COST-BENEFIT ANALYSIS OF VETIVER SYSTEM-BASED LAND REHABILITATION MEASURES: LANDSLIDE DAMAGED MOUNTAINOUS AGRICULTURAL AREAS

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I. Introduction

A landslide is a serious geological hazard common to almost every mountainous region in Thailand, particular in the steeply sloping areas. Landslides are typically associated with periods of heavy rainfall, whereas debris flows, sometimes referred to as mudslides or mudflows, are common types of fast-moving landslides. The 23rd May 2006 landslide-debris flow at Lablae, Muang, and Thapra Districts of Uttaradit Province, Northern Thailand, triggered by unusually extremely heavy rain, which was 330 mm per day of rainfall, has seriously damaged both the life and properties. The landslide has killed at least 75 people in Uttaradit while 28 people are still missing (Asian Disaster Preparedness Center, 2006). Lablae District is the most significant agricultural economic zone of Uttaradit province. The mountainous agricultural land in Meaphoon Subdistrict of Lablae District was the worst-hit area by landslide and debris-mud deposition. It was about 370.56 hectare of the high potential areas for agricultural productivity in Meaphoon Subdistrict (Land Development Department, 2006), particularly the mixed fruit three orchard on mountainous and sloping lands, were destroyed by landslides (Fig. 1). Boonyanuphap and Preamprasit (2009) assessed the degree of land susceptibility for landslide in Lablae district using a range of geo-pedological, topographical, and climate factors. Result shows the mountainous areas of Meaphoon Subdistrict were mostly classified as high susceptible area to future landslide (Fig. 2).

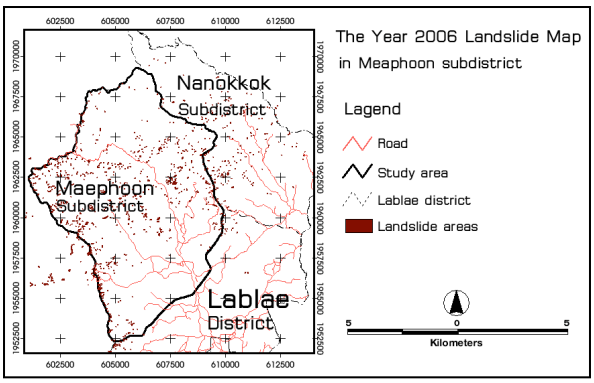

Fig. 1 Map of landslide in year 2006 in Maephoon Subdistrict

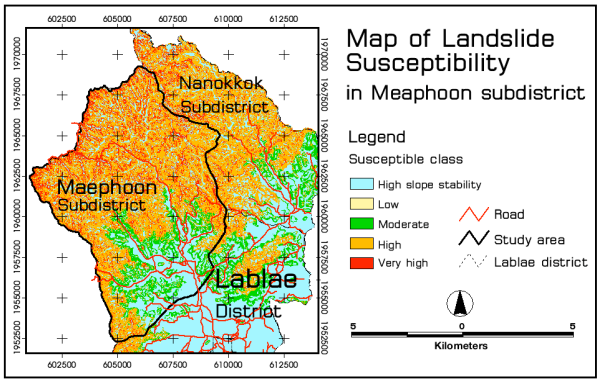

Fig. 2 Map of Landslide Susceptibility in Maephoon Subdistrict

Since the quality and supply of land resource in the areas exposed by landslide has completely changed on agricultural and other purposes, local people's awareness and understanding of landslide impacts and its consequences (soil erosion and sediment deposition) must be carefully created and managed. Soil erosion of landslide areas not only mainly leads to lowering soil productivity, but also high level of sediment in waterways at downstream region, which might caused the periodic flooding events because of silt and sand covered waterways. Although there are some fruit tree orchards in the landslide areas remaining productive, the loss of vegetation cover could result in a rapid movement of

surface runoff and sediment. The land rehabilitation in the agricultural areas damaged by landslide would be more favorable to maintain fruit tree productive lifespan and water available for irrigation and potable water used in the communities of both upstream and downstream areas. Therefore, the proper methods of land rehabilitation are urgently needed to be assessed for seeking the intervention measures of soil erosion control that would be most suitable and practical for their community.

It is still not clear which land rehabilitation measures that the local communities might be willing to adopt, since each method has its own advantage and disadvantages, which some methods provide extra income, but some need more management or higher investment. Various highly efficient methods for land rehabilitation controlling soil erosion must be examined to generate basic information needed for problem-solving. The cost-benefit analysis (CBA) is one of the most effective tools widely used to compare the impacts and social welfare of various options. Thus, the specific objectives of the research project are to undertake the cost-benefit analysis (CBA) of landslide rehabilitation measures under intervention options and status quo, and to determine the best intervention measure for landslide rehabilitation in the mountainous agricultural area.

