Research article

Forest Ecosystem Services and Agricultural Production of Communities in Protected Areas: A Case Study of Phu Kao - Phu Phan Kham National Park, Thailand

WIPADA JANTA*
Khon Kaen University, Khon Kaen, Thailand
Email: j.wipada19@gmail.com

ADCHARAPORN PAGDEE
Khon Kaen University, Khon Kaen, Thailand

SOMKID UTTARANAKORN
Head of Phu Kao–Phu Phan Kham National Park
Department of National Parks, Wildlife and Plant Conservation, Thailand

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Abstract Forest ecosystems provide goods and services that support our livelihoods. However, forestlands are often cleared for agriculture due to nutrient availability for crop growth. This study examined forest ecosystem services and agricultural practices of three villages at Phu Kao – Phu Phan Kham National Park, northeastern Thailand. A survey on agricultural production and socioeconomics was conducted in June 2016, together with GIS spatial analysis to examine correlations between agricultural productivity and forest-to-farmland distances (FD) and vegetative cover (VC) surrounding farmlands within a 100m radius. We hypothesized that farmlands closer to the forests and/or surrounded by greater vegetative structure would receive more benefits from forest ecosystem services than those farther away. In total, 100 household representatives answered the questionnaire. Cassava was a major cash crop planted with approximately 8.94 tons/ha. Production costs of cassava plantation (i.e., labor and fertilizer) were estimated 24,67.95 Baht/ha, mainly from harvesting costs and chemical fertilizers. Forest-to-farmland distances and VC did not result in significant yields (tons/ha). However, the total production costs of cassava plantations closer to the forest (<1 km) were significantly smaller than those farther away (mean difference = -7,053 Baht/ha, p = 0.007), while VC showed a marginal difference. Farmlands with less VC (<1 ha) resulted in greater total production costs than those with larger VC (mean difference = 2,540.00 Baht/ha, p = 0.073). These findings illustrate that adjacent forests provide ecosystem services to cassava production, at least to some degree. Farmers incur smaller production costs, thereby receiving greater economic returns when their farmlands were closer to the forest and surrounded by larger amounts of vegetation.

Keywords forest ecosystem services, agricultural production, protected areas, Phu Kao – Phu Phan Kham National Park, Thailand

INTRODUCTION

Forest ecosystems provide goods and services such as food, fuel, and other basic necessities of life that support at least half of the world's population (World Resource Institue, 2008). The Millennium Ecosystem Assessment (2005) categorized ecosystem services into four types: supporting, provisioning, cultural and regulating services. Supporting services include biodiversity, soil fertility, nutrient cycling and the provision of water, while pollination, natural pest control and water purification are examples of regulating services and traditional ecological knowledge represents example of cultural benefits. Consequently, forestlands are often cleared for agricultural use because of high nutrient availability, thus making agriculture the main force of deforestation (Lawson, 2014). Reducing the amount of deforestation caused by agriculture is not as simple as asking farmers to stop clearing the land, although it is the cheapest option in the short run. Furthermore, household livelihoods are a higher priority than forest protection. Several studies have shown the benefits of forests over agricultural production (Olschewski et al., 2006; Ricketts, 2004), so farmers can see what has been gained in the conversion process, especially supporting and regulating services e.g., pollination, soil fertility and pest control, in addition to direct provisioning services such as non-timber forest products and potential reserves for agricultural expansion.

Instead of simply asking villagers to stop land encroachment and/or agricultural expansion, this study showed the benefits of forest ecosystem services. It investigated farming practices and household socioeconomic conditions since these factors affect agricultural production. The study was conducted at Phu Kao – Phu Phan Kham National Park (PKNP) in northeastern Thailand. The area attracted some attention because of community settlement inside the park, which is not allowed in protected areas. However, this case was an exception since the villages claimed that they were established before the park was designated. Land conflict between villagers and park authorities continued until the Cabinet Solution in 1998 in which usufruct rights were granted to villagers who were able to prove existence before park designation. Following the 1998 Cabinet Solution, approximately 1,600 ha of protected lands were set aside for agricultural and residential use purposes, together with land use rules and regulations. Moreover, management authority was transferred from the Department of National Parks, Wildlife, and Plants Conservation to local authorities, complicating law enforcement efforts. Rule violations, including land encroachments outside the permitted area, agricultural expansion and plantations of prohibited crops/trees (i.e., para-rubber), can be observed. The PKNP authority recorded at least 21 lawsuits of land encroachments inside the park during 2015. Furthermore, the community has expanded substantially, from small villages of seven to 10 households at the beginning to 528 households in 2015 (Office of Civil Registration, 2015).

