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Environmental sustainability of highland agricultural land use patterns for Mae Raem and Mae Sa watersheds, Chiang Mai province

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ABSTRACT

The objectives of this study were: 1) to study the existing highland agricultural land use patterns; 2) to analyze the environmental sustainability of highland agricultural land use patterns; and 3) to determine the optimal highland agricultural land use patterns. Environmental indicators of concern were soil fertility, water quality, and chemicals used in crop cultivation. The results indicated that the 11 patterns in the Mae Raem watershed were: vegetables (45.5%), paddy field/field crops (22.7%), paddy field (12.8%), orchard/vegetables (5.0%), flowering plants (3.0%), orchard (3.0%), field crops (2.0%), paddy field/vegetables (2.0%), paddy field/field crops/orchard (2.0%), field crops/vegetables (1.0%), and paddy field/field crops/vegetables (1.0%). The single pattern in the Mae Sa watershed was vegetables (100.0%). After analyzing the sustainability of the environment at the watershed and village levels, it was found that within the Mae Raem watershed, Ban Pang I Ka and Ban Mae Khi-Pang Hai had very good opportunity to develop to a sustainable level (VGODS; 70.8% and 68.7%), and Ban Nong Hoi Mai had a moderate opportunity to develop to a sustainable level (MODS; 42.3%). In the Mae Sa watershed, Ban Nong Hoi had less opportunity to develop to a sustainable level (LODS; 26.4%). The complete sustainability level (CS; 82.5%) for the environmental sustainability of highland agricultural land use pattern was evident in the Mae Raem watershed, where Ban Pang I Ka had only one pattern, which was field crops that included planting upland rice, maize, peanuts, and kidney beans at the CS level of optimal highland agricultural land use pattern.

Introduction

Highland agricultural land use has mostly converted forest area to agricultural land, which has resulted from a population increase and the limited arable land which is not sufficient to increase yields to meet the food demand. Thus, the worked land has been expanded through forest encroachment and deforestation, which increase every year, especially in the forest region of which most is important as the country's watershed. Due to forest encroachment and deforestation, the forest area in Northern Thailand has been continuously decreasing so that from 1961, when Northern Thailand had 116,275 square km of forest or 68.54 percent of the provincial area, by 1998, this had decreased to 73,057 square km or 43.1 percent of the provincial area. Based on new, revised methods of calculation, in 2000, the forest area was estimated to be 96,270.3

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square km or 56.8 percent of the provincial area. However, in 2005, the forest area in Northern Thailand had reduced to 89,381.0 square km or 47.31 percent of the provincial area, which indicated a continuous trend of forest area reduction (Forest Land Management Bureau, 2014).

The Mae Raem and Mae Sa watersheds in Chiang Mai province also have problems of encroachment and destruction of natural resources and the environment. Forest area removal damages the watershed and affects the quality and quantity of water use in agriculture. Farmers mainly focus on growing economic crops or cash crops with a rapid return, good yield, and supported markets. As a result, farmers must increase inputs such as fertilizers and chemicals which then result in residual chemicals remaining in the soil and water and impacting negatively on the health of the farmers and the watershed environment (Awanasakul, 2001; Randawe, 2001).

Another major problem is that the land use practices adopted by the farmers are not suitable for the capacity of the area. Agricultural land use will likely cause problems with soil erosion, which results in soil degradation (Department of Agricultural Extension, 2000). Extensive disturbance to the natural ecosystem results in the accumulation of diseases and pests including weeds that are difficult to control (Angasithi, 1992). In addition, the majority of farmers are still experiencing problems with cultivation, with some types of plants only providing a single crop annually because they rely on natural rainfall. Consequently, the yield is vulnerable to climate variation and price fluctuations. Thus, the agricultural land use pattern and cropping systems applied by the farmers might not suit the environment. For this reason, The Royal Project Foundation (RPF) and the government has promoted and supported farmers accepting that permanent agriculture practices with continuous crop rotation, as well as prohibiting shifting cultivation, as measures to resolve and prevent intrusive deforestation. Nonetheless, the farmers are still affected by the problem of degradation of natural resources and environment compounded by drought and rain delays that damage crop yields. However, the farmers are able to live with such challenges and the relevant communities and authorities have set up cooperative networks to enhance learning and to promote the conservation of natural resources by the local communities. This involves forest preservation in order to prevent soil erosion and slow down the water flow which typically affect crops and the community. Such networks result in a sustainable environment.