2. Materials and Methods

2.1 Defining the stakeholder

The stakeholders were defined as a party in land rehabilitation and were categorized into two sets of stakeholder groups. There are **(1) on-site stakeholders** (Upstream), which consist of residents in Meaphoon Subdistrict, land owner who are not residents, local administrative offices, and social groups in Meaphoon Subdistrict, and **(2) off-site stakeholders (Downstream),** which consist of downstream recipients land rehabilitation and potential landslide damage. The upstream is a region of Meaphoon Subdistrict, where land rehabilitation measures are considered. While, the downstream is a region outside Meaphoon Subdistrict in the same watershed.

Stakeholder analysis was done by brainstorming from on-site stakeholders and researchers to investigate the levels of power/leadership, impact of this research project, and knowledge of land rehabilitation. To assess a better understanding of socio-economic impacts of landslide on the sets of stakeholders, a questionnaire was designed to collect a socio-economic data whereas current land use data of stakeholder communities were obtained from field survey and interview associated with secondary data collection.

2.2 Defining the measure options of rehabilitating areas worse-hit by landslide

The three measure options for land rehabilitation and soil erosion control were designed considering a concept of the vegetative-based methods. The measures mainly use the vetiver grass (*Chrysopogon zizanioides* L. Roberty) for controlling soil erosion, and use legume plants for soil fertility improvement, whereas fruit seedling can be planted with vetiver grass and legume plants as the intercropping to get an annual income. These measure options were as follow:

(1) Measure 1: Planting of the vetiver grass with constructions of waterway. The land will be naturally rehabilitated for 7 years. Thereafter, the land will be prepared for plantation of economic fruit trees (durian seedling).

(2) Measure 2: Planting vetiver grass with intercropping of fruit seedling and legume plants, and constructions of waterway throughout 20 years of project period.

(3) Measure 3: Planting vetiver grass with intercropping of fruit seedling and bananas, and constructions of waterway throughout 20 years of project period.

(4) Measure 4 (Status quo): Rehabilitation of land resources is naturally occurred by native pioneer plants. The land will be naturally rehabilitated for 7 years. Thereafter, the land will be prepared for plantation of economic fruit trees (durian seedling).

2.3 Listing of costs and benefits and potential impacts

The lists of costs and benefits can lead to well-designed questionnaire with reliability and validity. The costs and benefits were listed based on interviewing information from key stakeholders and reviews of documents, literature and article. Consequently, the list of costs and benefits can vary among measure options (Table 1). Assumption was made over the timing of the costs (investment or input) and benefits.

Table 1 List of costs and benefits of measures for land rehabilitation with project timeframe of 20 years

List of costs and benefits	Measure options			
	1	2	3	4
Costs				
• Cost of weeding and equipment rent	✓	✓	✓	✓
• Costs of waterway construction	✓	✓	✓	-
• Cost of vetiver grass	-	-	-	-
• Wage of vetiver grass planting	✓	✓	✓	-
• Costs of planting pit preparation for durian seeding	✓	✓	✓	✓
• Costs of basal fertilizer for durian seedling planting	✓	✓	✓	✓
• Wage of basal fertilizer application for durian seedling planting	✓	✓	✓	✓
• Costs of fertilizer applied throughout the year	✓	✓	✓	✓
• Wage of fertilizer application throughout year	✓	✓	✓	✓
• Costs of durian seedling and planting wage	✓	✓	✓	✓
• Costs of sunnhemp and planting wage	-	✓	-	-
• Costs of watering, weeding, and maintenance after planting	✓	✓	✓	✓
• Wage of durian harvest	✓	✓	✓	✓
• Costs of banana corm and planting wage	-	-	✓	-
• Wage of banana harvest	-	-	✓	-
• Wage of banana removal	-	-	✓	-
• Cost of removing sediments in drainage or streams	-	-	-	✓
• Loss of soil fertility (Surface layer; 0-5 cm. depth)				
• Nitrogen (N)	✓	-	-	✓
• Phosphorus (P)	-	✓	✓	✓
• Potassium (K)	✓	-	-	✓
• Soil organic matter (SOM)	-	-	-	-
Benefits				
• Increase in soil fertility (Surface layer; 0-5 cm. depth)				
• Nitrogen (N)	-	✓	✓	-
• Phosphorus (P)	✓	-	-	-
• Potassium (K)	-	✓	✓	-
• Soil organic matter (SOM)	✓	✓	✓	✓
• Banana yield	-	-	✓	-
• Durian yield	✓	✓	✓	✓

2.4 Questionnaire design and implementation

The questionnaire was designed based on the important required data for cost and benefit analysis (CBA) which listed costs and benefits were mainly concerned. This obtained from brainstorming of stakeholders and researchers by group discussion. The questionnaire consists of information about the status of household boss and economical state and the social of example household, information of plant species selected for land

rehabilitation, information on costs of soil erosion control, soil fertility improvement, and land rehabilitation. The cost-benefit analysis (CBA) was employed to compare the options for rehabilitating upstream area which have been worse hit by landslide. To illustrate the effectiveness of land rehabilitation and soil erosion control, this study estimated the costs against the benefits of land rehabilitation by comparing among three options of land rehabilitation for the open space of slopping agricultural land affected by landslides.

