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Transformation of Agroforestry from Invasive Forest to Encourage Food Security to Smallholder Farmers at Maekammee Watershed in Northern Thailand

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The rapid changing area in Yom watershed at Phrae province during 2002 - 2009, half of land using approximately 1.2 million hectare was forest and paddy rice area. On the other hand, a rest of land using approximately 1.1 million hectare was an invasive forest through maize area. The effect of changing land use not only the impact of ecosystem but also impact of socio-economics. Farmers' Maekammee watershed (the subbasin of Yom River) has had an awareness of a lack of water in agriculture. Because of the annual crop is paddy rice in rainy season and less water crops in dry season such as tobacco, maize, soybean, green bean, and vegetables. Farmers interested in agricultural used water planning by brainstorming in community. As researchers have been an awareness of watershed management with them for making suitable crop choice model. Goal was a transform of agroforestry from invasive forest to encourage food security to smallholder farmers at Maekammee watershed in Northern Thailand. We collected data in 2015 from population 11,016 persons in Phrae province by using stratified random sampling of farmers in up-middle-down stream of Maekammee watershed and then using simple random sampling collected 371 samples. Methodology was cost benefits analysis of crop production and Ordinary Least Squares (OLS) by multiple linear programming. We have transformed the agroforestry to smallholder farmers and have followed the results since 2015. The model was maximum net cash income in condition of saving rice for consumption in household. As a result, can get the maximum net cash income 260,189 baht/year. In rain season, the model selected paddy rice: maize which should 0.06: 1.8 hectare from total area 1.86 hectare and own investment 53,048 baht/total area without loan from financial institutes. Family labors had to use 20 manday/month and hired labor in August (planting)-November (harvest) was a few manday. Paddy rice yield was 297.79 kg (seed 27.96 kg: consumption in household 255.99 kg: payment for land rent 13.84 kg) and maize yield was 14,737.99 kg. On the other hand, the model selected planting tobacco: green bean which should 0.62: 1.25 hectare in dry season during December (planting) 5.97 manday to March (harvest) 127.37 manday can get the maximum net cash income was 311,519 baht. Family labor for doing activities on farm and hired labor. Yield of fresh tobacco: green bean were 2,509 and 5,845 kg. Water using was 41.37 48.82 and 21.69 m^3 respectively in December-February. Nevertheless,management of agricultural water usingby brainstorming with farmers, we have suggested to share some plot to be agroforestry. Farmers can reduce risk management of

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agricultural income because they can manage short term income while the tree provide longer-term revenue. Agroforestry can reduce the soil erosion on farm in long term and forest restoration with trees. Meanwhile, the agroforestry crop planning plays the human wellbeing for smallholder farmers in the future.

Keywords: agroforestry, food security, smallholder farmers

Introduction

Yom watershedincludes 11 sub basins, area has 2.3 million hectare.Maekammee watershed is a subbasin of Yom watershed covers 3 districts consists of Muang, Rongwang and Nongmuangkai at Phrae province, area has 45,618.4 hectare(Hydro and Agro Informatics Institute, 2012). As 15,902 households are agriculture area in Makkammee watershed. (Phrae Department of Provincial administration, 2009). The rapid changing area during 2002-2009 (Fig. 1), half of land using in Yom watershed approximately 1.2 million hectare was forest and paddy rice area. On the other hand, a rest of land using approximately 1.1 million hectare (Hydro and Agro Informatics Institute, 2012) was an invasive forest through maize area which the effect of changing land use with ecosystem functions and services not only the impact of ecosystem but also impact of socio-economics of small-holder agriculture.Moreover, increased population pressure on natural resources, which makes low income economies unsustainable (Hayami,1997).The relationship has also been portrayed as as downward spiral, with increasing poverty leading to increasing environmental degradation and hence the situation of both the poor and the environment getting worse and worse (Nunan, 2015).

