice crop was harvested, cassava was planted in the swidden field for two or three years before the field was finally fallowed. This led to a shortening of the fallow period to only four years, which was insufficient time to restore the soil before the next cultivation cycle. Consequently, crop yields quickly declined. Then the government forest department designated a large portion of the sloping land formerly used for swiddens as protected forest, causing further shortening of the fallow period on the much reduced area available for swiddening. Rice yields fell to the point where it was no longer worth growing. The villagers responded by increasing their exploitation of forest products to sell for cash to buy rice, intensifying production in their paddy fields, and converting former swiddens to tree and bamboo plantations. Some cassava swiddens were still cultivated but the importance of the swidden component of the composite system declined markedly.

Interestingly, the decline in swiddening first became obvious in government statistics, and only much later on the ground. In the early 1990s, our team was visiting the District People’s Committee in Tu Ly, the capital of Da Bac district, and was given an official briefing on agricultural land use in the district by the agricultural officer.

From where we sat in the People's Committee meeting room, we could see smoke rising from many burning swiddens on the surrounding hills. But the officer failed to make any mention of swiddening as a land use in the district. When I inquired about this omission, he replied with a straight face that there was no longer any swiddening in Da Bac district. In reality, of course, it was still a very widespread land use in the district but, having been renamed 'mixed gardening' by the local authorities, it had been classified out of existence.

2013: Ban Haet subdistrict, Khon Kaen province, northeast Thailand

Although rotational shifting cultivation of hill rice and native cotton was once widespread in the forested uplands of northeast Thailand, this agricultural system had virtually disappeared by the 1980s, when most of the forest was cleared to plant cassava as a cash crop. Continuous cropping of cassava for more than a decade depleted the soil so severely that hill rice could no longer be successfully grown. In recent years, however, many farmers have replaced cassava with sugar cane, which gradually restores soil fertility (Trelo-ges et al, 2004). Sugar cane is harvested 18 months after the first planting, followed the next year by a second ratoon harvest. After the second harvest, the fields are normally left fallow for six months until they are ploughed and reseeded in the next cane-planting season. However, in Ban Haet subdistrict in Khon Kaen province, some farmers have begun to intensify their agriculture by growing hill rice in the fallow period between sugar cane crops. After the cane is harvested, they burn the litter and root stalks, and the fire deposits mineral-rich ash on the soil and makes it easier to plough the field before they broadcast-sow the rice seed (Nongluck Suphanchaimat and Abraham Ghide-Tekie, personal communication, 21 October 2013; Ghide-Tekie, 2014). So it could be said that rotational swidden farming is once more being practised in northeast Thailand, although in a very different form from the rotational system of forest burning that was employed to grow upland crops there in the past.

What have I learned?

The following key points stand out from my personal experiences and studies of swiddening over the years:

1. There are many different types of swidden systems

Some swidden systems that I have seen were very diverse multi-layered polycultures of the sort idealized by Geertz (e.g., the Temiar *ladang*) but others were simple monocultures with only a single canopy layer (e.g., the Kekchi maize *milpa*). The systems described in this volume represent an even greater range of diversity. Lumping all these disparate systems together into the single category of 'swidden' may explain why, after all these years of effort, there is still no commonly accepted definition of the phenomenon we are all trying to understand.

2. The functioning of swidden systems is highly situation specific

Vital variables such as yield levels, the amount of soil erosion, the length of fallow needed to restore soil fertility, and the extent to which weeds are responsible for yield declines, are all determined by conditions specific to each locality. Soils at some sites are highly fertile and resistant to erosion, whereas others are infertile and easily eroded. Growth of weeds is the factor that causes abandonment of plots at some sites, but a decline in available nutrients is the trigger in other places. Because of this variability, it is extremely difficult to identify any common factors that explain the widely observed decline in swidden productivity; the validity of all generalizations about swiddening remains suspect.