2.5 Quantifying and Monetization of the outputs and impacts

In general, the changes in environmental quality and the costs of input used for implementing the soil erosion control was estimated to predict the magnitude of all outputs and impacts in terms of measurable units over the project life of a particular option measures. There were some impacts that cannot be measured or quantified in physical units such as losses of soil fertility. All outputs and impacts were then put in monetary terms so that the costs and benefits can be compared in common units. Conversions of market prices to social values were needed in order to reflect true economic value. Market prices and wage rates were used to value the change in agricultural productivity and the cost of planting, respectively. While, some impacts were not appropriate to be monetized using market prices or wage rates, thus the shadow prices or preventive expenditures method were used instead to assess the net costs and benefits. Additionally, the opportunity cost of farmers' labor was not different during different seasons.

2.6 Discount benefits and costs to obtain present values

The future benefits and cost are discounted relative to present benefits and costs. Since, the selection of the discount rate is the most important decision made during the valuation process. The values of the costs and benefits during the 20 years of the project period are discounted to get the present values. The discount rate of 6% was used as based case in this study. The present benefits and costs are calculated from the following equation:

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} \quad ;$$

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t}$$

Where: B = benefits; C = costs; i = discount rate; t = project period (1–n years)

2.7 Calculation of the net present value (NPV) of each option measures

The sum of discounted benefits and costs of the different option measures were compared. The result of the appraisal was presented in the forms of Net Present Value (NPV). The most effective measure for soil erosion control was judged according to highest positive NPV. Additionally, the alternative option measures could be considered in case of the NPV of social welfare is positive and B/C ratio is greater than 1. The NPV was calculated from the following equation:

$$NPV = PV(B) - PV(C) = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t}$$

Where: B = benefits; C = costs; i = discount rate; t = project period

2.8 Performing sensitivity analysis

This step attempts to deal with uncertainty about the magnitude of the impacts we predict and their monetary value. Sensitivity analysis was performed with respect to identified uncertain variables such as increase of raw material price and uncertain conditions of climate for agriculture. The discount rates of 3%, 8%, and 10%, which might allow the risk in the future cash flow stream, were used for sensitivity analysis.

2.9 Policy implication

The appropriate recommendations on the most efficient measure for land rehabilitation will be provide to Maephoon community. Therefore, the adopted option measure with the highest positive NPV will be needed to consider by Maephoon Subdistrict administration office (SAO) for the process of public policy making. Nevertheless, other options can be considered with providing some recommendations.

3. Results and Discussion

3.1 The Stakeholder Analysis

The criteria used for stakeholder categorization were power/leadership level, impact level, and knowledge level of land rehabilitation. The list of stakeholders is shown in Table 2. The result of stakeholder analysis shows that the level of power and leadership was different in each set of stakeholders. Chief executive and administrative persons of Maephoon Subdistrict administration office (SAO), members of the SAO Council, and Mayor of municipality of Hua Dong who directly are influent to policy making process in land rehabilitation. The research project will positively affect this group of stakeholders with high degree, particularly in term of politics. However, by interviewing, it turned out mostly that this high influent group has moderate knowledge in land rehabilitation. Therefore, to implement the appropriate measures resulting from this research project to land rehabilitation practically and successfully this set of stakeholders were chosen as key persons for in-depth interviewing the questionnaire, thereafter. These stakeholders will be provided more information regarding landslide and land rehabilitation to enhance their knowledge before being performed the interviewing for choosing the suitable measures in land rehabilitation.

Chiefs of Subdistrict and villages and social group leaders have degree of power on policy making, positive impact from research project and knowledge of land rehabilitation were classified into medium level. Thus, they were not chosen as key stakeholder group. Nevertheless, they will be interviewed by questionnaire due to this stakeholder group has strong influence on attitude of local communities whether to accept the implementation of project output. Most of on-site stakeholders are land owner and farmers in Maephoon who hold the least power and leadership for policy making process. They have been suffering from landslide impact since year 2006. Therefore, land rehabilitation can highly positively impact to socio-economic situation, quality of life, and environmental conditions. Some of this stakeholders group has much knowledge in land rehabilitation, while some have less knowledge. Due to they are majority community of on-site stakeholders together with high degree of impact this group of stakeholder are chosen as another key informant in this study.

Lastly, local scholars are one of the on-site stakeholder who possess good knowledge in land rehabilitation, even though they have rare opportunity to be involved in policy making and be less affected from the research output. However, since the local scholars can provide well understanding of real local environmental condition, their recommendation would be well considered. Population of off-site stakeholders are greater than on-site stakeholders but the power of policy making is less comparing with that of

administrative persons of on-site stakeholders. In case of off-site region, executive persons, communities, farmers and Lablae agriculture office were moderately to highly affect from the project. They have low-moderate level of knowledge in land rehabilitation except Lablae agriculture office. In this study communities and farmer in downstream region are, however, identified as key informant. Lablae agriculture office has task to provide information, knowledge and public service concerning land uses and management in agricultural purposes. Some duty of Uttaradit land development office is set similarly as of Lablae agriculture office. These above mentioned offices are not identified as key stakeholder in this study because they have no any terms of authorization in protected upstream region where all landslides occurred.