The situation of annual crop in Maekammee watershed is paddy rice in rainy season and choice of the crop in dry season which less water plants such as tobacco, maize, soybean, green bean, and vegetables etc. (RongKwang District Agricultural Office, 2012) because the lack of agricultural water in dry season. Effects of climate change on agriculture including through changes in rainfall, diseases and pesticides, soil fertility, and the varieties of crops. Farmers' Maekammee watershed has the lack of agricultural water awareness on farm. Therefore, they were an interested in integrated watershed management by community brainstorming for crop planning because plays the management efficiency by themselve (Bach *et al.,* 2011). As well as, a wide variety of arguments have been advanced for increasing the level of participation in environmental decision making. That is, reasons that participation is the right way to make decision regardless of what the content of that decision might turn out to be (Sarkar *et al.,* 2016).

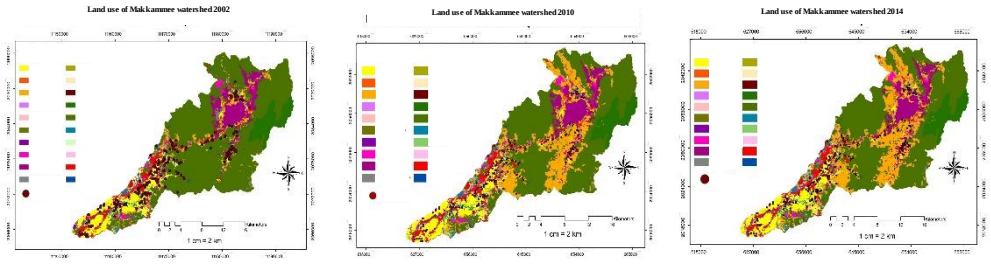

Figure1. Changing land use at Makkammee watershed 2002-2014
Source: The results project

Objectives: to study the transform of agroforestry from invasive forest to encourage food security to smallholder farmers at Maekammee watershed in Northern Thailand because of smallholder have accused of deforestation.

Assumption as the suitable model and participation of smallholder farmers can solve the problem of agriculture to encourage food security by agroforestry at Maekammee watershed (Fig. 2).

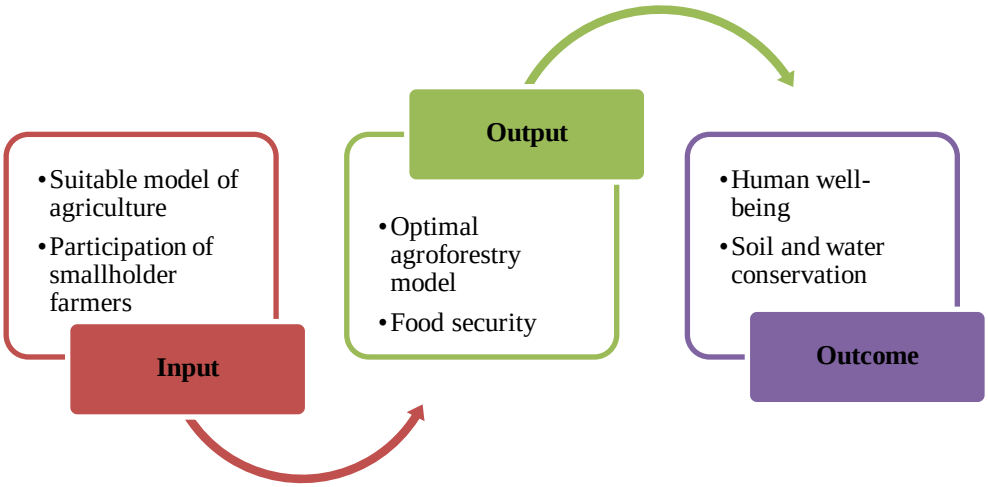

Figure2. Conceptual framework transformation of agroforestry to smallholder farmers at Maekammee watershed in Northern Thailand.

Materials and methods

Materials

Study area in Phrae province consists of upstream (Huayrongsubdistrict, Paitonsubdistrict at Rongkwang district), middle stream (Rongkwangsubdistrict, Thungsrisubdistrict, Rongkhemsubdistrict at Rongkwang district) and downstream (Maekammeesubdistrict, Nongmaugkai district and Maekammeesubdistict, Muang district). We collected data in 2015 from population 11,016 persons by using stratified random sampling of farmers in up-middle-down stream and then using simple random sampling collected 371 samples. Samples size equation by Jaroenwatanan and chunsiriporn, (2011).

$$n = \frac{X^2 Np(1-p)}{e^2(N-1) + X^2 p(1-p)}$$

where n = sample size, N = population, e = statistical errors, X^2 = the chi-squared distribution with k degrees of freedom is less than the significance level (0.05) (X^2=3.841), and p = population proportion (p = 0.5)

Methods

Methodology was cost benefits analysis of crop production in Maekammee watershed and Ordinary Least Squares (OLS) by multiple linear programming.