OBJECTIVES

This study examined correlations between agricultural productivity, FD and VC surrounding the farmlands. We hypothesized that farmlands closer to the forests and/or surrounded by greater VC would receive more ecosystem benefits than those more isolated (Olschewski et al., 2006; Ricketts, 2004). Therefore, farmers should obtain greater yields and/or incur less costs.

METHODOLOGY

Study Area

The boundary of PKNP, Thailand's 50th national park, crosses three provinces in northeast Thailand (Khon Kaen, Nong Bua Lamphu, and Udon Thani) covering approximately 32,200 ha. The park consists of two main areas, including Phu Kao and Phu Phan Kham. This study took place at Phu Kao (PK), located between latitudes 16° 51' - 17° 1' N and longitudes 102° 24'- 102° 31'E in Nong Bua Lamphu. Phu Kao consists of diverse landscapes, including sandstone mountains, undulating topography, and a vast floodplain of Pong River, creating the Ubonrattana Reservior – the largest dam in the northeast. The major vegetation is dry Dipterocarp forest, covering approximately 80% of PK, followed by mixed deciduous forest and dry evergreen forest. Intermixed within the park are Phu Kao National Forest Reserves, making forest access less restrictive when compared to the national park lands because they are managed by a different agency, the Royal Forest Department. Moreover, approximately 1,600 ha of park lands were set aside for community agricultural and residential use purposes as part of the 1998 Cabinet Solution. These communities include Dongbak, Wangmon and Chaimongkol village. Management authority over this designated area was transferred to local administrative organizations of Nonsang District, Nong Bua Lamphu Province.

Data Collection on Agricultural Production and Household Socioeconomic Conditions

A questionnaire was used to collect data on agricultural production, household socioeconomic conditions, and other relevant information e.g., forest use and villager adaptation to environmental and socioeconomic change. The survey was semi-administered by household representatives (i.e., head of the family, spouse and/or main labors) who were personally interviewed by the researchers. The interview was conducted in the following order: household socioeconomic information, agricultural activities and production, boundary locations of farmlands, crop yields, and production costs. The village leaders were contacted prior to the actual visits, which occurred in June 2016, to inform them of the study and seeking their permission to participate. In total 100 household representatives from all three villages were selected randomly. In addition, personal interviews with the village leaders and onsite observations were performed for confirmation and clarification.

Spatial Data Analysis

In addition to surveyed data, FD and VC surrounding the farmlands were estimated using ArcGIS 10.1. First, household representatives were asked to identify their farm location and boundaries using GoogleEarth images. Midpoint coordinates for each of the identified farmlands were specified for calculation of FD and VC surrounding the farmlands. Calculation of FD were performed using Ruler Tool to measure a distance from each farmland midpoint to the nearest forest. Furthermore, calculation of VC was done using farmland coordinates and images downloaded from GoogleEarth. The coordinate system: WGS1984 UTM Zone 48N was used as referenced data for farmland coordinates and sizes of the actual areas before the dereferencing pointer adjusted the processed images to get accurate coordinates. The farmland midpoint coordinates from Excel were imported into ArcGIS, creating an entire data set of farmland coordinates. Afterwards, shapefiles were created to digitize VC within a 100m radius before reclassification and specification of areas and values of cells. The last stage was to buffer each sampled area within a 100m radius using the Calculate Geometry tool to compute size of VC until the set of farmland coordinates was completed.

Statistical Analysis

Data from the survey and spatial analysis were entered into SPSS version 20 for statistical analysis. Descriptive statistics were used to describe household socioeconomic conditions and their agricultural production activities. Pearson correlations were used to examine socioeconomic factors relating to agricultural production. Finally, independent t-tests were used to compare yields, farm inputs and production costs between farmlands with different FD and surrounding VC. Mean values i.e., 1,000 m for FD and 10,000 m^2 (1 ha) for VC, were used to classify the variables (i.e., yields and production costs) into two groups.

RESULTS AND DISCUSSION

Household's Socioeconomic Conditions

In total, 100 household representatives (36 from Wangmon, 30 from Chaimongkol, and 34 from Dongbak), including village leaders, participated in the survey. Their socioeconomic conditions are shown in Table 1.