Table 2 Stakeholder analysis result

Stakeholder group	power/leadership level	impact level		knowledge level
		Positive	Negative	
On-site stakeholders (upstream)				
1. Chief executive and administrative persons of Maephoon Subdistrict administration office (SAO)	High	High	-	Medium
2. Members of the SAO Council	High	High	-	Medium-High
3. Mayor and administrative persons of municipality of Hua Dong	High	High	-	Medium
4. Subdistrict and village chiefs	Medium	Medium	-	Medium
5. Social groups leaders	Medium	Medium	-	Medium
6. Land owner and Farmers in Maephoon	Low	High	-	Low-Medium
7. Local scholars	Low	Low	-	High
Off-site stakeholders (downstream)				
1. Chief executive and administrative persons of Subdistrict administration office in downstream regions	Medium	Medium	-	Medium
2. Communities in downstream regions	Low	High	-	Low-Medium
3. Farmers in downstream regions	Low	Medium-High	-	Low-Medium
4. Lablae Agriculture Office	Medium	Medium	-	High
5. Uttaradit Land Development Office.	Medium	Low	-	High
6. Local researcher, academic and journalist in Uttaradit Province	Low	Low	-	Medium

3.2 Defining the measure options of rehabilitating areas worse-hit by landslide

The measures options were designed according to the result of knowledge and experience sharing from brainstorming among researchers and key stakeholders. The detail of each measure is shown as follows.

- Measure 1: Planting of the vetiver grass with constructions of waterway. The Planting vetiver grass space is 5 cm with the row space of 4 m. Number of vetiver grass is 760 grasses per planting row. Total vetiver grass per Rai (1 Rai = 0.16 hectare.) are 8,360 grasses. Size of water way on both sides of the plot is one meter wide and 50 cm. deep. The land will be rehabilitated for 7 years. Thereafter, the land will be prepared for plantation of economic fruit trees (durian seedling).
- Measure 2: Planting of vetiver grass with intercropping of fruit trees (2 years durian seedling) and sunnhemp (*Crotalaria juncea*), and constructions of waterway. The planting space of durian seedling is 8 by 8 m. (25 durian seedling per Rai). Vetiver grass is planted in half sphere shape with top opened to trap soil sediment and water outside the fruit canopy. The space between vetiver grass and durian seedling is 2 m. Sunnhemp is seeded in which space between seeding and rows of fruit seedling is about 4 m. Size of water way on both sides of plot is one meter wide and 50 cm. deep.

- Measure 3: Planting of vetiver grass with intercropping of 2 years durian seedling and bananas (*Musa sapientum* Linn), and constructions of water ways. The planting space of durian seedling is 8 by 8 m. (25 durian seedling per Rai). Planting vetiver grass in half sphere shape with top opened to trap soil sediment and water outside the fruit canopy. The space between vetiver grass and durian seedling is 2 m. Bananas is planted in parallel row with durian seedling in which planting space of 2 m. and space between durian seeding and rows of banana is about 4 m.
- Measure 4 (Status quo): Rehabilitation of land resources is naturally occurred by native pioneer plants such as *Nephelium melliferum* Gagnep, cogon grass, wild banana, bitter bush, *Colona auriculata* (Desf.) Craib, and bamboo grass. The land will be naturally rehabilitated for 7 years. Thereafter, the land will be prepared for plantation of economic fruit trees (durian seedling).

3.3 Rehabilitation measures chosen by the respondents

The questionnaires designed based on the important required data for cost and benefit analysis were performed with 156 on-site and 52 off-sites stakeholders. The proportions and reasons of choosing rehabilitation measures were shown in Table 3. The stakeholder can be finely categorized in to 7 subgroups in On-site stakeholders and 6 subgroups in Off-site stakeholders as shown in Table 2. It was found that group of high power/leadership persons, consisting chief executive, administrative persons, SAO Council members and chiefs of Sub district and villages, agree that Measure 3 is the most appropriate rehabilitation (about 50%). While 25% of this correspondent group chose the Measure 2. The reasons declared were mostly because of local availability, cash benefit and multipurpose uses of banana. Moreover, the Measure 2 and 3 can provide them the income benefit with low investment cost from fruit trees. Nevertheless, due to less knowledge of uses of vetiver grass and sunnhemp and no demonstration of rehabilitation in severe landslide damaged areas the respondents did not choose the Measure 1 and instead, Measure 4 was chosen. By consideration the highest proportion of On-site stakeholder which is land owner and farmers in Maephoon (non-member of any social groups), chose Measure 3 as the best option to rehabilitate the damaged land (63%). Similar to the reasons given by the previous stake holder group banana is multi purposes plants for household uses and alternative income source during rehabilitation period. Moreover, they have knowledge of using banana as a nursing plant for fruit seedling and utilization of vetiver grass for soil erosion control.