From the statement of the problems and actions mentioned above, the researcher became interested in studying the existing and optimal agricultural highland use patterns as well as the environmental sustainability of agricultural highland use patterns for the Mae Raem and Mae Sa watersheds, Chiang Mai province. This study will help to encourage farmers to better manage permanent agricultural land through applying a pattern of agricultural land use suitable for sustainable production and a sustainable environment. This should result in ceasing the destruction of forests and intrusion into the watershed as a result of shifting or expanding cultivation, as well as helping farmers to broaden production in order to have sufficient food for consumption throughout the year, and to sell the excess to raise income. The outcomes will be self-reliance and sustainable agricultural highland land use.

Objectives of the Study

1. To study the existing highland agricultural land use patterns for the Mae Raem and Mae Sa watersheds, Chiang Mai province.
2. To analyze the environmental sustainability of highland agricultural land use patterns for the Mae Raem and Mae Sa watersheds, Chiang Mai province.
3. To determine the optimal highland agricultural land use patterns for the Mae Raem and Mae Sa watersheds, Chiang Mai province.

Materials and Methods

Materials and Equipment

1. Topographic maps, land use maps and watershed classification maps of the National Environmental Board, series number L 7018, sheet number 4746 I, scale 1:50,000 of the Royal Thai Survey Department.
2. Aerial photographs, scale 1:50,000 of the Royal Thai Survey Department.
3. Equipment for field survey composed of:
   - 3.1 Global Positioning System: GPS, altimeter, and compass
   - 3.2 Distance measurement tape
   - 3.3 Camera
4. Equipment used for Geographic Information System (GIS):
   - 4.1 Computer Program: ArcMap version 9.2
   - 4.2 Digitizer, scanner and printer
5. Interview schedule of household heads or household representatives:
   - 5.1 Respondent profile
   - 5.2 Socio-economic
   - 5.3 Land use
   - 5.4 Environment

Population and Samples

1. Population: the population in this study consisted of household heads or household representatives in the Mae Raem and Mae Sa watersheds, Chiang Mai province. There were 232 households.
2. Samples: multi-stage sampling first identified the study area based on physical characteristics, using the watershed to determine the scope of the study area. Afterwards, villages were selected to represent the study area, using the height above sea level and agricultural land use patterns in the Mae Raem and Mae Sa watersheds, Chiang Mai province. Then the sample was divided using the proportion of the population, in order to have samples which represented the population, resulting in 101 households in the villages of Mae Raem watershed, there were 45 households in Ban Mae Khi-Pang Hai, 33 households in Ban Nong Hoi Mai, and

23 households in Ban Pang I Ka. In the Mae Sa watershed, there were 45 households in Ban Nong Hoi. Thus, the total number of samples used in the study was 146 households.

Data Collection

1. Primary data: new data were collected from original sources directly from the interview schedules of the 146 household heads or household representatives. Afterward, plot sample data from each household were obtained.
2. Secondary data: data which had been collected and studied before was obtained from documents, research reports, statistical data, and geographic data such as maps, satellite photographs, and aerial photographs together with the data on agricultural and forestry policy from the relevant offices such as the Department of Agricultural Extension, Highland Research and Development Institute (Public Organization), the Department of Land Development, the Department of National Park, Wildlife and Plant Conservation, and the Royal Forest Department (RFD).

Data Analysis

Data from all the interviews were analyzed using percentages with the environmental sustainability of highland agricultural land use patterns for the Mae Raem and Mae Sa watersheds evaluated using as indicators of environmental sustainability three variables: 1) soil fertility 2) water quality, and 3) chemicals used in crop cultivation; the variables were arranged in three levels of importance. Group 1 consisted of soil fertility and soil potential in crop cultivation, with a weight of seven. Group 2 consisted of appropriate water quality, with a weight of five. Group 3 consisted of impact awareness of chemicals used in crop cultivation, with a weight of three. The details are provided in Table 1.

Results and Discussion

The results of the study (Table 3) found that the existing highland agricultural land use patterns in the Mae Raem watershed consisted of 11 patterns, including vegetables having very high cultivation patterns (45.5%), with paddy field/field crops, paddy field, and orchard (fruit trees)/vegetables equaling 22.7 percent, 12.8 percent, and 5.0 percent, respectively. Flowering plants and orchard (fruit trees) had equivalent patterns of agricultural land use equaling 3.0 percent. Field crops, paddy field/vegetables, and paddy field/field crops/orchard (fruit trees) had equivalent patterns of agricultural land use equaling 2.0 percent. Patterns of agricultural land with very low cultivation such as field crops/vegetables and paddy field/field crops/vegetables were both 1.0 percent. For the Mea Sa watershed, the single pattern of agricultural land use was vegetables (100%).