Net cash income = return – cost

whereturn is cash income of farm production,and costs are cash and noncash expenditures from production which includes in seed, fertilizer,pesticide,labor,and logistic

Multiple linear programming

$$\text{Max } C_1X_1 + C_2X_2 + \ldots + C_nX_n$$

subject

$$a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n \leq b_1$$
$$a_{21}X_1 + a_{22}X_2 + \ldots + a_{2n}X_n \leq b_2$$
$$a_{m1}X_1 + a_{m2}X_2 + \ldots + a_{mn}X_n \leq b_m$$
$$X_n \geq 0$$

whereC_j was income of each activity; j = 1…n

X_j was agricultural activity in Maekammee watershed; j = 1…n

a_{ij} was coefficient of resource i in activityj; i = 1…m , j = 1…n

b_i was resource in condition of each activity ;i = 1…m

Activities

1) Planting (ha) is planting in rainy season and dry season
2) Hired labor (manday) is full family labor working and then model can hire labor for planting or harvesting
3) Loan (baht) is finance institutes which farmers have to payment in 1 year
4) Watering (m^3) is water requirement of each plant
5) Selling is return from farm production all year

Constraints

1) Land (ha) is total agricultural land use of farmers
2) Labor (manday) is full time family labor in household
3) Investment (Baht) is money of farmers for agriculture
4) Loan (baht) is farmers can borrow money from finance institution in condition 1 year
5) Runoff (m^3) is the draining away of water from the surface of an area of land, a building or structure, etc.

Net Present Value (NPV)

In case of rubber in farm, we have to use net present value (Institiute and Faculty of Actuaries, 2013) which period 15 years and NPV>0 shows potential of production,

$$NPV = \left[\sum_{t=1}^{n}\left(\frac{C_t}{(1+r)^t}\right)\right] - I$$

where I = total initial investment costs, C_t = net cash inflow during the period t, r= discount rate, and t = number of time periods

Finally, we share the result to smallholder farmers' Maekammee watershed brainstorming about the optimal crop planning model. Furthermore, the next step to analysis the optimal agroforestry model and have transformed the agroforestry to them then have followed the results since 2015.

Results

Optiaml crop planning model

The crop planning optimization model in agriculture with the results, model selected farm activities in condition of saving rice for consumption in household provided that maximum net cash income. Results demonstrated the suitable model obtain the maximum net cash income 260,189 baht/year. In rain season during August - November, the model selected paddy rice: maize crop

as area 0.06:1.8 hectare from total area 1.86 hectare and own investment 53,048 baht/total area without loan from financial institutes. Family labors had 20 manday/month and hired labor in August (planting) –November (harvest) was 0.61, 2.22, 2.22 and 16.4 respectively with wage 300 baht/manday. Output of agricultural production, paddy rice yield was 297.79 kg (seed 27.96 kg: consumption in household 255.99 kg: payment for land rent 13.84 kg) and maize yield was 14,737.99 kg. However, transfer money from rain season through own agricultural investment dry season was 93,144 baht. No dout, water in agriculture was not a constraint because rainy season has lots of advantages in water.In dry season during December - March, the model selected tobacco: green bean crop as area 0.62: 1.25 hectare so receive the maximum net cash income was 311,519 baht. Hired labor for planting (December) 5.97 manday and harvesting (March) 127.37 manday. Output of agricultural production, yield of fresh tobacco: green bean were 2,509 and 5,845 kg. Water using was 41.37 48.82 and 21.69 m3 respectively in December - February (Table 1).

