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Assessment of Spatial Variability of *Tambons* Based on Farming Systems Characteristics for Scaling-up of Diversification in Khon Kaen Province, Thailand

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Abstract

Data from 174 non-irrigated farms in 50 *tambons* (sub-districts) in Khon Kaen Province, Thailand, taken by the Office of Agricultural Economics (OAE) on land area by type of agricultural use and income source by agricultural activity were combined with data from the Soil Survey Laboratory of the Land Development Department (LDD) on predominant soil types in each *tambon*. Farms were assigned to agricultural activity types based on combinations of primary agricultural income source (≥ 50% of total agricultural income) and secondary agricultural income sources (10–49% of total agricultural income). A diversification index was calculated as the sum of the number of primary and secondary income sources. Soils were characterized by texture, slope, drainage, and pH of each soil type. Six clusters of *tambons* were formed based on similarities among these variables. Three clusters contained 86% of the *tambons*: the rice-based farm cluster (31%), the field crop-based farm cluster (22%) and the cluster combining animal and vegetable-based production (33%). A fourth cluster (8%) combined field crop and animal production. The remaining two clusters (6% together) represented non-traditional and highly diversified farms, respectively. There was regional specialization in emphasis on rice (South) versus field crops (South Central, North), but *tambons* combining animal and vegetable production were distributed throughout all regions of the province. *Tambons* with heavier soils, less slope and poorer drainage had proportionally more land area in rice. These *tambons* also had proportionally more income from animal production. Conversely, *tambons* with lighter soils, more slope and better drainage had proportionally more land area in field crops and more income from field crops. Soil characteristics were not indicative of diversification. No spatial gradient either East-West or North-South was found for land use, income or diversification variables. Differences among clusters were more important than spatial differences. Stepwise regression indicated that six variables accounted for 76% of the variation in income. Three variables accounted for 65% of the variation in income: total land area (39% of variation), percentage of income from animal production (14%) and proportion of land area in field crops (13%). Three other variables contributed the remaining 11% of variation explained by the model: drainage (negative contribution); proportion of land area in other crops; and farms with their proportion of income from vegetable production greater than 50%. Animal production may be an indicator of potential for diversification-oriented research to increase the income contribution of horticultural production in farming systems.

Discipline: System research
Additional key words: animals, horticultural crops, rice, upland crops

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Introduction

Participatory on-farm research is both site-specific and intensive. To what extent results obtained through participatory research in one or a few villages can be applied throughout a region is unclear. Determination of the location of villages with conditions similar to sites where intensive on-farm research yields promising results could assist to target the scaling out of results. In Northeast Thailand, where rainfed agriculture is predominant, diversification from traditional rainfed rice and upland crops into animal, fruit and vegetable production is a high priority of farmers[3], for reasons explained below. A method for assessment of spatial variability of farming systems to target diversification research could help bridge the gap between site-specific on-farm research, soils mapping and statistical assessment of farming systems characteristics at a larger scale.

Spatial mapping of soil fertility and topography has been done by the Land Development Department (LDD) of Thailand. Soils, rainfall, land cover, and salinity data have been mapped using Geographical Information Systems (GIS)[5,10]. However, these approaches are all based on biophysical measurements only. Spatial analysis of socio-economic data at the scale of units within a region or province has not yet been carried out, nor have socio-economic data been combined with biophysical data spatially at this scale. Multiagent Systems (MAS)[2] is a method for combining biophysical and socio-economic data, as well as results of participatory role playing, but it is currently applied at the smaller scale of a village-level watershed.

Agricultural statistical sampling is carried out by the Office of Agricultural Economics (OAE), Thailand, with the objective of characterizing agriculture at the level of provinces. The most recent detailed survey was carried out in 1995–96. Districts, sub-districts and farms are selected by a multi-stage random sampling process. The data are cumulated and summarized in the annual Agricultural Statistics of Thailand[7], in which summary statistics for Khon Kaen Province as a whole can be found. These are the only data on agriculture assembled in one location. To obtain data from a larger sample of districts, villages and farms could only be done by physical visits for collection of local data, a method that would require much more resources and time than the use of data from statistical sampling.