Table 1 Socioeconomic information of farmers participated in the study

Socioeconomic conditions	% of respondents			
	Wangmon (n=36)	Chaimongkol (n=30)	Dongbak (n=34)	Summed (n=100)
Gender				
Female	14	11	21	46
Male	22	19	13	54
Main occupation				
Farmer	35	25	34	94
Merchant	1	1	-	2
Government service	-	1	1	2
Hired labor	-	2	-	2
Household income (Baht/year)	141,083	111,340	183,894	135,538
Averaged size of agricultural lands (ha)	2.81	3.77	4.00	3.52

The majority of villagers (98%) earned most of their income from selling agricultural products, essentially cassava; and a small number of them made additional income from selling non-timber forest products (approximately 100 Baht/month). About 57% of participants reported growing rice. This number is small compared to other agricultural-based communities in the northeast, which is nearly 100%. Perhaps this is due to topographic unsuitability for rain-fed rice cultivation, which usually occurs in the lowlands, but the three villages are located on hilly terrain. All villagers indicated growing rice for personal consumption which helped to reduce household spending. However, almost three-fourths (71%) of the farmers faced rice shortage, so they needed to purchase extra amounts for household consumption. The estimated amounts of rice purchased were 392.21 kg/household or approximately 12,855 Baht/household per year.

Land Use and Agricultural Production

Two common cash crops were planted i.e., cassava and sugarcane for income generation. Since sugarcane prices have dropped in recent years while production costs remain high, many farmers have switched to cassava. Only five per cent of the villagers reported planting sugarcane during 2014-2015 crop year, while 98% grew cassava. Rice is cultivated for household consumption rather than income generation. Three farmers (one from each village) reported planting para-rubber trees even though this tree is prohibited to preserve natural forests in the park. High market demands, especially in the past 10 years when the government promoted para-rubber plantations in the northeast, gave villagers economic incentives to plant this tree, despite rules and regulations against it. Although this incident is considered illegal, park officers often compromise to avoid conflict by asking villagers not to expand their plantations.

Average sized farmlands, about 3.52 ha, are mainly used for cash crop plantations i.e., cassava. Average yields of cassava was 8.94 tons/ha, which is much lower than the average provincial yield (21.18 tons/ha) in 2015 (Office of Agricultural Economics, 2015). Total production costs were estimated from explicit costs of labor used in each of the plantation stages, together with costs of fertilizer application, including manure and chemical fertilizers. The average production costs were 24,676.95 Baht/ha. Harvesting accounted for the highest proportion of total production costs (53%), followed by farm maintenance (34%), planting processes (8%) and land preparation (5%) (Table 2). Farming is becoming more market-driven. Cash returns from agricultural activities are thought to be more valuable than subsistence benefits. Therefore, farmers increase crop productivity in an attempt to serve increasing market demands by using more chemical fertilizers and relying on hired labor. Subsequently, production becomes expensive with relatively smaller profits (Bowman and Zilberman, 2013).

Table 2 Production costs of cassava plantation

Process of cassava production	Households samples (n = 94)
Total costs of cassava production (Baht/ha)	24,676.95
1) Land preparation	1,335.15 (5%)
2) Cassava planting	1,853.52 (8%)
3) Farm maintenance	8,391.33 (34%)
3.1) Chemical fertilizer application	5,884.59 (70%)
3.2) Manure application	147.90 (2%)
3.3) Weeding	2,358.84 (28%)
4) Harvesting costs	13,096.95 (53%)

Factors Affecting Farmer Agricultural Production

Farm production depends on both ecological and socioeconomic factors. Ecological conditions e.g., nutrient contents, soil pH and moisture, and amounts of rainfall, directly influence crop growth. Nonetheless, quality of farmlands absolutely relies on farming practices, especially farm maintenance and land conservation. In this study, total production costs, amounts and costs of chemical fertilizers used in cassava plantations showed significant correlations with size of farmlands ($r = 0.363$, -0.247 and -0.241, $p<0.05$, respectively). All farmers reported using chemical fertilizers to help improve crop productivity. The amount and cost of chemical fertilizers varied according to the size of farmlands, which subsequently influenced the total production costs. The larger the planting areas, the smaller the amounts and costs of chemical fertilizers used per hectare. Size of agricultural lands also affected the amount of farm input since farmers can only provide so much labor, fertilizer, and other inputs to maximize crop yields. Nonetheless, average yields did not show significant correlations with total costs, amounts and costs of fertilizers and labor costs. Although farm input directly affected crop productivity, ecological conditions, including climatic and soil factors, also played an important role in determining productivity.