Table 1. Result of optimal corp planning model

List		**constraint**	**optimum**	slack
Net cash income 260,189 baht				
Rainy season (August-November)				
(1land) hectare(	paddy rice		0.06	
	maize		1.8	
	Total land		1.86	
(2family labor (manday)	August	20.00	20.00	
	September	20.00	20.00	
	October	20.00	20.00	
	November	20.00	20.00	
(3hired labor (manday)	August		0.61	
	September		2.22	
	October		2.22	
	November		16.40	
(4investment(baht)	Owner	65,312.50	53,048.45	12,264.05
	Villager fund	36205.13,	-	
	BAAC	33,954.31	-	
	Co-operation of agriculture	24,848.52	-	
(5yield (kilogram)	Paddy rice selling		-	
	Paddy rice consumption		255.99	
	Paddy rice seed		27.96	
	Paddy rice for land rent		13.84	
Maize selling			14,737.99	
(6Transfer money from rainy season through dry season (baht)			93,144.11	
Dry season (December-March)				

Table 1. (Con.)

(7land (hectare)	Maize		-	
	Maize seed		-	
	Tobacco		0.62	
	Soybean		-	
	Green bean		1.25	
	Chili		-	
(8family labor (manday)	December	20.00	20.00	
	January.	20.00	7.58	12.42
	February	20.00	10.38	9.62
	March	20.00	20.00	
(9hired labor (manday)	December		5.97	
	January		-	
	February		-	
	March		127.37	
(10yield (kilogram)	Maize selling		-	
	Maize seed selling		-	
	Tobacco selling		2,509.41	
	Soybean selling		-	
	Green bean selling		5,845.18	
	Chili selling		-	

Net present value of perennialcrop

Net present valuein period 15 years of perennial crop, similar to compare the income a year because teak wood and rubber have mature tree in 15 years. Net present valueof perennial crop have net cash income of rubber 68,597.78, bamboo 26,548.58, *Melienthasuavis* Pierre 25,731.45, banana 14,518, and teak 3,387.28 baht/year respectively (Table 2).

Table 2.NPV of plant in Maekammee watershed in period 15 years

List	**teak wood**	**banana**	***Melienthasuavis* Pierre**	**bamboo**	**rubber**
Cost (baht/year)	364.65	15,177.82	6,839.47	8,805.23	18,635.54
Income (baht/year)	3,751.93	29,695.82	32,570.91	35,353.81	87,233.42
Net cash income (baht/year)	3,387.28	14,518.00	25,731.45	26,548.58	68,597.78

Output of brainstorming with smallholder farmers

After, we shared the result to smallholder farmers' Maekammee watershed brainstorming about the optimal crop planning model. We have

discussed about it is possibile to be agroforesty system on farm. Therefore, we have been still working the transformation of agroforestry to them and then have been following the results since 2015. As researchers have advised the optimal agroforestry model for making decision the suitable crop and the advantage of requiring low labor between planting and harvest of family labor. A major of agroforestry(Hondrade *et al.,* 2017), alley cropping involves growing field crops between rows of trees that can be grown for teak/rubber/fruit tree, while the alley crops can include a variety of vegetables. The crops provide short-term income while the trees provide longer-term revenue. Thus, the short-term income conform to be rice and mungbean intercropped with rubber have been adopted by farmers. There are other possibilities for incorporating agroforestry systems, with the potential for a range of benefits including increased household food security and wider ecosystem services. Of course, agroforestry has positive effects on soil and water quality (Wilson and Lovell, 2016). Soil quality is improved by increased levels of organic matter, more diverse microbial populations, and improved nutrient cycling, which may increase crop productivity and the ability to cope with drought.

The reason why, we have adjusted the model to be an optimal agroforestry with perennial crop. The result of adjusted the optimal agroforestry model was paddy rice: maize: bamboo: rubber crop as area 0.59: 0.59: 0.55: 0.13 hectare, receive the maximum income 139,625.84 baht/year in the condition of food security.Farmers can decide dpecies of tree on farm as depend on the farmer experiences, agricultural labor of household, water and soil. We had a brainstorming with farmers at Makkammee watershed and they have a good attitude for changing some plot to be agroforestry. To conclude with the optimal agroforestry model have shared information to farmers as we have been following farmers since 2015. Attitudes' farmers have changedfrom intensive farm to agroforestry farm approximately 5 percent from total samples (18 samples). Nevertheless, farmers can reduce risk management of agricultural income because they can manage short term income while the tree provide longer-term revenue. Agroforestry can reduce the soil erosion on farm in long term and forest restoration with trees but agroforestry management has largely failed to protect forest resources when local communitieswere not involved (Suyantoet al., 2005). Eventually, the crop planning plays the human wellbeing for smallholder farmers in the future.