This 1995–96 survey data set was initially used by Ooraikul[8] to examine farming systems types based on agricultural activity combinations for Khon Kaen Province as a whole. That analysis showed that farms with only rice and/or upland crops made up 37% of the total sample, while 63% had diversified by adding other activities in addition to the two base crops of rice and sugarcane. Farms which had diversified by adding animals comprised 37%, farms which had diversified into vegetables and/or fruits comprised 6% and farms with animals and vegetables/fruits together comprised 14%. However, this analysis did not indicate whether diversification was uniform across the province or localized in specific regions or villages.

The need for diversification was made clear by Ando[1] in an assessment of farm management, including land use and income, of 55 farms in Nong Saeng, Khon Kaen Province. He concluded that farmers were trapped in an economy of dependence on sugarcane with high debt. He examined five farmers who had successfully diversified, adding fruits and/or vegetables as income sources. He concluded that diversification could be one way to break out of the dependence trap, through concurrent development of market linkages with informal networks and/or better producer organization.

In this study, the same data set that Ooraikul used was combined with soils and topography data from LDD, with the following objectives:

1. To determine what groupings of *tambons* existed within the province based on soil characteristics, land use, income sources, agricultural activity combinations, and level of diversification considered together;
2. To determine if spatial patterns could be identified in the location of such *tambon* groupings, and if such patterns corresponded to a priori regions within the province;
3. To determine which variables were most important in defining the *tambon* groupings;
4. To determine if soil characteristics were related to patterns in land use and income;
5. To determine which variables contributed most to increased income.

Methods

Two sets of data were used in this analysis. The first data set consisted of data from surveys of 174 non-irrigated farms in 50 *tambons* (sub-districts) in Khon Kaen Province obtained by the Office of Agricultural Economics (OAE) in 1995–96. The survey used a multi-stage sampling process: 1) selection of *tambons* within the province; 2) selection of villages within *tambons*; and 3) selection of farms within *tambons*. This process covered 28% of the 181 non-urban *tambons* of the province (not including those belonging to Khon Kaen City).

Data for each farm consisted of two groups of variables, 1) land area by type of agricultural use, and 2) income source by type of agricultural activity. Land use was divided into the following categories, using original data labels: rice (flooded, irrigated, upland), non-rice crops (field, fruit, tree, vegetable, flower) and other agricultural uses (grass, fallow, forest, fish, livestock, mixed, other). Agricultural income came from crops (rice, non-rice food, factory, oil, fiber, vegetable, flower, tree), animal production (meat, milk, swine, broiler, other livestock) and fish. For each farm, the percentage of farm area in rice, total income and the percentage of total income from rice, horticultural crops (primarily vegetables but also including flowers), field crops, animals, and other agricultural activities (including fish) were calculated using a computer spreadsheet (Microsoft Excel). Farms were assigned to agricultural activity types based on combinations of primary agricultural income source (an agricultural activity providing ≥ 50% of total agricultural income) and secondary income sources (an agricultural activity providing 10–49% of total agricultural income). A diversification index was calculated as the sum of the number of primary and secondary income source agricultural activities.

The second data set consisted of percentages of land area of the two most predominant soil types in each *tambon* in the province and the texture (scale 1-6), slope (as a percentage), drainage (scale 1-4 in 0.5 increments), and pH of each soil type. Thai soil type labels were related to the USDA soils classification[6]. East-West and North-South gradient values were determined from GIS data. These data were prepared by the Soil Survey Laboratory of the Land Development Department (LDD). Data were available for all but one of the 50 *tambons* of the OAE data set.

The above two sets of data were combined and imported together into the Statistical Analysis System (SAS)[9]. A preliminary analysis examined differences among the above variables based on six a priori geographical areas within the province, to assess whether diversification was regionally concentrated, but no clear pattern related to diversification was evident. For this reason, cluster analysis was used to identify groups of *tambons* with similar characteristics, and from this determine if spatial patterns of clusters could be identified. Six clusters of *tambons* were formed based on similarities among the above variables using PROC FASTCLUS[9]. The average values of the characteristics of each *tambon* were transferred to the Integrated Land and Water Information System (ILWIS)[4] software for mapping by clusters.

Relationships among variables were examined through correlation and regression analysis. Pearson product-moment correlations and probabilities were calculated for a matrix of variables on *tambon* means using PROC CORR[9]. Dependence relationships between farm income as the dependent variable and soil characteristic variables, total land area, percentage of farm land area in rice, income component percentage variables, and *tambon* spatial location (north-south and east-west; map resolution 30 × 30 digital units) as independent variables were assessed on *tambon* means using stepwise regression in PROC REG[9].