Farm Production Based on Forest-to-farmland Distance and Vegetative Cover

The analysis used to examine if FD influenced agricultural production illustrated that total costs in farm maintenance and total production costs (i.e., labor, manure and chemical fertilizers) of farmlands located closer to the forest were significantly smaller than those farther away (Table 3). Costs of chemical fertilizers showed a marginal difference; cassava plantations closer to the forest resulted in lower costs. Although average yields were not significantly different, they were smaller for cassava plantations with smaller VC, while total production cost and total labor cost were marginally higher for cassava plantations having smaller vegetative cover (Table 3).

To some extent, these findings imply positive contributions or services from the forest to cassava plantations, including the influence of FD on total costs in farm maintenance, total production costs and costs of chemical fertilizers used in planting cassava, and the impact of VC on total production costs and labor costs. However, average yields did not reveal connections with FD and VC because they do not solely depend on farm input, but also from climatic factors and soil conditions. History of landuse, crop rotation and farm maintenance practices directly influence agricultural land conditions and productivity. Longevity of land use, especially continuous use of chemical fertilizers, leads to a decrease in soil nutrients and higher erosion (FAO, 2016; Virto et al., 2015), which in turn, reduces crop yields. Moreover, some studies reveal that VC can hinder crop growth since it could reduce sunlight and other necessary growth factors, causing low productivity of crops (Yasmin et al., 2016; Wang et al., 2012; Cerdan et al., 2012).

Table 3 Comparisons of agricultural production (t-tests) between farmlands with different forest-to-farmland distances and vegetative cover

Group variables	Test Variables	$\bar{x}$ ±SD	Mean Difference	t-test: t	t-test: N	t-test: p-value
Forest-to-farm Distances	1) Costs of chemical fertilizer application (Baht/ha)					
	Zone 1 (0-1,000 m)	5,212±4,216	-1,466.61	-1.726	51	0.088
	Zone 2 (>1,000 m)	6,679±3,966			43	
	2) Total costs in farm maintenance (Baht/ha)					
	Zone 1 (0-1,000 m)	9,805±6,149	-7,063	-2.99	51	0.004*
	Zone 2 (>1,000 m)	16,868±14,379			43	
	3) Total production costs of cassava plantation (Baht/ha)					
	Zone 1 (0-1,000 m)	15,215±7,631	-7,053	-2.77	51	0.007*
	Zone 2 (>1,000 m)	22,269±15,115			43	
Vegetative covers	1) Total production costs of cassava plantation (Baht/ha)					
	Zone A (0-10,000 m^2)	19,273±16,411	2,540.00	0.898	49	0.073
	Zone B (>10,000 m^2)	16,733±9,489			45	
	2) Total labor costs (Baht/ha)					
	Zone A (0-10,000 m^2)	13,712±15,998	3,616.77	1.323	49	0.092
	Zone B (>10,000 m^2)	10,095±9,332			45	

*Note: * significantly different p<0.05, underlined numbers represent marginal difference*

CONCLUSION

There is a strong interdepency between forests and farmers, although it can be difficult to quantify. The forest provides benefits and services that support farmer livelihoods, while its existence depends on farming practices. Increasing demands for food and other types of agricultural products e.g., energy crops, force farmers to expand their production, which in turn, leads to deforestation. Unfortunately, authorities cannot simply ask farmers to stop agricultural practices just to halt deforestation. Therefore, one way to motivate farmers not to expand their agricultural lands into nearby forests is to show how the forests can contribute to their production. This study illustrates that FD and VC influence farm production, at least to some extent. Farmlands close to the forest and/or surrounded by large patches of vegetation benefit from the forest, resulting in lower costs of chemical fertilizers, total costs in farm maintenance and total production costs. Finally, the protected forest in Phu Kao, Nong Bua Lamphu Province is an example to reiterate that it helps provide ecosystem services that improve farmer's agricultural production. Typically, forest protection and agriculture are in opposition, but should be viewed as complementary. Therefore, effective forest protection is beneficial for agricultural production rather than hindering it – a new paradigm to better understand their interconnectivity.

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