Kasetsart Journal of Social Sciences 38 (2017) 264–272

Contents lists available at ScienceDirect

Kasetsart Journal of Social Sciences

journal homepage: http://www.elsevier.com/locate/kjss

Agricultural commercialization: Risk perceptions, risk management and the role of pesticides in Thailand

Suthathip Riwthong [a, *], Pepijn Schreinemachers [b], Christian Grovermann [c], Thomas Berger [a]

[a] Department of Land Use Economics in the Tropics and Subtropics (490d), Universität Hohenheim, 70593 Stuttgart, Germany
[b] World Vegetable Center, Kasetsart University, P.O. Box 1010, Bangkok 10903, Thailand
[c] Food and Agriculture Organization of the United Nations (FAO) – Viale delle Terme di Caracalla, 00153 Rome, Italy

A R T I C L E   I N F O

Article history:
Received 18 September 2016
Received in revised form 9 November 2016
Accepted 17 November 2016
Available online 18 December 2016

Keywords:
developing countries,
land use intensification,
pest management,
sustainable agriculture

A B S T R A C T

The transformation of agriculture in lower income countries from subsistence-to market-oriented production systems has important implications for farmers' risk exposure and risk management yet only few studies have paid attention to this. This paper fills this gap and particularly focuses on the role of pesticides in managing the risk from crop pests and diseases, which is major source of risk to farmers. Data were collected for 240 Thai upland farmers stratified by ten levels of agricultural commercialization. The results show that risk perceptions and management strategies are strongly associated with levels of agricultural commercialization. Key strategies for commercial farmers included monitoring market prices, diversifying sales channels and applying large quantities of pesticides, while crop diversification and debt avoidance were more important for subsistence-oriented farmers. High levels of pesticide use at commercial farms were not accompanied by a safer handling practices, as farmers largely neglected pesticide health risks. The results point at the importance of tailored agricultural policies to strengthen farmers' resilience against risk at varying levels of commercialization, rather than following a one size fits all approach.

Introduction

Risk and uncertainty are inherent to agricultural production. In the context of lower income countries, risk and uncertainty are closely linked to vulnerability of farm households to remaining in or falling into poverty. Yet sources of risk and uncertainty are not uniformly spread over all farmers, neither are they constant over time. As farming systems in lower income countries transform from subsistence-to market-oriented production, the sources of risk to which farm households are exposed change (Kahan, 2008). Understanding the change brought about by commercialization is important for policy-makers to better manage the sustainable intensification of agriculture.

Whereas commercialization and land use change in Asia have been widely studied (e.g Pingali & Rosegrant, 1995; Tipraqsa & Schreinemachers, 2009; Vanwambeke, Somboon, & Lambin, 2007; von Braun, 1995), the relationship of commercialization to risk and risk management has received little attention. Most likely this is because commercialization and changes in risk are difficult to study as they require longitudinal data. Some studies have examined commercialization as a driver of farm productivity and rising farm household incomes, partly also

* Corresponding author. Fax: +49 711 459 24248.
E-mail address: suthathip.riwthong@gmail.com (S. Riwthong).
Peer review under responsibility of Kasetsart University.

http://dx.doi.org/10.1016/j.kjss.2016.11.001

considering market risk (Jayne, Haggblade, Minot, & Rashid, 2011; Pandey, 2006; Zeller et al., 2013). Other studies have put a focus on analyzing farmer decision-making under risk (Aimin, 2010; Akcaoz, Kizilay, & Ozcatalbas, 2009; Harwood, Heifner, Coble, Perry, & Somwaru, 1999; Liu & Huang, 2013; Waibel, 1990).

However, the role of risk that farmers face in the process of commercialization and market integration is underappreciated. It is therefore the first objective of this study is to improve the understanding of how risk and risk management of farmers change in the course of agricultural commercialization.

One of the sources of risk of greatest concern to farmers is crop pests and diseases. The unpredictability of pest and disease incidence and resulting crop damage creates much anxiety among farmers. Lack of functioning extension services, absence of pest and disease monitoring systems, and poor levels of education, magnify such anxieties. There is also heightened pest pressure from the introduction of cash crops that are often poorly adapted to farmers' agro-ecological conditions and the simplification of cultivation patterns with widespread mono-cropping. Therefore, in the process of commercialization, farmers turn to using synthetic pesticides, which also become more accessible, to lower their risk exposure and to increase the odds of a good harvest. The second objective of this study thus is to analyze the relationship between commercialization and the role of synthetic pesticides in managing the risk of crop pests and diseases.

The paper starts by describing our methods and data. It then identifies the various sources of risk as perceived by the farmers, shows their main risk management strategies, and shows how these vary with the level of agricultural commercialization. The second part of the results section then concentrates on the role of pesticides in risk management and estimates a regression model to identify drivers of pesticide use. We then discuss our findings and conclude.