From the analysis of the environmental sustainability of highland agricultural land use patterns for the Mae Raem and Mae Sa watersheds, Chiang Mai province, using the indicators of environmental sustainability, the following environmental impacts on the sustainability of the highland agricultural land use were determined as summarized in Table 4:

1. Soil fertility. The study found that the average score of soil fertility in the Mae Raem watershed, consisting of Ban Pang I Ka, Ban Mae Khi-Pang Hai and Ban Nong Hoi Mai, was on average 2.5, indicating that the soil, representative of the three villages, had medium fertility. When considered at the watershed level, it was found that the soil from the Mae Raem watershed also exhibited a medium level of fertility. For the Mae Sa watershed, Ban Nong Hoi had an average soil fertility rating of 1.0, showing that this soil had low fertility, which was the level also assumed for the Mae Sa watershed. The average soil fertility score for both watersheds (Mae Raem and Mae Sa), was 2.1, indicating the soil in these two watersheds had medium fertility. However, FAO (n.d.) suggested that increased soil fertility could be achieved by incorporating legumes (such as groundnuts and beans) to fix nitrogen in the soil. When their green parts and roots rot, the nitrogen released can be used by other crops such as maize, resulting in higher, more stable yields, without the need to apply expensive inorganic fertilizer.
2. Water quality. The study found that the average score for water quality in the Mae Raem watershed for both Ban Pang I Ka and Ban Mae Khi-Pang Hai was 4.0, which was equivalent to the standard of surface water. Secondly, Ban Nong Hoi Mai, which had an average score of 1.0, showed that the water quality there was higher than the standard of surface water, while in the Mae Sa watershed the average score of water quality for Ban Nong Hoi was 1.0, showing that the water quality there too was higher than the standard of surface water. When considered at the watershed level, the Mae Raem and Mae Sa watersheds had an average score of water quality of 2.5, which indicated it was higher than the standard of surface water. Thus, the farmers could use water from various water bodies available as necessary and appropriate.
3. Chemicals used in crop cultivation. The study found that the average score of chemicals used in crop cultivation in the Mae Raem watershed, Ban Pang I Ka had a highest score equal 1.7 of full score 4.0. Followed by Ban Mae Khi-Pang Hai and Ban Nong Hoi Mai, with average scores of 1.2 and 1.0, respectively. In the Mae Sa watershed, Ban Nong Hoi had an average score of chemicals used in crop cultivation of 1.3, showing that most farmers there use chemicals in crop cultivation in order to control diseases, pests, and weeds. Some farmers use chemicals by following the instructions on the label or in the manual attached to the product. Considering overall for the Mae Raem and Mae Sa watersheds, the average score was 1.3, showing that the level of chemicals used in crop cultivation in both watersheds was the same, namely most farmers used chemicals in crop cultivation and some farmers used chemicals by following the instructions in the manual. According to Rerkasem (1995), agricultural chemicals, fertilizers, and pesticides have become

Table 1
Environmental sustainability analysis

Variables	Identification of indicators/ variable	Divided level of score		Grouped according to their importance (score)	
		Level	Score	Group	Weight
Soil fertility (such as: Texture, pH, OM, N, P, K, Ca and Mg)	Indication of soil fertility and soil problems in the area	- Low fertility - Medium fertility - high fertility	1 2.5 4	1 Soil fertility and soil potential in crop cultivation	7
Water quality (such as: NO_3-N and BOD)	Appropriate indicator of water quality and water pollution problems in the area	- Lower than the standard of surface water - Standard of surface water - Higher than the standard of surface water	1 4 1	2 Appropriate water quality	5
Chemicals used in crop cultivation	Showed chemicals used in crop cultivation for farmers, includes before used, while used and after the used of chemicals	- Used chemicals in crop cultivation all the time - Used chemicals by following the instructions in the manual - No use of chemicals in crop cultivation	0 2 4	3 Impact awareness of chemicals used in crop cultivation	3

The possible values ranging from 1% (low sustainability) to 100% (high sustainability) were applied to the level of environmental sustainability, which could be divided into five levels as shown in Table 2