Discussion

Agroforestry for human wellbeing, the result of adjusted agroforestry model have accepted the crop planning as short term and long term.

Agroforestry model was paddy rice: maize: tobacco: green bean: banana: rubber/fruit tree receive the maximum income 139,625.84 baht/year/1.86 hectare accord with household income of farmers' Chiangmai province was 163,968 baht/year/2.53 hectare (Mekanupak and Sreshthaputra, 2016). It depends on agricultural experiences,labor of household, water and rice yield for consumption in household. That conform to the result of Rice (2008) which transformation from intensive farm to be agroforestry have to aware socio-economics value from agroforestry which can serve be human wellbeing. The data here confirm the replacement of mixed cropping with more simplified. In term of agroforestry, defined as the tree such as teak, rubber, bamboo, banana and fruit tree etc. and think of demand as consumers to pay for agricultural production. The timber products at Bolivia of Schneider *et al.* (2016) into farm's certification could enhance the value of timber derived therein. Likewise the productivity of cocoa by-crops in agroforestry systems may contribute to local food security and risk distribution in smallholder contexts. On the contrary, in the condition of rice yield for enough consumption in household per year that play food security of agroforestry system through be a human wellbeing in the long term. In addition, the result of PanpakdeeandLimnirankul, (2017)the developing social-ecological resilience indicators of organic rice production were perspective, indigenous knowledge, infrastructure, practices and skill. On the contrary, northern farmers interested in the sufficient amount of rice yields of household all year. As same as the result of Nissen *et al.* (2001) and Waldron *et al.* (2017) which intercropping timber with food crops in the Philippines uplands becomes more attractive as labor becomes scarcer relative to land, the need to minimize cash inputs becomes more important to farmers, and trees increase in value relative to annual crops. Further the consensus is that need an agriculture that can multi-functionally increase food production while simultaneously enhancing social and environmental goals, as committed to in the sustainable development goals. Agroforestry also increases resilience of crops and farm livelihoods, especially among the most vulnerable food producers. However, conventional yield-enhancement strategies have naturally dominated the debate on food production, hindering implementation of more multifunctional alternatives.

Agroforestry for soil and water conservation, the result of adjusted agroforestry model have advised less water vegetables in dry season because most area of Makkammee watershed have the lack agricultural water problem. The rich farmers can do pumping water from river but it is a high cost of crop.As the same time, poor farmers cannot access the water because of lessmoney for agricultural investment. As well as the result of Fraiture *et al.* (2010), the current situation and the long-term outlook require a fresh look at

approaches that combine different elements such as the importance of access to water for the poor, providing multiple ecosystem services, rainwater management, adapting irrigation to new needs, enhancing water productivity, and promoting the use of low-quality water in agriculture. However, agroforestry can reduce soil erosion which support to the result of Trivino *et al*. (2016), conservation agriculture with trees helps restore the eroded and impoverished soils in the uplands, and consequently increase yields and incomes. It involves minimum tillage, crop rotation and diversification, covering the soil with organic matter or groundcover plants, and integrating trees that anchor the soil and help prevent landslides. The integration of trees also increases soil carbon levels, thus the system plays a role in reducing global warming. The system has helped in stabilizing and building up soils, conserving water, and preventing landslides in the uplands, while increasing food productivity and farmers' incomes (Trivino *et al.,* 2016).

Conclusion

Maekammee watershed is destroyed forest by farmers thus we have advised the optimal agroforestry model to smallholder farmers which the crop provide short term and long term income within the condition of have food security in household. The short term crop support to paddy rice, maize, tobacco, green bean etc. and the long term corp is a fruit tree or timber. Smallholder farmers have satisfied of the optimal agroforestry model. The reason why a few farmers have changed from intensive farm to agroforestry farm because can reduce risk management of agricultural income. Besides, they can manage short term income while the tree provide longer-term revenue. Agroforestry can reduce the soil erosion on farm in long term and forest restoration with trees. Meanwhile, the agroforestry crop planning plays the human wellbeing for smallholder farmers in the future.

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