Material and Methods

Data

The uplands of northern Thailand are ideal for this type of study because the mountainous terrain creates unequal opportunities for agricultural development within a relatively small geographical area. A few decades ago, rice was the main crop grown virtually everywhere. Yet current land use patterns are much more diverse and include rice alongside many high-value crops such as maize, soybean, vegetables, fruits and flowers (Rerkasem, 1998; Vanwambeke et al., 2007).

We selected three northern provinces for our research: Nan, Chiang Rai and Chiang Mai because they form a north—south axis from the main urban center of Chiang Mai. It appeared logical to assume that opportunities for commercial agriculture increase with the proximity to a major urban center. These provinces have 1,079 rural upland villages. We used secondary data from the Highland Research and Development Institute in Chiang Mai to find a proxy for agricultural commercialization. The best available proxy variable was the average income per adult employed in agriculture. We ranked the villages by this variable and divided them into ten equal segments. We selected the median village from each segment. To represent the extremes, we additionally selected the village at the 25th percentile of the first segment and at the 75th percentile in the last segment. This resulted in a sample of 12 villages of roughly equal size on a spectrum of agricultural commercialization.

We developed a structured questionnaire to collect data on risk perceptions and risk management strategies as well as about farm production and farm household characteristics. The questionnaire was tested in three out-of-sample villages (one subsistence, one semi-subsistence and one commercial village) and refined after each test. Survey data were collected over a five-month period between November 2011 and March 2012, using a 12-month recall period. In each sample village we first conducted a focus group discussion with a small group of farmers and then compiled a list of all households with the village headmen. From this list we randomly selected 20 farm households for an interview.

Respondents were asked to indicate the level of importance of various sources of risk using a 5-point Likert scale ranging from one (not important) to five (very important). Sources of risk were grouped into four categories, including production, market, financial as well as human and personal risk. For each source, respondents were asked to explain how they tried to control it and how effective each of the mentioned control methods were; again, using a 5-point Likert scale ranging from one (useless) to five (very useful). These risk management strategies were initially taken from the literature and refined through the pre-tests and focus group discussions. We also quantified the value of input use and output for each crop. For pesticide use, we recorded the product name and the quantity applied. Secondary data were collected for each pesticide product to convert quantities of formulated product into quantities of active ingredients.

Quantifying Commercialization

Agricultural commercialization was quantified using farm performance indicators as originally suggested by Dillon, Hardaker, and Food & Nations A. O. o. t. U (1993) and later applied by Tipraqsa and Schreinemachers (2009) for a study in northern Thailand. More specifically, we used two indicators: (1) integration into farm input markets, defined as the value of variable inputs bought relative to the total value of variable inputs used on the farm (including seeds, fertilizers, hormones, labor and any other inputs, but excluding pesticides); and (2) integration into farm output markets or marketable surplus, defined as the gross farm output sold as a quotient of the total gross farm output at average farm gate selling prices.

$$\text{Integration into variable input markets} = \frac{\text{Value of variable inputs bought}}{\text{Total value of variable inputs used}} \tag{1}$$

$$\text{Integration into farm output markets} = \frac{\text{Gross farm output sold}}{\text{Total gross farm output}} \quad (2)$$

These two variables were transformed into z scores and then combined additively into a single index, ranging from zero (subsistence farming) to unity (fully commercialized farming). Neither variable was considered more important than the other and were thus given equal weight. As based on terciles of this index, households were classified into three equal groups, of subsistence, semi-subsistence and commercial. This allowed exploring differences between farming systems at distinct stages of commercialization.

For ordinal variables such as Likert scales, we used the non-parametric Kruskal–Wallis test to test if the relationship to agricultural commercialization was statistically significant. For continuous variables, we used a pairwise t-test and Bonferroni post-hoc test. For categorical variables including binary variables, we used a Chi-square test.

Regression Model

Regression analysis was used to identify determinants of pesticide use and to test the hypothesis that agricultural commercialization leads to greater pesticide use. The selected method follows previous studies that have identified determinants of pesticide use (Carlberg, Kostandini, & Dankyi, 2012; Gong, Baylis, Kozak, & Bull, 2016; Rejesus, Palis, Lapitan, Chi, & Hossain, 2009).

The use of ordinary least squares to regress pesticide quantities on a set of household-level determinants would yield incorrect results for two reasons. First, a substantial proportion of farm households practicing subsistence agriculture have not yet adopted pesticides. Partial adoption at the farm-level results in incidental truncation and, possibly, sample selection bias (Baum, 2006). Second, the pesticide use variable for adopters contains excess zeros because some farm households that previously adopted pesticides decided not to use pesticides on certain crops, such as crops used for home consumption (e.g. upland rice and taro), and certain perennial crops that have little pest problems (e.g. coffee and tea). The former problem can be addressed by using a stepwise estimation approach with two sequential equations, the latter by estimating the model at the crop-level. The first equation explains farmers' choice to apply or not to apply pesticides, while the second equation explains farmers' choice about the quantity of pesticides to apply.