Results and discussion

Across the entire sample, average farm land area was 24.1 rai (3.7 ha: 1 rai = 0.16 ha). An average of 75% of each farm's area was in rice. Average total farm income was 24,130 bahts ($965, using the pre-1997 rate of 25 bahts/U.S.$). Overall, sources of income were divided fairly equally among rice, field crops (predominantly sugarcane and cassava) and animal production, but this masked large differences among the six clusters. Soil characteristics were less variable (Table 1). Clusters were named based on their predominant land use and/or predominant income source. These represented three major alternatives for land use and income sources: rice, the primary food staple of farmers; traditional cash field crops; and alternate income sources of vegetables and animal production.

Three of the six clusters contained 86% of the *tambons*. These clusters represented rice-based *tambons* (31% of the *tambons*), field crop-based *tambons* (22%) and *tambons* combining animal and vegetable production (33%). A fourth cluster (8%) consisted of *tambons* combining field crop and animal production. The remaining two clusters (6% together) represented non-traditional and highly diversified farms, respectively.

Tambons in the rice-based cluster had 83% of agricultural land in rice. They had low agricultural income, 29% less than the average of the 49 *tambons*. Rice was the most important income source, comprising 79% of agricultural income. Soil texture, slope, drainage, and pH were similar to the averages for the 49 *tambons*. The most common soil types in these *tambons* were the loamy soils 18 (Fine-loamy, mixed, semiactive, isohyperthermic Aeric Endoaqualfs) or 18 in association with 17 (Fine-loamy, mixed, subactive, isohyperthermic Aeric Kandiaquults) or 22 (Coarse-loamy, mixed, nonacid, isohyperthermic Fluvaquentic Endoaquepts), predominant in 43% of the *tambons*, followed by loamy/coarse loamy soils 36/40 (Fine-loamy, mixed, isohyperthermic Typic Rhodustalfs/ Coarse-loamy, siliceous, isohyperthermic Typic Kandiustults) and sandy soils 41 (Loamy, siliceous, subactive, isohyperthermic Oxyaquic Arenic Haplustalfs) and

Table 1. Characteristics of six clusters of 49 *tambons* in Khon Kaen Province, Thailand

Variable	Cluster						
	Rice	Field crops	Field & animal	Vegetables & animal	Non-traditional	Diversified	All
Cluster no.	1	4	2	5	3	6	
Tambons	15	11	4	16	2	1	49
Agricultural income (1,000 bahts)	17.1	24.7	77.6	24.7	1.5	32.4	24.1
Land (rai)	19.3	17.9	46.7	15.5	16.6	16.5	20.3
Predominant soil (% of land)	39	34	43	40	20	33	39
Texture1)	3.3	2.5	3.8	4.1	3.0	4.0	3.3
Slope (%)	1.3	1.8	1.0	1.1	1.5	1.0	1.4
Drainage2)	1.6	2.1	1.3	1.0	1.5	1.0	1.5
pH	6.4	6.4	6.9	6.9	6.4	7.0	6.6
Land use3)							
Rice (%)	83	63	41	81	97	89	75
Field crops (%)	4	27	37	4	1	9	12
Other (%)	13	10	22	15	2	2	13
Income sources4)							
Rice (%)	79	11	8	14	0	21	34
Field (%)	3	85	56	6	19	10	29
Animal (%)	13	4	29	49	0	46	22
Vegetable (%)	5	1	7	30	0	23	11
Other agricultural income (%)	0	0	0	0	81	0	4
Diversification index5)	1.5	1.2	2.3	1.7	1.5	4.0	1.7

1): Scale 1-6; 1 = sand ~ 6 = clay.
2): Scale 1-4; 1 = poor drainage ~ 4 = excessive drainage.
3): Percentage of total farm area.
4): Percentage of total agricultural income.
5): Number of agricultural activities contributing at least 10% of agricultural income.

44 (Loamy, siliceous, isohyperthermic Grossarenic Haplustalfs), together comprising another 30%.