The result also shows that the local scholars, voluntary soil doctor and community-based volunteer groups for landslide monitoring and early warning, who have more knowledge and experience on sloping land rehabilitation was happened to choose Measure 3, as well. The additional reasons rather than mentioned above was banana can increase soil moisture and organic matters. In addition, investigation was also performed with Off-sit stakeholder and it was found that high power/leadership persons and policy makers, farmers and land owners chose the Measures 3 with the major reason of banana availability and benefits. Contradictory, Land Development officers chose Measure 1 and 2 as the most appropriate options because they have high knowledge and professional experience on using *Crotalaria juncea* for nitrogen fixation and vetiver grass for soil erosion control. However, Lablae Agriculture officers and local researchers in Uttaradit Province agree that Measure 2 and Measure 3 can be the best measures for Maephoon area. This due to *Crotalaria juncea* can increase nitrogen content, banana help to increase soil moisture and organic matters, and combined planting of vetiver grass and *Crotalaria juncea* can improve soil fertility and control soil erosion.

Table 3 The proportions and reasons of choosing rehabilitation measures among stakeholder group

Stakeholder group	Number of respondents (%) Measure options 1	2	3	4	Total	Reasons
On-site stakeholders (upstream)						
1. Chief executive and administrative persons of Maephoon Subdistrict administration office (SAO)	0 (0)	1 (25)	2 (50)	1 (25)	4	• Banana is locally available • Banana is multi purposes plants for household uses • Cash benefit from banana products • Less knowledge of vetiver grass and *Crotalaria juncea* utilization • Proposed measures cannot rehabilitate severe damaged area • Growing fruit tree can gain income benefit with low investment cost
2. Members of the SAO Council	0 (0)	3 (27.27)	6 (54.55)	2 (18.18)	11	
3. Mayor and administrative persons of municipality of Hua Dong	1 (25.0)	1 (25.0)	2 (50.0)	0 (0.0)	4	
4. Subdistrict and village chiefs	1 (8.33)	3 (25.0)	6 (50.0)	2 (16.67)	12	
5. Social groups leaders and members	7 (15.22)	5 (10.87)	25 (54.35)	9 (19.57)	46	• Banana is potential nursing plant for fruit seedling • Cash benefit from banana products • Banana is multi purposes plants for household uses • Obtained knowledge in utilization of vetiver grass for soil erosion control • *Crotalaria juncea* is nitrogen fixation plant, which can increase nitrogen in soil • Easy to plant *Crotalaria juncea* on sloping area • Proposed measures cannot rehabilitate severe damaged area
6. Land owner and Farmers in Maephoon (non-member of any social groups)	12 (18.75)	4 (6.25)	40 (62.5)	8 (12.5)	64	• Banana is potential nursing plant for fruit seedling • Cash benefit from banana products • Banana is multi purposes plants for household uses • Obtained knowledge in utilization of vetiver grass for soil erosion control
7. Local scholars	1 (6.67)	3 (20.0)	11 (73.3)	0 (0)	15	• Banana can increase soil moisture and organic matters • Banana is potential nursing plant for fruit seedling • Cash benefit from banana products • Banana is multi purposes plants for household uses • *Crotalaria juncea* is nitrogen fixation plant, which can increase nitrogen in soil • *Crotalaria juncea* can grow as weed control plant

Table 3 The proportions and reasons of choosing rehabilitation measures among stakeholder group (continued)

Stakeholder group	Number of respondents (%) Measure options 1	2	3	4	Total	Reasons
Off-site stakeholders (downstream)						
1. Chief executive and administrative persons of Subdistrict administration office in downstream regions	0 (0)	1 (33.33)	2 (66.67)	0 (0)	3	• Banana is locally available • Banana is multi purposes plants for household uses • Cash benefit from banana products • Easy to plant *Crotalaria juncea* on sloping area • Growing fruit tree can gain income benefit with low investment cost
2. Communities in downstream regions	1 (10.0)	1 (10.0)	2 (20.0)	6 (60.0)	10	• Less benefit can be obtained land rehabilitation • Cash benefit from banana products
3. Farmers in downstream regions	7 (23.33)	2 (6.67)	17 (56.67)	4 (13.33)	30	• Banana is locally available • Banana is multi purposes plants for household uses • Cash benefit from banana products
4. Lablae Agriculture Officers	0 (0)	1 (33.33)	2 (66.67)	0 (0)	3	• High knowledge of utilization of *Crotalaria juncea* for nitrogen fixation • High knowledge of utilization of banana used as nursing plant for fruit seedling and increase soil moisture and organic matters
5. Uttaradit Land Development Officers	1 (50.0)	1 (50.0)	0 (0)	0 (0)	2	• High knowledge of utilization of *Crotalaria juncea* for nitrogen fixation • High knowledge of utilization of vetiver grass for soil erosion control
6. Local researcher, academic and journalist in Uttaradit Province	0 (0)	2 (50.0)	2 (50.0)	0 (0)	4	• Planting vetiver grass with soil building plants can improve soil fertility and control soil erosion. • Planting vetiver grass with banana provide economical and environmental benefits
Total	31 (14.9)	28 (13.46)	107 (56.25)	32 (15.38)	208 (100)	

Note: Measure 1: planting of the vetiver grass with constructions of waterway; Measure 2: planting of vetiver grass with intercropping of fruit trees and sunnhemp, and constructions of waterway; Measure 3: Planting of vetiver grass with intercropping of fruit trees and bananas, and waterway constructions; Measure 4: Status quo (natural rehabilitation)

Interestingly, the result also shows that choosing rehabilitation measures by 208 samples is gender independent (Pearson Chi-Square; $p>0.05$). Most of male and female respondents were happened to choose the Measure 3 as the most potential approach for land rehabilitation (Fig. 2). This support strongly that benefit in terms of income and multipurpose uses particularly, from additional banana yield would be the main reason for choosing land rehabilitation measure.