Starting with the second equation, the amount of pesticide use is the dependent variable y and reflects the scale of adoption. The vector of strictly exogenous variables that determines y is denoted as x_j, while z_j is the vector of strictly exogenous variables that determine pesticide adoption. Finally, β_j and γ_j are the vectors of the parameters to be estimated and u_{ij} are household specific error terms.

$$y_i = x_j\beta_j + u_{1j} \quad [\textit{regression equation}] \quad (3)$$

The dependent variable is not always observed. For observation j it is observed if,

$$z_j\gamma_j + u_{2j} > 0 \quad [\textit{selection equation}] \quad (4)$$

where,

$$u_1 \sim N(0;\sigma);\ u_2 \sim N(0;1);\ corr(u_1;u_2) = \rho \quad (5)$$

Sample selection bias occurs if $\rho \neq 0$ and a Heckman correction would then be needed to provide consistent and efficient estimates for all the parameters (Baum, 2006). Such procedure would estimate the Inverse Mills Ratio, capturing all observed and unobserved characteristics that affect the probability of pesticide application as well as the choice of pesticide quantity, and then include this in the regression equation (Baum, 2006). However, if $\rho = 0$ then it is sufficient to run a separate probit for sample inclusion followed by a linear regression, referred to as the two-part model (Manning, Duan, & Rogers, 1987).

The model was estimated at the crop level (n = 503) because pesticide decisions are crop-specific. Based on previous studies, e.g. Rahman (2003) and Rejesus et al. (2009), we expected that pesticide use (y_i) is determined by the following variables: household size, age, sex and education of the farm manager, years of experience in each crop grow, farm specialization, labor use, plot size, amount of seed used, the perceived level of pest intensity, perceived level of pest risk (Table 1). To this list we added the level of agricultural commercialization. We note that the pesticide variable was not used to construct the commercialization variable; these variables are hence independent.

Table 1
Variables used in the regression analysis

Variable name	Definition	Sample mean	Standard deviation
Hh size	Household size (persons)	4.57	1.94
Age	Farmer age (years)	41.73	12.13
Male	Person managing the crop is male (dummy)	0.63	0.48
Experience	Experience growing the crop (years)	14.22	12.88
Education	Education higher than primary school (dummy)	0.48	0.50
Subsistence crop	Subsistence crops (dummy)	0.53	0.50
Field crop	Maize or grain legume (dummy)	0.21	0.41
Perennial crop	Perennial crop (dummy)	0.11	0.31
Labor input	Total labor input (person-days/ha/year)	210.42	256.12
Plot size	Area of cultivated land (ha)	1.01	1.14
Seed	Amount of seed and seedling used[a]	1.36	1.98
Med. pest intensity	Medium level of pest intensity (dummy)	0.72	0.45
High. pest intensity	High level of pest intensity (dummy)	0.14	0.34
Pest risk	Perceived level of pest risk[b]	1.52	0.45
Commercialization	Agricultural commercialization index (0–1)	0.46	0.32

[a] Variables for seed and seedlings transformed with cube root and combined

[b] Perceived level of pest risk = level of perceived pest risk (rated by farmers from 1 to 5)/level of perceived risk averaged over all risk sources (rated by farmers from 1 to 5)

Results

Commercialization

Figure 1 plots the level of agricultural commercialization against the relative share of subsistence crops (rice) and cash crops (e.g. vegetables, fruit, flowers). Assuming that we can interpret the commercialization index as a time dimension in our cross-sectional data, it shows that cash crops gradually replace rice at higher levels of commercialization. Yet even highly commercial farms continued to grow rice, which is an important food security strategy for most upland households.

Perceptions and Management of Risk

Commercial and subsistence farmers felt equally exposed to a range of risk factors, including natural disasters, water shortages, credit access, debt repayment, insecure land ownership and livestock diseases and mortality (Table 2). Commercial farmers perceived crop pests and diseases, low crop prices as well as the inability to hire labor as more important sources of risk than subsistence farmers did. For subsistence farmers, on the other hand, the risk of a family member falling sick had a greater perceived influence on farm performance. For all sources of risk combined, as shown in the bottom row of Table 2, commercialized farmers perceived risk to be more important than subsistence farmers.

Table 3 lists the strategies used by farmers to manage these sources of risk. For 9 out of the 17 strategies there appeared to be a significant correlation between the share of farmers using them and their level of commercialization. More subsistence farmers chose crop diversification, storage facility and avoiding debt as strategies to reduce their risk. Significantly fewer commercial farmers chose crop diversification and debt avoidance as a risk management strategy. Significantly more commercial farmers chose to apply pesticides to reduce risk, monitored market prices, did contract farming, diversified sales channels, saved money, and selected crops that were profitable. The results therefore show marked differences in risk management strategies by level of agricultural commercialization.