Tambons in the field-crop based cluster had 12% smaller agricultural land areas than rice-based *tambons*, and field crops occupied 27% of their land area. Income from field crops comprised 85% of their agricultural income. Their agricultural income was close to the average of the 49 *tambons*. Their soils overall were lighter and had more slope and better drainage than rice-based farms. The most common soil types were the loamy/coarse loamy 36/40 (Fine-loamy, mixed, isohyperthermic Typic Rhodustalfs/Coarse-loamy, siliceous, isohyperthermic Typic Kandiustults), the loamy/sandy 36/41 (Fine-loamy, mixed, isohyperthermic Typic Rhodustalfs/Loamy, siliceous, subactive, isohyperthermic Oxyaquic Arenic Haplustalfs), and the sandy 41 (Loamy, siliceous, subactive, isohyperthermic Oxyaquic Arenic Haplustalfs) and 44 (isohypothermic Grossarenic Hapulsalfs), predominant in 73% of the *tambons*.

Tambons in the cluster combining animal production with field crops had the highest overall incomes, more than three times the average of the 49 *tambons*. They also had more than twice as much agricultural land area. They had the lowest proportion of land area in rice and the highest proportion in field crops. Income was predominantly from field crops (56%), with a second important source from animals (29%). The loamy soil 18 (Fine-loamy, mixed, semiactive, isohyperthermic Aeric Endoaqualfs) was predominant in 75% of these *tambons*.

Tambons in the cluster combining animal production and vegetables had smaller agricultural land area, only 77% of the average of the 49 *tambons*, but achieved an income level similar to the overall average. Nearly half of its agricultural income was from animal production, supplemented by 30% from vegetables. The loamy soil 18 (Fine-loamy, mixed, semiactive, isohyperthermic Aeric Endoaqualfs) or 18 in association with 22 (Coarse-loamy, mixed, nonacid, isohyperthermic Fluvaquentic Endoaquepts) was predominant in 81% of the *tambons*.

The remaining two small clusters represented contrasting situations of divergence from the predominant rice and field crop-based clusters. Both had small agricultural land areas with the great majority in rice, but their income sources were very different. The non-traditional cluster *tambons* used almost all land for rice production and had very low agricultural income. Over 80% of their agricultural income was from other activities besides rice, field crops, animal, or vegetable production. The highly diversified cluster, consisting of only one *tambon*, had the highest diversification index, 4, with income from rice, field crops, animals, and vegetables. Its agricultural income was 60% higher than the average of the 49 *tambons*.

Fig. 1 shows the spatial distribution of *tambons* by cluster, and Table 2 summarizes this distribution grouped into the six a priori regions that can be used easily by local applied research and extension personnel. One third of the 15 *tambons* in the rice-based cluster were found in the South region, where 63% of the *tambons* were rice-based. The North and West regions had few rice-based *tambons*. More than half of the 11 *tambons* in the field crop-based cluster were located in the South Central and North regions, and few were found in the South and Central regions. The four *tambons* in the cluster combining field crops and animals were dispersed among four regions. The 16 *tambons* in the cluster combining animals and vegetable production were found throughout the province. The three non-traditional and diversified *tambons* were found in the Central and North regions. These results show that there is regional differentiation in emphasis on