3. The distinction between pioneering and rotational swidden systems is greatly under-appreciated

The ranks of what might be called ‘swidden fundamentalists’ consist mainly of anthropologists who have studied subsistence-oriented rotational-swidden systems managed by ethnic minorities living in autonomous communities in the mountains of Southeast Asia (like my observations of the Teniar *ladings* in Malaysia). These pre-capitalist agricultural systems are highly sustainable because the area that must be cleared each year is relatively small; it must yield only enough food to meet the needs of the local people. In contrast, pioneering swiddening, which is aimed at large-scale production of cash crops for the market, is inherently more environmentally destructive and much less sustainable. Pioneering systems, including the maize *milpas* of the Kekchi and the opium fields of the Hmong, consume the forest at far too high a rate to allow successful regeneration before the next cycle of cultivation. As Harold Brookfield has pointed out in his chapter in this volume, the documented cases of swiddening causing environment destruction are all cases of pioneering swiddening. Thus, I think that P. S. Ramakrishnan in his chapter in this volume goes too far in denying that shifting cultivators bear any responsibility for deforestation and land degradation in the tropics. Although I certainly agree with him (and Raintree and Warner as well) that the main culprits are government policies and market pressures, including commercial agriculture and logging, I think we also need to acknowledge that in some areas, pioneering swiddening has caused significant environmental degradation. When trying to defend swiddening against attacks by government forestry officials and conservationists, we need to be careful to define the type of system we are defending.

4. Gender is an important dimension of swiddening and deserves more attention

As a male who came of age in the 1950s, I must confess that I was insufficiently sensitive to gender issues in my early research. I took my middle-class American cultural preconceptions (‘men work, women keep house and raise children’) with

me into the field. They conditioned what I saw and, more importantly, what I failed to see. Thus, while doing my first fieldwork among the Kekchi in British Honduras, I arranged with a few literate men in the village to keep detailed daily records over several months of the time they spent on different activities. I am embarrassed to admit that it never occurred to me to have them also record the work done by their wives, despite the fact that I had often participated in mixed groups of men and women who worked together to clear, plant and harvest their swiddens. It was only in later years, after I had come to recognize the deep truth of Carol Colfer's observation in her chapter on gender issues in this volume that 'women have active roles in most swidden systems...', that I began to pay more attention to gender issues. In particular, I came to perceive how the exclusion of women from full participation in public meetings with development officials, agricultural extension agents and researchers (as was the usual practice in the mountain minority communities I studied in Vietnam) prevented the people who had the best understanding of swiddening in their communities from sharing that knowledge with outsiders who needed the information. Of course, it also denied the women access to any new information about agricultural development that might be provided by outsiders.

5. What happens in swidden fields is determined as much, or even more, by external forces than by local factors

As my own experience has revealed, and as is abundantly documented in this volume, the fate of swidden agriculture is frequently determined by 'outside' forces. These include government restrictions on land use – even outright prohibition of swiddening – incorporation of large areas of forest into national parks and forest reserves, destruction of the forest resource base by commercial logging, changes in market demand for products and availability of new technologies. Government efforts to suppress shifting cultivation remain relentless in many Asian countries. Few officials would go so far as to adopt the intention of the provincial leader in Yunnan, China (mentioned earlier), to shoot some swiddeners to make examples of them, but most officials have a hostile view of shifting cultivation.

Although we should recognize the strong, often decisive impact that government policies can have on local cultivation systems, we should also recognize that such policies are not always implemented successfully in the countryside. Vast resources have been wasted on programmes like Vietnam's *dinh canh dinh cu* scheme, which attempted to 'sedentarize' shifting cultivators, most of whom were already living in settled conditions, but lacked any viable alternatives to practising shifting cultivation. So swiddening continues, but is concealed from official view by being given a new name, like the adoption of 'mixed gardens' as the official synonym for swiddening in Vietnam's Da Bac district. Thus, local officials ensure their bureaucratic success by resorting to terminological tricks that allow them to avoid using terms like shifting cultivation in reports to higher administrative levels. Such semantic gimmicks, as

Carol Colfer, Janis Alcorn, and Diane Russell observe in their chapter in this volume, are effective in ‘...hiding the prevalence of swiddens.’