Farmers were asked to assess the usefulness of each strategy that they adopted to manage the various sources of risk shown in Table 4. For 9 out of the 17 strategies there appeared to be a significant correlation between the perceived usefulness and the level of agricultural commercialization. More subsistence farmers than commercial farmers reported that growing more than one crop, having a storage facility and having many children were useful to them. Significantly more commercial farmers perceived the following as useful: Application of pesticides, diversified market channels, contract farming, monitoring market prices, choice of highly profitable crops, and saving money. The results clearly show that farmers' perception of risk management strategies is correlated to the level of agricultural commercialization.

Higher levels of commercialization are associated with higher levels of income from agriculture, but also with higher levels of farm household debt (Table 5). The ratio of debt-to-income, which reflects the ability to pay back debt, is also higher for the commercialized farms. The table also shows a very substantial increase in the quantity of pesticide use and the in the share of pesticides in total variable input costs. We will analyze this in the following.

Role of Pesticides

Agricultural commercialization is associated with an exponential increase in pesticide use (Figure 2). Yet there is high level of variation in pesticide quantities, which was analyzed using the regression model.

The correlation between the error terms of the equations (1) and (2) was $\rho = .343$, but it was not statistically significant ($p>|z| = .576$). This suggests that sample selection bias is not an issue in our data. It is therefore not necessary to use a Heckman correction and a simple two-part model is sufficient. Multicollinearity was also not an issue in the regression equations as the variance inflation factor was below 3.5 for all independent variables.

The selection model had a goodness-of-fit of 0.31 (pseudo R^2) and the model explaining the quantity of pesticide use had a goodness-of-fit of 0.32 (R^2) as shown in Table 6. The marginal effects in the probit regression suggest that a switch from subsistence to commercial farming

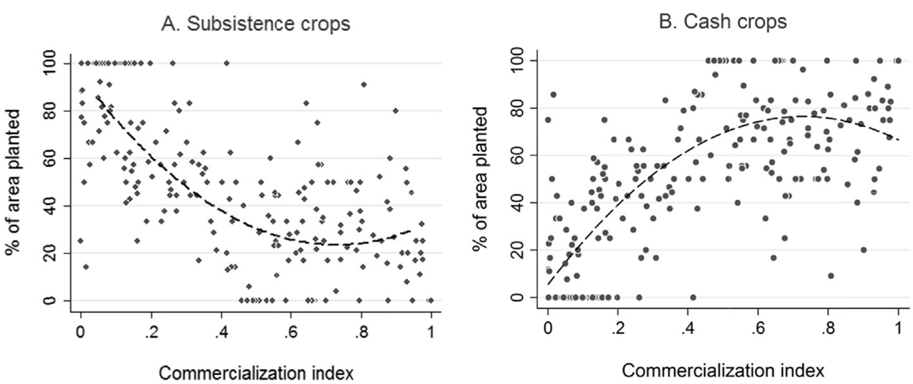

Figure 1 Correlation between the level of agricultural commercialization of farm households and their area share of subsistence crops (left diagram) and cash crops (right diagram) in Thai upland agriculture, 2011 (n = 240)

Table 2
Perceived importance, scaled from 1 (not important) to 5 (very important), of various sources of risk to farm performance by level of commercialization in Thai upland agriculture, 2011

Source of risk[b]	Subsistence (n = 80)	Semi-subsistence (n = 80)	Commercial (n = 80)	*p*[a]
Production risk				
Insufficient water supply	2.34	2.21	2.26	.76
Natural disaster	2.13	2.11	1.94	.64
Crop pests and diseases	2.88	2.69	3.05	.05
Market risk				
Low crop prices	1.40	2.48	3.13	<.01
Being unable to sell produce	1.28	1.28	1.53	.13
Being unable to hire labor	1.05	1.14	1.28	.01
Financial risk				
Being unable to get credit	1.40	1.25	1.43	.82
Ability to repay debt[c]	1.95	1.79	1.91	.86
Human and personal risk				
Losing land ownership	1.53	1.43	1.75	.15
Family member falling sick	3.21	3.06	2.75	.07
Sick or dead livestock[d]	1.45	1.54	1.47	.96
Average all sources	1.87	1.92	2.05	.04

[a] Kruskal Wallis test
[b] Sources of risk were divided into four categories based on Kahan (2008). The mean values in the table refer to a Likert scale from 1 (not important) to 5 (very important)
[c] For farmers having debt
[d] For farmers having livestock

Table 3
Choice of risk management strategies by level of agricultural commercialization for Thai upland agriculture, in % of farmers per category using a strategy, 2011