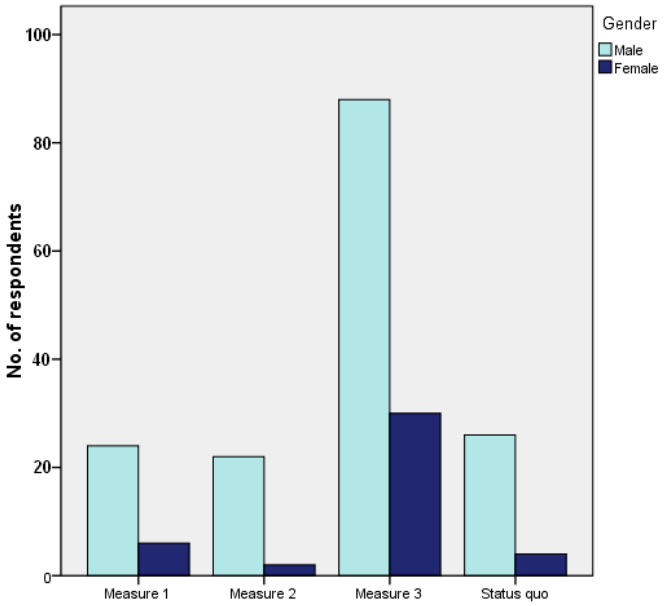

Fig 2. Rehabilitation measures chosen by 208 respondents based on gender.

3.4 Quantifying costs and benefits

Generally, cost and benefits was quantified using the responses data from stakeholders and adjusted by expert knowledge. The cost could be listed into two major categories namely measure independent costs and dependent costs. The former was defined as the cost which is not according to the measures; the latter was depended on the measure options. Project timeframe was setup for 20 years. For Measure 1 and Measure 4, after 7 years of planting vetiver grass and natural land rehabilitation, respectively, durian seedling is supposed to replant in year 8th. Therefore, additional costs and benefits regarding planting preparation, maintenance, and harvest including yields will also be accounted.

In detail, costs of planting pit preparation, fertilizers, durian seedling, and wage of fertilizer application were quantified in year 8th for Measure 1 and Measure 4. While, those costs were counted in the 1st year for Measure 2 and Measure 3. In case of fertilizer application and maintenance after planting they were in charged from year 8th to year 20th for Measure 1 and Measure 4, and from year 1st to year 20th for Measure 2 and Measure 3. Additionally, since productive time for durian is 6 years after planting the wage of durian harvest and benefits from durian yield were considered for year 13th to 20th for Measure 1 and Measure 4, and from year 6th to year 20th for Measure 2 and Measure 3. In case of measure 3, banana was grown as nursing plant and the total number of 50 banana trees in one Rai (0.16 hectare) could yield 200 hands per tree after one year of planting.

Due to farmers can harvest banana from year 2nd to year 4th, wage of banana harvest and benefits from banana yield in that period were also quantified. Since mature banana tree can prevent the sunlight for durian growth the removal is thus necessary after four year planting. The removal wage was thus added at year 4th. The wage of banana harvest would cost the farmer approximately 200 Baht/day/Rai and the removal wage would cost 900 Bath/Rai. However, considering the cost of removing sediments in

drainage and streams listed in Measure 4 Local Administration Office is supposed to spend the budget only from year 1st to year 7th. This because of the natural rehabilitation process is possibly sufficient.

Costs and benefits were quantified in particular unit per Rai (1 Rai = 0.16 Hectare). By this, the planting pattern was designed to have planting space of fruit seedling with 8 x8 m. and finally would provide 25 fruit trees per rai. However, in-depth interview revealed that among other fruit trees such as langsat, longkong, mangosteen, and plum mango, the most profitable plant is durian. Commonly, durian fruits can yield 70 kg/tree/year. Therefore, it is supposed to have 1,750 kg/Rai/year. In addition, wage of durian harvest and transportation from the orchard to the market was also accounted which its cost would be 5 Baht/kg. However, the benefits of measures for land rehabilitation include increase in soil fertility particularly in term of major elements (N, P, K) and organic matters contents, banana produces, and durian yield. Due to Uttaradit Land Development Office provides the vetiver grass and sunnhemp seeds without any charges the cost of vetiver grass were ignored in all measures. Additionally, in order to obtain the most possible accurate quantity of important scientific parameters for soil fertility, the data was drawn from research conducted by Boonyanuphap and Thonglemt (2010). The loss of soil fertility and increase in soil fertility in surface soil (at the depth of 0-5 cm) could be calculated in terms of the weights of major soil nutrients and organic matter, which is shown in Table 4.