Table 2
Level of environmental sustainability

Level of environmental sustainability	Environmental sustainability (%)
Not sustainable (NS)	1–20
Less opportunity to develop to sustainability (LODS)	21–40
Moderate opportunity to develop to sustainability (MODS)	41–60
Very good opportunity to develop to sustainability (VGODS)	61–80
Complete sustainability (CS)	81–100

Source: Adapted from Forest Research Center (2010)

Table 3
Highland agricultural land use patterns for Mae Raem and Mae Sa watersheds

Watershed	Village	Highland agricultural land use pattern	Highland agricultural land use pattern (%)
Mae Raem	Ban Pang I Ka	Vegetables	45.5
		Paddy field/field crops	22.7
	Ban Mae Khi-Pang Hai	Paddy field	12.8
		Orchard (fruit trees)/ vegetables	5.0
	Ban Nong Hoi Mai	Flowering plants	3.0
		Orchard (fruit trees)	3.0
		Field crops	2.0
		Paddy field/vegetables	2.0
		Paddy field/field crops/ orchard (fruit trees)	2.0
		Field crops/vegetables	1.0
		Paddy field/field crops/ vegetables	1.0
Mae Sa	Ban Nong Hoi	Vegetables	100.0

essential production inputs in the highlands. Hilltribe farmers who have adopted intensive cash cropping are very open to using agricultural chemicals. Therefore, having knowledge on the correct usage of chemicals in terms of amounts and application techniques should be widely distributed to prevent environmental and health hazards spreading from inappropriate use (Thungwa, 2010).

However, the level of environmental sustainability could be divided into five groups (Table 2).

1. The results of the study showed that the group of complete sustainability (CS) with a score of 82.5 percent involved a single cultivating farmer in the Mae Raem watershed in Ban Pang I Ka with the single pattern of agricultural land use including field crops (upland rice, maize (field corn), peanuts (groundnut), and kidney beans).
2. The group with very good opportunity to develop to sustainability (VGODS) scored from 62.5–72.5 percent and consisted of 67 cultivating farmers, all in the Mae Raem watershed comprising 22 farmers in Ban Pang I Ka with 5 patterns of agricultural land use: paddy field, field crops, paddy field/field crops, paddy field/field crops/ orchard (fruit trees), and paddy field/field crops/vegetables and 45 farmers in Ban Mae Khi-Pang Hai with 9 patterns of agricultural land use: paddy field, vegetables, flowering plants, orchard (fruit trees), paddy field/field crops, paddy field/vegetables, field crops/vegetables, orchard (fruit trees)/vegetables, and paddy field/field crops/orchard (fruit trees).
3. The group with moderate opportunity to develop to sustainability (MODS) scored from 47.5 percent consisted of 16 cultivating farmers, with all being in the Mae Raem watershed and all in Ban Nong Hoi Mai with a single pattern of agricultural land use: vegetables.
4. The group with less opportunity to develop to sustainability (LODS) scored from 30.0 – 37.5 percent consisting of 44 cultivating farmers, with 17 in the Mae Raem watershed involving 17 farmers in Ban Nong Hoi Mai with 2 patterns of agricultural land use: vegetables and

Table 4
Score level of environmental sustainability

Height above sea level	Watershed	Village	Score level of environmental sustainability		
			Group 1	Group 2	Group 3
550–800 m	Mae Raem	Ban Pang I Ka	2.5	4.0	1.7
800–1,050 m	Mae Raem	Ban Mae Khi-Pang Hai	2.5	4.0	1.2
1,050–1,300 m	Mae Raem	Ban Nong Hoi Mai	2.5	1.0	1.0
1,050–1,300 m	Mae Sa	Ban Nong Hoi	1.0	1.0	1.3
Grand average			2.1	2.5	1.3

Notes: Group 1 = soil fertility and soil potential of crop cultivation; Group 2 = appropriate water quality; Group 3 = impact awareness of chemicals used in crop cultivation

Table 5
Villages and watershed level of environmental sustainability

Height above sea level	Watershed	Village	ESA (%)	Level of sustainability
550–800 m	Mae Raem	Ban Pang I Ka	70.8	VGODS
800–1,050 m	Mae Raem	Ban Mae Khi-Pang Hai	68.7	VGODS
1,050–1,300 m	Mae Raem	Ban Nong Hoi Mai	42.3	MODS
1,050–1,300 m	Mae Sa	Ban Nong Hoi	26.4	LODS
Grand average			51.8	MODS

Note: ESA = Environmental Sustainability Analysis, LODS = Less opportunity to develop to sustainability, MODS = Moderate opportunity to develop to sustainability, and VGODS = Very good opportunity to develop to sustainability

orchard (fruit trees)/vegetables and 27 farmers in the Mae Sa watershed in Ban Nong Hoi with a single pattern of agricultural land use: vegetables.