Risk management strategy	Subsistence (n = 80)	Semi-subsistence (n = 80)	Commercial (n = 80)	*p*[a]
Production risk				
Grow more than one crop	53	26	15	.000
Practice intercropping	45	45	35	.334
Have a storage facility	93	80	88	.065
Use pesticides	31	46	80	.000
Follow GAP/organic standards	3	8	5	.349
Use non-chemical inputs	3	1	3	.815
Use new technologies (innovate)	9	11	19	.146
Market risk				
Diversify sales channels	6	21	41	.000
Do contract farming	0	10	15	.002
Monitor market prices	8	19	46	.000
Financial risk				
Grow highly profitable crop	11	30	41	.000
Family member earns non-farm income	53	58	63	.441
Make budget plan	6	13	13	.327
Avoid debt	53	41	35	.077
Save money	23	40	44	.011
Human and personal risk				
Have many children	26	23	20	.639
Educate children	38	41	34	.619

[a] Chi^2 test

increases the probability of pesticide use by 38%; and the exposure to high pest intensity increases the probability of pesticide use by 23%. The level of perceived pest risk is not a significant determinant of whether or not pesticides are used. The coefficients also show that subsistence and perennial crops are negatively associated with pesticide use while a larger plot size is positively associated with pesticide use.

The right-hand side of the table shows factors that explain the level of pesticide use conditional on households having adopted pesticides on a particular crop. Interpreting the exponentiated coefficient, it can be said that an increase in agricultural commercialization proliferates the quantity of pesticides used by 105% for those households who apply pesticides. The results also show that pesticide risk perception is significantly ($p < .05$) and positively associated with quantity of pesticides used. This confirms that farmers apply greater quantities of pesticides as a strategy to reduce risk.

Contrary to the probit selection model, the OLS regression shows that farmers use a lower application rate if they cultivate larger plots. This is consistent with the idea that smaller plots are cultivated more intensively. The results also show that farmers apply fewer pesticides on subsistence crops than on cash crops. Contrary to the results of the selection equation, a high intensity of pest pressure is

Table 4
Perceived usefulness, scaled from 1 (not useful) to 5 (very useful), of various risk management strategies by level of commercialization in Thai upland agriculture, 2011

Risk management strategy	Subsistence (n = 80)	Semi-subsistence (n = 80)	Commercial (n = 80)	p[a]
Production risk				
Grow more than one crop	2.05	1.45	1.21	.000
Practice intercropping	1.85	1.83	1.58	.641
Have storage facility	3.38	2.96	2.96	.069
Use pesticides	1.64	2.14	2.98	.000
Follow GAP/organic standards	1.05	1.16	1.09	.456
Use non-chemical inputs	1.08	1.04	1.05	.643
Use new technologies (innovate)	1.16	1.20	1.38	.156
Market risk				
Diversify sales channels	1.11	1.43	1.86	.000
Do contract farming	1.00	1.20	1.33	.048
Monitor market prices	1.15	1.35	1.90	.000
Financial risk				
Grow highly profitable crops	1.16	1.55	1.76	.001
Some of family member get non-farm income	2.06	2.10	2.18	.873
Make budget plan	1.16	1.25	1.21	.100
Avoid debt	2.56	2.24	2.10	.151
Save money	1.54	1.84	1.88	.058
Human and personal risk				
Have many children	1.59	1.55	1.35	.059
Educate children	1.48	1.51	1.36	.546

[a] Chi^2 test

Table 5
Pesticide use, agricultural income, pesticide costs and household debt by level of agricultural commercialization for Thai upland agriculture, 2011

	Subsistence (n = 80)	Semi-subsistence (n = 80)	Commercial (n = 80)	Correlation coefficient[a]	*p*[a]
Cash income from agriculture (USD/hh/year)	59	908	3,563	0.37	<.01
Household debt (USD/hh)	299	432	1,020	0.26	<.01
Quantity of pesticide use (kg/ha/year)	2.7	2.8	21.5	0.33	<.01
Share of pesticide cost in total variable cost (%)	3.32	4.18	21.63	0.33	<.01

[a] Pairwise correlation (t-test); n = 240

associated with a higher application of pesticides. Labor use per hectare has a positive and significant effect on the pesticide application rate, which makes sense because spraying is done manually.

It is clear from the above that agricultural commercialization is significantly associated with more widespread use and increasing quantities of pesticides. This trend does not necessarily mean higher levels of pesticide health risks, if farmers are using pesticides in a safe way. However, our results do not show that agricultural commercialization is accompanied by overall improvements in pesticide handling practices (Table 7). There was a significant negative correlation ($p = .001$) between commercialization and the mixing of pesticides as commercialized farms not only used more pesticides but also combined different pesticide products into a single spray. However, there was a significant positive correlation ($p = .010$) between agricultural commercialization and the observance of wind direction during spraying.