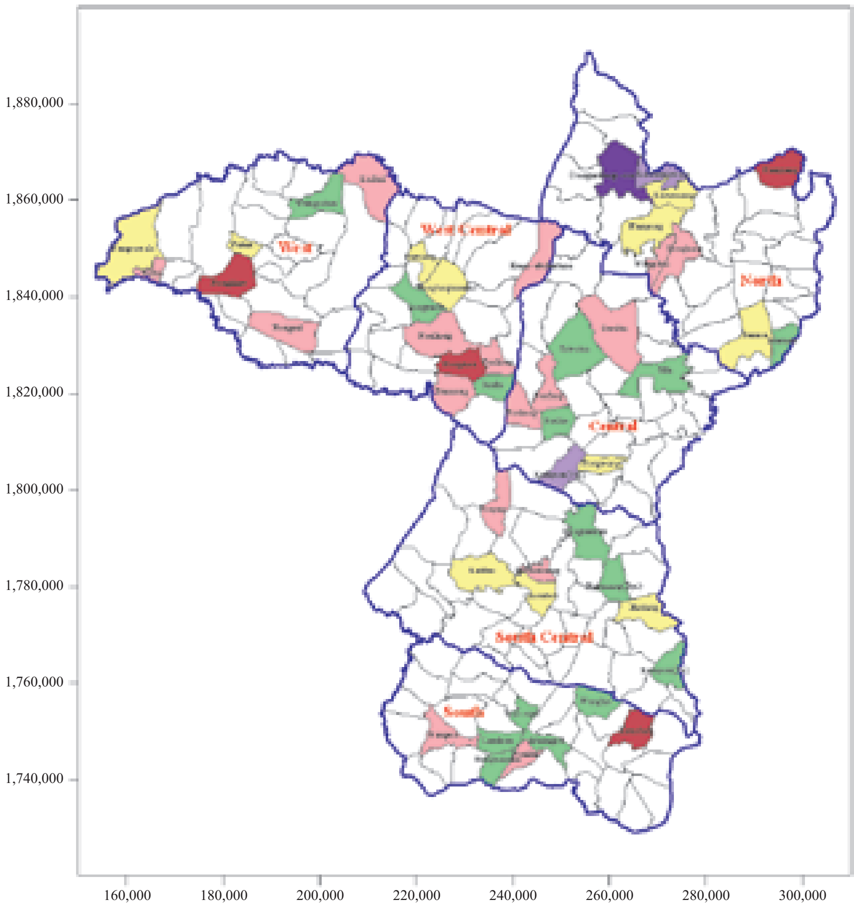

Fig. 1. Spatial distribution[1)] of six clusters based on soil characteristics, land use, income sources, and agricultural activity combinations of 49 *tambons* in Khon Kaen Province, Thailand

1): Coordinates from Universal Transverse Mercator, zone 48Q.

(green): Average texture, rice, smaller area, lower income.

(pink): Heavier texture, vegetable + animals, smaller area, lower income.

(yellow): Lighter texture, field crops, average area, average income.

(light purple): Average texture, non-agricultural, smaller area, very low income.

(red): Heavier texture, field crops + animals, larger area, high income.

(dark purple): Heavier texture, diversified, smaller area, higher income.

Table 2. Location of clusters of 49 *tambons* in six geographical regions of Khon Kaen Province, Thailand

Region[1)]	Cluster (n)[2)]						Total (n)
	Rice	Field crops	Field & animal	Vegetables & animal	Non-traditional	Diversified	
South	5	0	1	2	0	0	8
South Central	3	3	0	2	0	0	8
Central	3	1	0	3	1	0	8
North	1	3	1	2	1	1	9
West Central	2	2	1	4	0	0	9
West	1	2	1	3	0	0	7
Total	15	11	4	16	2	1	49

1): Geographical regions shown in Fig. 1.
2): Clusters descriptor.

Table 3. Correlations between characteristics of predominant soil and agricultural land area, land use proportions, agricultural income, and income source proportion in Khon Kaen Province, Thailand

Variable	Texture[1,2)]	Slope (%)[1)]	Drainage[1,3)]	pH[1)]
Land (rai)	–0.05 NS	–0.02 NS	0.02 NS	0.13 NS
Rice (%)[4)]	0.31 *	–0.34 *	–0.25 +	0.11 NS
Field crops (%)[4)]	–0.27 +	0.34 *	0.21 NS	–0.15 NS
Horticultural crops (%)[4)]	0.02 NS	–0.10 NS	–0.10 NS	–0.06 NS
Agricultural income (bahts)	0.13 NS	–0.05 NS	–0.20 NS	0.05 NS
Rice (%)[5)]	–0.01 NS	0.05 NS	0.06 NS	–0.12 NS
Field (%)[5)]	–0.31 *	0.43 **	0.28 +	–0.11 NS
Animal (%)[5)]	0.27 +	–0.23 NS	–0.29 +	0.22 NS
Vegetable (%)[5)]	0.14 NS	–0.27 +	–0.12 NS	0.21 NS
Other agricultural income (%)[5)]	0.02 NS	0.01 NS	–0.03 NS	–0.22 NS

**: Correlation significant at $P < 0.01$; *: correlation significant at $P < 0.05$; +: correlation non-significant at $0.05 < P < 0.10$;
NS: correlation non-significant at $P \geqq 0.10$.
1): Predominant soil type in each *tambon*.
2): Scale 1-6; 1 = sand ~ 6 = clay.
3): Scale 1-4; 1 = poor drainage ~ 4 = excessive drainage.
4): Percentage of total farm area.
5): Percentage of total agricultural income.

rice versus field crops, but suggest that diversification into animals and vegetables occurs throughout the province. The dispersion of diversified *tambons* confirmed the preliminary analysis that on-farm research for diversification does not need to be regionally focused, but is feasible throughout the province.