5. The group that was not sustainable (NS) scored from 20.0 percent and consisted of 18 cultivating farmers in the Mae Sa watershed in Ban Nong Hoi with a single pattern of agricultural land use: vegetables.

Table 5 shows that at the village level, it was found that the environmental sustainability level of Ban Pang I Ka and Ban Mae Khi-Pang Hai were at the VGODS level (70.8% and 68.7%, respectively), Ban Nong Hoi Mai had the MODS level (42.3%) and Ban Nong Hoi had the LODS level (26.4%). However, at the watershed level, it was found that the level of environmental sustainability of the Mae Raem and Mae Sa watersheds were at the MODS level (51.8%).

Nevertheless, environmental sustainability is crucial to highland agricultural land use patterns, because if farmers are aware of and responsible for the environment, farmers can enjoy a sustainable lifestyle and the environment will return to fertility and further enhance sustainability.

Conclusion

Environmental sustainability of highland agricultural land use patterns in the Mae Raem and Mae Sa watersheds, Chiang Mai province was considered using indicators of environmental sustainability, namely soil fertility, water quality, and chemicals used in crop cultivation. The existing optimal highland agricultural land use pattern is field crops such as upland rice, maize (field corn), peanuts (groundnut), and kidney beans, for which the soil fertility is at the medium level. The water quality has the standard value of surface water and does not require the use of chemicals for fertility and pest control and includes the cultivation of various kind of plants, with crop rotation and repeated continuous cultivation in the same area. Moreover, the agricultural land uses mentioned are controlled and will provide soil improvement benefits through the use of plants for soil improvement and soil conservation including legumes such as peanuts (groundnut) and kidney beans, which have the ability to increase soil nutrients to plants and these plants will help to cover the soil, control droughting and soil temperatures, reduce surface water runoff, and help to balance the ecosystem of the cultivation area of the farmers. Consequently, there is complete sustainability (CS) within the Mae Raem watershed in Ban Pang I Ka. In the Mae Sa watershed, Ban Nong Hoi has an agricultural land use pattern based on vegetables and has less opportunity to develop to the sustainability level (LODS) and remains not sustainable (NS), because the soil fertility is low. The water quality there was higher than the standard of surface water, and also most farmers use chemicals in cultivation, while there are some who sometimes follow the label instructions or the manual attached to the product.

However, agricultural land use patterns with a variety of plants, in conjunction with the suitable cultivation of crops appropriate to the area, will help to reduce soil erosion as well as help to improve the soil production potential and also help the community to enjoy a better environment. As a result, farmers will be able to use the land effectively and permanently without encroaching into the forests searching for new arable land. Furthermore, the existing optimal highland agricultural land use patterns can contribute to the extension and development of highland agricultural land use patterns in other areas, which have the same or similar conditions.

Recommendations

1. Encourage both permanent and rotational use of agricultural land use in order to solve problems of limited

existing cultivation areas and to reduce the risks of poor production. Then, farmers can plant continuously throughout the year, without encroaching on forests or land expanding. As a result, yield and income will be sufficient for a sustainable livelihood.

2. Improve the knowledge of soil and water conservation among farmers, including such techniques as terraced management of soil. In addition, support agroforestry as well as cover cropping. These methods contribute to temperature and humidity control in the soil and reduce soil erosion, thus improving the soil and the environmental balance.
3. Extend appropriate agricultural technology to areas with proper conditions, in order to reduce degradation of natural resources and the environment, such as reducing the build up of chemicals in soil and water bodies. As a result, farmers will be able to plan their planting properly and make effective land use decisions within their area, without having to move or encroach into forest to expand into new arable land.
4. Encourage and support highland agricultural land use patterns which are completely sustainable, including crop rotation, sequential cropping and mixed cropping by using them as examples of how to develop agricultural land use patterns in similar situations. In addition, the promote ways to improve or change the agricultural land use patterns of farmers will lead toward sustainable practices.

Conflict of Interest

There is no conflict of interest.

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