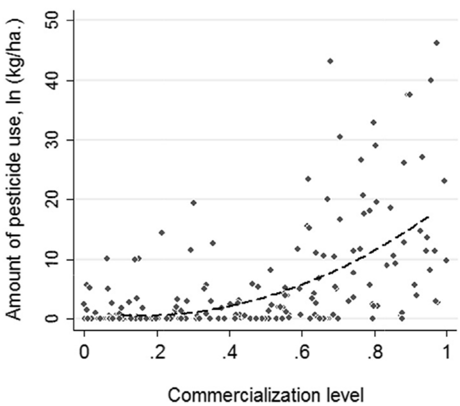

Figure 2 Amount of pesticide use by farm household plotted against the level of agricultural commercialization for Thai upland agriculture, 2011

Discussion

Agriculture inherently is a risky business. This is especially true for developing countries where government support for agriculture is much weaker than in developed countries, with limited public social security guarantees to fall back onto if farm operations fail. Therefore it is important to better understand the sources of risk to which farm operations are exposed. The contribution of this paper is to show that not all farms are equally exposed to each

Table 6
Determinants of pesticide adoption (left equation) and pesticide application rate (conditional on adoption; right equation) for Thai upland agriculture, 2011

Explanatory variables	Pesticide application (probit selection equation)		Quantity of pesticide use, ln(kg/ha)	
	Coefficient	*p*	Coefficient	*p*
Hh size (persons, ln[a])	0.222	.193	0.041	.920
Age (years, ln[a])	−0.053	.838	−0.110	.843
Male farmer (=1)	0.084	.562	−0.203	.539
Experience (years, ln[a])	0.009	.895	0.123	.430
Education (high = 1)	−0.220	.164	0.578	.101
Subsistence crops (=1)	−1.248	.000	−1.784	.001
Maize or grain legume (=1)	−0.470	.131	0.545	.297
Perennial crops (=1)	−2.838	.000	−0.415	.701
Labor input (person-days/ha, ln[a])	−0.129	.111	0.434	.028
Plot size (ha, ln[a])	0.176	.066	−0.417	.067
Seed and seedling[b,c]	0.059	.221	−0.029	.692
Pest intensity (medium = 1)	0.274	.150	0.060	.912
Pest intensity (high = 1)	0.861	.003	0.678	.279
Perceived pest risk[d]	0.013	.929	0.683	.048
Commercialization index (0−1)	1.464	.000	2.356	.000
Constant term	0.806	.508	−3.799	.148
Observations (n)	503		284	
(Pseudo) R-squared	0.313		0.324	

[a] Transformation with natural logarithm (ln) was applied for variables with values > 0
[b] Cube root transformation was used for variables with zero values
[c] Variables for seed and seedlings transformed with cube root and combined
[d] Perceived pest risk = level of perceived pest risk (rated by farmers from 1 to 5)/level of perceived risk averaged over all risk sources (rated by farmers from 1 to 5)

Table 7
Farmers' pesticide handling practices by level of commercialization in Thai upland agriculture, 2011 (in % of respondents using pesticides, n = 159)

Pesticide handling	Subsistence	Semi-subsistence	Commercial	Average	*p*[a]
Follow instructions on the label	56	55	71	62	.137
Observe wind direction when spraying	63	69	87	75	.010
Always avoid contact with skin	81	84	90	86	.192
Take shower immediately after spraying	93	86	81	86	.251
Don't drink during or soon after spraying	88	88	78	84	.274
Don't mix different pesticides	88	69	52	67	.001

[a] Chi^2-test

source of risk and that there is much variation in farm-level decisions on how to manage risk. Most importantly, the study illustrated that risk sources and management are strongly associated with the level of agricultural commercialization.

For farmers who are predominantly subsistence-oriented, personal health is a major source of risk to farm performance, as are factors affecting crop production, such as water supply, natural disasters and crop pests and diseases. Predominantly market-oriented farmers are even more concerned with crop pests and diseases, but also with low crop prices and the ability to hire enough outside labor for their farm. This finding is important for social as well as agricultural policies and shows that a diversity of approaches towards mitigating risks is needed.

To manage risk in subsistence agriculture, farmers use crop diversification and intercropping, try to store enough rice for own consumption on the farm, try to employ household members outside agriculture, and avoid debt. Storing enough food on the farm and employing family members outside agriculture were also important for commercially-oriented farmers. Other key strategies for these farmers included diversification of sales channels, growing crops that are profitable, monitoring market prices, using pesticides and saving money – all of which were only of minor importance to subsistence-oriented farmers. Hence, there are marked differences in risk management by levels of commercialization. Agricultural policies thus need to strengthen farmers' risk management capacities in more than one way. For instance, Thai government agencies could focus on crop diversification in areas where farming is subsistence-oriented, while promoting market diversification in places where commercial farming dominates.