Table 4 loss of soil fertility and increase in soil fertility in surface soil

List of costs and benefits	Measure options			
	1	2	3	4
Loss of soil fertility[a]				
• Nitrogen (kg)	72.73	0.00	0.00	109.09
• Phosphorus (kg)	0.00	0.55	0.36	0.07
• Potassium (kg)	27.64	0.00	0.00	8.29
• Organic matter (kg)	0.00	0.00	0.00	0.00
Increase in soil fertility[a]				
• Nitrogen (kg)	0.00	400.00	72.73	0.00
• Phosphorus (kg)	0.15	0.00	0.00	0.00
• Potassium (kg)	0.00	8.29	7.60	0.00
• Organic matter (kg)	363.64	727.27	2,909.09	1,454.55

[a]According to relevant studies (Boonyanuphap and Thonglemt, 2010).

3.5 Monetization of the outputs and impacts

All cost and benefits was put in monetary terms in order to compare in common units. Market prices and wage rates were used to value the change in agricultural productivity and the cost of planting, respectively. They were mostly costs for land preparation and waterway constructions, fertilizers, banana and fruit seedlings, and maintenance. While, some impacts are not appropriate to be monetized using market prices or wage rates, thus the shadow prices or preventive expenditures method are used instead to assess the net costs and benefits. Refer to the experimental result conducted in study area (Boonyanuphap and Thonglemt, 2010), change in contents of major elements and soil organic matter could be obtain and was then monetized corresponding to amount presented in commercial fertilizer. The price of fertilizers is supposed to increase according to its market prices by 10 % over time. The negative change of the soil fertility was put in the list of cost, while the positive ones were counted as benefits. The detail of monetization of soil fertility parameters are shows in Table 5.

Table 5 monetization of those soil fertility parameters (1 USD=30.55 Baht)

Costs and benefits	Measure options				Fertilizer formula	Price (Baht/kg)
	1	2	3	4		
Loss in soil fertility						
Nitrogen (Baht)	465.0	0	0	697.5	46-0-0 (N-P_2O_5-K_2O)	6.394
Phosphorus (Baht)	0	1.33	0.88	0.2	15-15-15 (N-P_2O_5-K_2O)	2.43
Potassium (Baht)	67.16	0	0	20.2	15-15-15 (N-P_2O_5-K_2O)	2.43
Organic matter (Baht)	0	0	0	0	Organic fertilizer (25% of organic)	1.33
Fertility Improvement						
Nitrogen (Baht)	0.00	2,557.6	465.0	0	46-0-0 (N-P_2O_5-K_2O)	6.394
Phosphorus (Baht)	0.35	0	0	0	15-15-15 (N-P_2O_5-K_2O)	2.43
Potassium (Baht)	0	20.2	18.5	0	15-15-15 (N-P_2O_5-K_2O)	2.43
Organic matter (Baht)	120.91	241.8	967.3	483.6	Organic fertilizer (25% of organic)	1.33

Note: Measure 1: planting of the vetiver grass with constructions of waterway; Measure 2: planting vetiver grass with intercropping of fruit trees and sunnhemp, and constructions of waterway; Measure 3: Planting vetiver grass with intercropping of fruit trees and bananas, and waterway constructions; Measure 4: Status quo (natural rehabilitation); Price of organic matter was calculated using factors of 0.3325 (25% of organic fertilizer price).

3.6 Net present value (NPV) of rehabilitation measures

Net present value was calculated using 6% discount rate according to a current interest. The values of the costs and benefits in this study were counted for 20 years project period. From in-depth interview of local scholar and farmers the proper time of 7 years for natural rehabilitation of landslide damaged area should be taken. In addition, the acceptable productive time for durian is 6 years after planting (in case of using 3 year seedling). Measure 1 and Measure 4 are the rehabilitation options in which replanting of durian seedling at year 7^{th} would be included. However, as mentioned above productive time starts from year 6^{th}, therefore income from durian production can be obtained from year 6^{th} to year 20^{th} for Measure 2 and Measure 3 and from year 13^{th} to year 20^{th} for Measure 1 and Measure 4.

The farmers are supposed to gain income from banana produced in the second year to the fourth year after planting. However, the wage of banana removal was present in Measure 3 due to farmers need to cut mature banana tree that prevent the sunlight for durian growth. The removal would perform at year 4^{th}. Therefore, the net present value wage for harvest and removal was calculated using only value from the second to the fourth year and at year 4^{th}, respectively. Additionally, the assumption of amount change in major elements and organic matters was fixed throughout project period. Maephoon Sub district Administration Office has annual expenditure for removing sediments in drainage and natural stream since the 2006 landslide event. One million and eight-hundred thousand Baht was spent for removing sediments covering the total landslide damaged area of 4,523.69 Rai (723.79 ha.). Therefore, the estimated cost for 1 Rai area would be 397.91 Baht.