Soil characteristics were correlated with land use and income sources. *Tambons* with heavier soils, less slope and poorer drainage had proportionally more land area in rice. These *tambons* also had proportionally more income from animal production. Conversely, *tambons* with lighter soils, more slope and better drainage had proportionally more land area in field crops and more income from field crops (Table 3).

Total income was positively correlated with total land area and percentage of land area in field crops, and negatively correlated with the percentage of land area in rice (Table 4). The percentage of land area in rice was also negatively correlated with total land area (–0.53**, data not shown in Table 4). These results suggest that farmers appear to want to maintain a certain level of rice production area even when land area is small. Total income was positively correlated with percentages of income from animal production, but not correlated with percentages of income from rice, upland crops or horticultural crops.

Relationships among income sources and land variables were consistent with their correlations with total income. Total farm land area was not correlated with the percentages of income from any income source. However, the percentage of income from upland crops was negatively correlated with the percentages of income from both rice and animal production. This suggests that diversification into animal production is an alternative to upland crops, rather than an accompanying strategy. The percentage of income from horticultural production had weak negative correlations with both percentages of income from rice and animal production. No income source showed a correlation with either the East-West or North-South gradients. The diversification index was not correlated with land, income or income source variables.

Stepwise regression indicated that six variables accounted for 76% of the variation in income (Table 5). Three variables accounted for 65% of the variation in income: total land area (39% of variation), percentage of income from animal production (14%) and proportion of land area in field crops (13%). All three variables had positive contributions, indicating that farms with more land area, a higher percentage of income from animal production and a higher proportion of land area in field crops had higher incomes. Three other variables contributed the remaining 11% of variation explained by the model: drainage (negative contribution); proportion of land area in other crops; and proportion of income from vegetable production over 50% (negative contribution). Spatial gradients in either the North-South or East-West directions did not enter into the model.

Conclusions

The above analysis showed that there were differences among regions in emphasis on rice (South) versus

Table 4. Correlations among income, land area and income components of 49 *tambons* in Khon Kaen Province, Thailand

Parameter	Correlation and probability					
	Total income	Rice (%)	Upland crops (%)	Animal (%)	Horticultural (%)	Diversification index
East-West gradient	0.23 NS	0.01 NS	0.10 NS	–0.04 NS	0.02 NS	0.24 NS
North-South gradient	0.14 NS	–0.26 NS	0.09 NS	–0.13 NS	0.21 NS	–0.20 NS
Total farm land	0.65 **	0.01 NS	0.20 NS	0.04 NS	–0.18 NS	0.14 NS
Land in rice (%)1)	–0.61 **	0.29 +	–0.48 **	0.09 NS	–0.03 NS	–0.02 NS
Land in upland crops (%)1)	0.59 **	–0.34 *	0.68 **	0.11 NS	–0.22 NS	–0.06 NS
Rice income (%)2)	–0.19 NS		–0.51 **	–0.19 NS	–0.28 +	–0.08 NS
Upland crop income (%)2)	0.18 NS			–0.38 **	–0.20 NS	–0.16 NS
Animal income (%)2)	0.33 *				–0.26 +	0.28 NS
Horticultural income (%)2)	–0.25 +					0.06 NS
Diversification index3)	0.18 NS					

**: Correlation significant at P < 0.01; *: correlation significant at P < 0.05; +: correlation non-significant at 0.05 < P < 0.10;
NS: correlation non-significant at P ≧ 0.10.
1): Percentage of total area (%).
2): Percentage of total agricultural income (%).
3): Number of agricultural activities contributing at least 10% of agricultural income.

Table 5. Stepwise regression of land, income, activity combinations, soil characteristics, and spatial variables on total income of 49 *tambons* in Khon Kaen Province, Thailand

Variable entered	Step entered into model	Parameter estimate	Partial R-square	Model R-square	F value
Intercept		5,977			
Total farm land area	1	+683	0.39	0.39	24.11 **
Income from animals (%)	2	+266	0.14	0.53	10.78 **
Land area in field crops (%)	3	+706	0.13	0.65	13.06 **
Drainage of predominant soils	4	–9,733	0.05	0.69	4.66 *
Land area in other uses (%)	5	+586	0.04	0.74	5.88 *
>50% of income from vegetables	6	–17,488	0.02	0.76	2.98 +

**: F value significant at P < 0.01; *: F value significant at 0.01 ≤ P < 0.05; +: F value significant at 0.05 ≤ P < 0.10.

field crops (South Central, West), but that diversification into animals and vegetables occurs throughout the province. No spatial gradient either East-West or North-South was found for land use, income or diversification variables. Differences among clusters were more important than spatial differences based on a priori regions.