Another key finding of our study is the strong association between agricultural commercialization and the use of pesticides. The average subsistence farm used pesticides at 2.7 kg/ha, while the average commercial farms used 21.5 kg/ha (the global average is about 3.6 kg/ha according to Schreinemachers and Tipraqsa, 2012). We showed that this increase has not been accompanied by a safer use of these chemicals, potentially increasing health risks. Amplified pesticide health risk tends to be neglected or underappreciated by farmers. As a case in point, such hazards were not mentioned as a major source of risk by the farmers during the focus group discussions that preceded the questionnaire survey. It is well-documented that farmers in lower income countries have limited awareness about the risk of pesticides and therefore do not use enough protection (Ngowi, Mbise, Ijani, London, & Ajayi, 2007; Oluwole & Cheke, 2009; Riwthong, Schreinemachers, Grovermann, & Berger, 2015; Snelder, Masipiqueña, & de Snoo, 2008).

The logical conclusion is that the promotion of cash crops such as vegetables, fruit and flowers needs to be accompanied by greater efforts to support alternative methods of pest management and to raise awareness about the negative health effects of pesticides. Our study also found that farmers growing high-value perennial crops, such as tea and coffee, use much less pesticides than seasonal cash crops (0.14 kg/ha for perennials as compared to 24.5 kg/ha for seasonal cash crops), while having a comparable level of income. However, the production of quality coffee and tea requires particular agro-ecological conditions, and is not equally suitable everywhere in the Thai uplands. Production is furthermore prone to supply gluts on global markets; hence farmers face increased market risks.

The findings of this study are relevant to other developing countries, because land use intensification and agricultural commercialization are global phenomena. More detailed policy-oriented studies would be useful to identify policy options that support farmers in their transition to market-oriented production. This study supports the notion that pathways to sustainable agriculture are location-specific. It highlights the consequent need to strengthen local capacities in agricultural research and extension to deal with the challenges rather than formulating a one size fits all policy for all farmers.

Conclusion

Thai upland agriculture is transforming from subsistence-based rice farming to the intensive production of high value cash crops. This process has a profound impact on farmers' risk exposure, perceptions of risk and their choice of risk management strategies. With commercialization, market prices and pests and diseases become the most prominent sources of risk to farm performance. Farmers respond by monitoring market prices, diversifying sales channels and applying large quantities of synthetic pesticides. Crop diversification, on the other hand, tends to become a less important risk management strategy for commercial farms, which might further stimulate pesticide use. Average levels of pesticide use on subsistence farms was 2.7 kg/ha, while commercial farms used 21.5 kg/ha. This rapid increase, under conditions of poor pesticide handling practices, exposes farmers to health risks, which they, however, do not fully recognize. There is a need for a diversified approach to agricultural research and extension that captures the different challenges and opportunities of farmers at varying levels of commercialization.

Conflict of Interest

There is no conflict of interest.

Acknowledgments

This work was supported by Mrs. Edith-Karla Eiselen commemorating her late husband Dr Hermann Eiselen, founder of the Fiat Panis Foundation. Additional contributions from the Deutsche Forschungsgemeinschaft (DFG) for SFB-564 are acknowledged. The second author acknowledges Humidtropics, a CGIAR Research Program that aims to develop new opportunities for improved livelihoods in a sustainable environment.

References

Aimin, H. (2010). Uncertainty, risk aversion and risk management in agriculture. *Agriculture and Agricultural Science Procedia, 1*(0), 152–156. http://dx.doi.org/10.1016/j.aaspro.2010.09.018.

Akcaoz, H., Kizilay, H., & Ozcatalbas, O. (2009). Risk management strategies in dairy farming: A case study in Turkey. *Journal of Animal and Veterinary Advances, 8*(5), 949–958.

Baum, C. F. (2006). *An introduction to modern econometrics using Stata.* Texas: Stata press.

von Braun, J. (1995). Agricultural commercialization: Impacts on income and nutrition and implications for policy. *Food Policy, 20*(3), 187–202. http://dx.doi.org/10.1016/0306-9192(95)00013-5.

Carlberg, E., Kostandini, G., & Dankyi, A. (2012). The effects of integrated pest management techniques (IPM) farmer field Schools on groundnut Productivity: Evidence from Ghana. In *Paper presented at the selected paper prepared for presentation at the Agricultural & Applied Economics Associations 2012 Annual Meeting*.

Dillon, J. L., Hardaker, J. B., & Food, & Nations, A. O. o. t. U. (1993). *Farm management research for small farmer development: Food and Agriculture Organization of the United Nations*.