I think we should also be cautious in attributing too much efficacy to new international programmes such as REDD+. It is a very long way from the meeting rooms of the United Nations in New York to the swidden fields of Southeast Asia.

6. In studying swidden systems we are dealing with a rapidly moving target that is undergoing constant change and adaptation

The speed with which swidden systems can change is sometimes breathtaking. In the case of the composite swidden system of the Da Bac Tay people in Tat hamlet, what appeared to my Vietnamese colleagues and me to be a stable and highly sustainable subsistence-oriented system in the early 1990s evolved into a much more market-oriented system by the mid-2000s. The hill-rice swiddens, which had been the key to households having rice sufficiency in the early 1990s, had almost disappeared within a decade. Although the village’s cassava swiddens had been a major source of cash income, their extent was declining and former swidden areas were being planted with trees and bamboo. Household decision-making was driven by concern for earning cash income.

The rapid changes in Tat hamlet’s agricultural system are far from unique. As Harold Brookfield, citing the words of Paula Brown, notes earlier in this volume, ‘...change is the most common condition’ in both cultivation systems and societies in developing countries. Michael Dove, in his chapter in this volume, usefully reminds us that this state of change is not a phenomenon unique to our time; rather, we should recognize that ‘...the global history of swidden cultivation is a staggered one, with different countries at different times diverging not just in the presence or absence of swidden, but in the social, economic, and political context of the practice.’

7. Predicting the future of swiddening is very difficult – if not impossible

I would very much like to answer Joseph Weinstock’s question, ‘does swidden agriculture have a place in the 21st century?’ However, I have seen so many predictions, including a not insignificant share of my own, turn out to be wrong, that I am reluctant to do so. Identification of clear trajectories is very difficult, precisely because the situation in the uplands of Southeast Asia is so fluid and dynamic, with so many countervailing factors in play. Prediction is further complicated by the often decisive impact of external forces, especially government policies and economic changes, which nobody seems to be able to foresee. In their chapter in this volume, John Raintree and Katherine Warner look back on their earlier attempt to set an agenda for swiddening research. They have the honesty to admit that, ‘What we didn’t anticipate was the dramatic economic growth that has occurred, especially in Asia; its transformation of societies and its impact on the world’s forests and forest communities.’ They are far from alone in having failed to spot this trend. If anyone had tried to tell me in 1962 that the Kekchi village I was studying in the rainforest

of British Honduras would 50 years later be hosting a stream of foreign tourists, I would have thought them crazy. And when I first saw Tat hamlet, in the mountains of Northern Vietnam in 1992, I could never have imagined the isolated settlement, where people still used bamboo torches to light their way at night, would within less than two decades, have a regular bus service, a market and different shops, and colour TVs in almost every house. Despite these reservations, however, I think the answer to Weinstock's question must be an unambiguous 'yes, swiddening does have a place in the 21st century.' But it is the precise nature of that place that remains problematic. I suspect that Jefferson Fox is correct in arguing, as he does in his foreword to this volume, that swidden agriculture will disappear from large parts of South and Southeast Asia, but will remain important in more remote and inaccessible places for some time to come. And, as the case of growing hill rice after sugar cane in northeast Thailand suggests, swiddening may reappear in new and unexpected forms in places where it has long been abandoned. Thus, as I argued in my concluding chapter to the earlier volume in this series, I still expect that swiddening will survive in some form in some places for a long time to come, because there really are no superior alternative systems of agriculture available to millions of resource-poor farmers living in upland areas of Asia and the Pacific.

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To whom it may concern,

This is to certify that the article titled "The Agrarian Transformation in Northeastern Thailand: A Review of Recent Research" by A. Terry Rambo was accepted by the editorial board of *Southeast Asian Studies* on January 19, 2017 and will be included in Vol.6, No.2, the special issue titled "Rural Northeast Thailand in Transition: Recent Changes and their Implications for the Long-term Transformation of the Region" (August 2017).

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Managing Editor

Southeast Asian Studies

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