The factors of total land area, percentage of income from animal production and percentage of land area in upland crops can be used as key indicators to identify farms with greater income. Horticultural production contributes negatively. This suggests that horticultural production has not yet developed into a stable income source.

Soil texture and slope can be used as indicators of emphasis on rice versus field crops. However, soil characteristics are not directly indicative of diversification into animal or horticultural production.

A major difficulty for assessment of spatial variation of socio-economic variables compared with physical variables lies in data collection methods. Data on physical characteristics can be obtained by methods that require only limited numbers of personnel, through placement of remote sensors, aerial photography or satellite photography and measurements. On the other hand, data on socio-economic characteristics of individual farms can only be obtained through personnel-demanding survey techniques. This study explored the possibility of identifying areas for diversification based on disaggregation of macro-level socio-economic data collected for statistical purposes of aggregation at the provincial and national levels, and identification of relationships with macro-level soil characteristics. The above results indicate, however, that in the province focused on, there were no spatial trends that could be used to identify areas with *tambons* with greater potential for diversification.

A more productive approach for moving from the site-specific to the regional level may be to target *tambons* with greater animal production, as the first step in moving to diversification for increased income. In these *tambons*, experimentation to stabilize horticultural production may enable farmers to use the increased income from animal production for greater diversification of income sources. Such experimentation is necessary to change the relationship of horticultural production from the current negative contribution to a positive contribution to increased income.

References

1. Ando, M. (2003) Potential and constraints for intensive land use with pond irrigation in Northeast Thailand. Paper presented at the international symposium, Alternate approaches to enhancing small-scale livelihoods and natural resources management in marginal areas – experience in monsoon asia –, 29–30 October 2003, United Nations University, Tokyo, Japan.
2. Barreteau, O., Kam, S. P. & Le Page, C. (2002) MAS, GIS, and integrated watershed management. Chiang Mai University, Chiang Mai, Thailand and CIRAD, Montpelier, France, pp.154.
3. Caldwell, J. S. et al. (2006) A framework for farmer participatory technology research. *In* Increasing economic options in rainfed agriculture in Indochina through efficient use of water resources, proceedings of JIRCAS rainfed agriculture project workshop, JIRCAS working report no. 47, eds. Ito, O. et al., JIRCAS, Tsukuba, Japan, 109–114.
4. ILWIS (Integrated Land and Water Information System) (2001) User's guide. International Institute for Aerospace Survey & Earth Sciences, Enschede, The Netherlands, pp.530.
5. Karnchanasutham, S. (2000) Land use analysis in Thailand through GIS. *In* GIS applications for agro-environmental issues in developing regions, JIRCAS international symposium series no. 8, eds. Kokubun, M., Uchida, S. & Tsurumi, K., JIRCAS, Tsukuba, Japan, 119–124.
6. Land Development Department (2005) Characteristics and properties of established soil series in northeast region of Thailand, technical paper no. 55/03/48. Office of Soil Survey and Land Use Planning, Land Development Department, Bangkok, Thailand, pp.67 [In Thai].
7. OAE (Office of Agricultural Economics) (1999) Agricultural statistics of Thailand, crop year 1997/98. OAE, Bangkok, Thailand, pp.309.
8. Ooraikul, S. (2000) Farming systems types in Northeast Thailand: importance, geographical distribution, and technology needs. Presentation given at the workshop, Linkages between biological and social science research in the Northeast Thailand Comprehensive Project, 16 June 2000, International Training Center for Agricultural Development (ITCAD), Department of Agriculture, Khon Kaen, Thailand.
9. SAS Institute (2001) The SAS system release 8.2 (TS2MO) for Windows©. SAS Institute Japan Ltd., Tokyo, Japan.
10. Yamamoto, Y. & Uchida, S. (2000) GIS studies at JIRCAS in collaboration with foreign institutes. *In* GIS applications for agro-environmental issues in developing regions, JIRCAS international symposium series no. 8, eds. Kokubun, M., Uchida, S. & Tsurumi, K., JIRCAS, Tsukuba, Japan, 131–140.