Gong, Y., Baylis, K., Kozak, R., & Bull, G. (2016). Farmers' risk preferences and pesticide use decisions: Evidence from field experiments in China. *Agricultural Economics, 47*(4), 411–421. http://dx.doi.org/10.1111/agec.12240.

Harwood, J. L., Heifner, R., Coble, K., Perry, J., & Somwaru, A. (1999). *Managing risk in farming: Concepts, research, and analysis: US Department of Agriculture, Economic Research Service*.

Jayne, T. S., Haggblade, S., Minot, N., & Rashid, S. (2011). Agricultural commercialization, rural transformation and poverty reduction: What have we learned about how to achieve this. In *Paper presented at the synthesis report prepared for the African Agricultural Markets Programme Policy Symposium, Alliance for Commodity Trade in Eastern and Southern Africa April*.

Kahan, D. (2008). *Managing risk in farming (Farm management extension guide). From Food and agriculture organization of the United Nations*.

Liu, E. M., & Huang, J. (2013). Risk preferences and pesticide use by cotton farmers in China. *Journal of Development Economics, 103*(0), 202–215. http://dx.doi.org/10.1016/j.jdeveco.2012.12.005.

Manning, W. G., Duan, N., & Rogers, W. H. (1987). Monte Carlo evidence on the choice between sample selection and two-part models. *Journal of Econometrics, 35*(1), 59–82.

Ngowi, A. V. F., Mbise, T. J., Ijani, A. S. M., London, L., & Ajayi, O. C. (2007). Smallholder vegetable farmers in Northern Tanzania: Pesticides use practices, perceptions, cost and health effects. *Crop Protection, 26*(11), 1617–1624.

Oluwole, O., & Cheke, R. A. (2009). Health and environmental impacts of pesticide use practices: A case study of farmers in Ekiti State, Nigeria. *International Journal of Agricultural Sustainability, 7*(3), 153–163. http://dx.doi.org/10.3763/ijas.2009.0431.

Pandey, S. (2006). *Upland rice, household food security, and commercialization of upland agriculture in Vietnam*. Los Banos, Philippines: International Rice Research Institute (IRRI).

Pingali, P. L., & Rosegrant, M. W. (1995). Agricultural commercialization and diversification: Processes and policies. *Food Policy, 20*(3), 171–185. http://dx.doi.org/10.1016/0306-9192(95)00012-4.

Rahman, S. (2003). Farm-level pesticide use in Bangladesh: Determinants and awareness. *Agriculture, Ecosystems & Environment, 95*(1), 241–252. http://dx.doi.org/10.1016/S0167-8809(02)00089-0.

Rejesus, R. M., Palis, F. G., Lapitan, A. V., Chi, T. T. N., & Hossain, M. (2009). The impact of integrated pest management information dissemination methods on insecticide use and efficiency: Evidence from rice producers in South Vietnam. *Applied Economic Perspectives and Policy, 31*(4), 814–833.

Rerkasem, K. (1998). Shifting cultivation in Thailand: Land use changes in the context of National development. *ACIAR Proceedings, 87*, 54–63.

Riwthong, S., Schreinemachers, P., Grovermann, C., & Berger, T. (2015). Land use intensification, commercialization and changes in pest management of smallholder upland agriculture in Thailand. *Environmental Science & Policy, 45*(0), 11–19. http://dx.doi.org/10.1016/j.envsci.2014.09.003.

Schreinemachers, P., & Tipraqsa, P. (2012). Agricultural pesticides and land use intensification in high, middle and low income countries. *Food Policy, 37*(6), 616–626. http://dx.doi.org/10.1016/j.foodpol.2012.06.003.

Snelder, D. J., Masipiqueña, M. D., & de Snoo, G. R. (2008). Risk assessment of pesticide usage by smallholder farmers in the Cagayan Valley (Philippines). *Crop Protection, 27*(3–5), 747–762.

Tipraqsa, P., & Schreinemachers, P. (2009). Agricultural commercialization of Karen Hill tribes in Northern Thailand. *Agricultural Economics, 40*(1), 43–53. http://dx.doi.org/10.1111/j.1574-0862.2008.00343.x.

Vanwambeke, S. O., Somboon, P., & Lambin, E. F. (2007). Rural transformation and land use change in northern Thailand. *Journal of Land Use Science, 2*(1), 1–29. http://dx.doi.org/10.1080/17474230601145943.

Waibel, H. (1990). Pesticide subsidies and the diffusion of IPM in rice in Southeast Asia: The case of Thailand. *Plant Protection Bulletin, FAO, 38*(2), 105–111.

Zeller, M., Ufer, S., Van, D. T. T., Nielsen, T., Schreinemachers, P., & Tipraqsa, P. (2013). *Policies for sustainable development: The commercialization of smallholder agriculture sustainable land Use and rural Development in Southeast Asia: Innovations and Policies for mountainous areas* (pp. 463–490). Springer.