The result of NPV with 20 year project period shows that the highest value can be obtained from Measure 2 followed by Measure 3, Measure 4 (Status quo) and Measure 1, respectively (Table 6). Considering the total costs of all measures it was found that the least investment for land rehabilitation is contributed to Measure 1. Whereas, the most beneficial measure option is Measure 3 due to high income from banana produces and benefit from soil fertility improvement, particularly organic matters content. This suggests

that Measure 2 and Measure 3 would probably be the most appropriate options according to the highest NPV in Measure 2 and highest benefit obtain from Measure 3. However, from the response of stakeholders they were mostly happened to choose Measure 3 as the best option with the major reason of banana availability and benefits.

Table 6 Costs, benefits and NPVs estimated for rehabilitation measures under discounted rate of 6%, and project period of 20 years. (Baht per Rai; 1 USD=30.55 Baht; 1 Rai = 0.16 ha.)

List of costs and benefits (Baht)	Measure options			
	1	2	3	4
Costs				
Cost of weeding and equipment rent	900	900	900	598.55
Costs of waterway construction	2,000	2,000	2,000	0
Cost of vetiver grass	0.00	0.00	0.00	0.00
Wage of vetiver grass planting	750.00	500.00	500.00	0.00
Costs of planting pit preparation for durian seeding	522.07	785.00	821.19	522.07
Costs of basal fertilizer for durian seedling planting	529.27	795.83	1,045.54	529.27
Wage of basal fertilizer application for planting durian seedling	403.26	609.09	606.36	403.26
Costs of fertilizer applied throughout the year	6,066.83	11,730.83	22,839.52	6,066.83
Wage of fertilizer application throughout year	3,914.66	7,626.42	8,170.62	3,914.66
Costs of durian seedling and planting wage	1,948.57	3,487.50	2,929.93	1,948.57
Costs of sunnhemp and planting wage	0.00	395.83	0.00	0.00
Costs of watering, weeding, and maintenance after planting	11,467.46	22,340.54	34,321.03	11,467.46
Wage of durian harvest	28,623.37	67,313.85	67,313.85	28,623.37
Costs of banana corm and planting wage	0.00	0.00	1,424.44	0.00
Wage of banana harvest	0.00	0.00	1,069.20	0.00
Wage of banana removal	0.00	0.00	755.66	0.00
Cost of removing sediments in drainage or and streams	0.00	0.00	0.00	2,354.56
Loss of surface soil fertility (0-5 cm. depth)				
Loss in nitrogen	5,653.75	0.00	0.00	8,480.62
Loss in phosphorus	0.00	16.12	10.70	2.15
Loss in potassium	816.49	0.00	0.00	244.95
Loss in organic matter	0.00	0.00	0.00	0.00
Total Costs	**63,595.73**	**118,501.01**	**144,708.03**	**65,156.32**
Benefits				
Increase in surface soil fertility (0-5 cm. depth)				
Gain in nitrogen	0.00	31,095.60	5,653.54	0.00
Gain in phosphorus	4.30	0.00	0.00	0.00
Gain in potassium	0.00	244.95	224.56	0.00
Gain in organic matter	1,470.03	2,940.05	11,760.18	5,880.11
Banana yield	0.00	0.00	26,730.12	0.00
Durian yield	200,363.57	471,196.92	471,196.92	200,363.57
Total Benefit	**201,837.89**	**505,477.52**	**515,565.32**	**206,243.67**
NPV (per Rai)	**138,242.16**	**386,976.51**	**370,857.29**	**141,087.35**

Note: Measure 1: planting of the vetiver grass with constructions of waterway; Measure 2: planting of vetiver grass with intercropping of durian seedling and sunnhemp, and constructions of waterway; Measure 3: Planting of vetiver grass with intercropping of durian seedling and bananas, and waterway constructions; Measure 4: Status quo (natural rehabilitation)

3.7 Sensitivity analysis

The sensitivity analysis was performed using discount rates of 3%, 8%, and 10%. In case of up price materials, it is assumed that the cost would be increased by 30%. Those costs include cost of weeding and equipment rent, operation costs of watering, weeding and maintenance, costs of basal fertilizer for fruit seedling planting, costs of fertilizer

applied throughout the year, costs of maintenance after planting, wage of durian harvest, wage of banana harvest and removal, cost of removing sediment in drainage, and costs of fruit seedling and planting wage. In addition, the assumption of uncertain conditions of climate was defined as drought, cold wave, and summer storm. These conditions would decline banana and durian production yields by 30%.

The results are shown in Table 8. It can conclude that Measure 2 provides the highest NPV, follows by Measure 3, Measure 4 and Measure 1 in all cases of discount rates and scenarios. However, the net present values of Measure 2 and Measure 3 is not different significantly, particularly in based case of 6% discount rate. Moreover, the sensitivity analysis also reveals that all measure options for land rehabilitation in this study including status qua could provide positive NPV and B/C ratio greater than one in all cases. This would imply that if the landslides were to reoccur all measure options including status qua that we proposed in this study would give quite high benefit to the stakeholders in aspects of soil erosion control, soil fertility improvement and agricultural production yield and income.

It can also explained that planting of only vetiver grass in Measure 1 would provide the most effective control of soil erosion compared to other options. Consequently, the risk of landslide could be reduced and bring about a decrease of damage in landslide area. Additionally, comparing Measure 2 and Measure 3 to status qua in term of damage reduction it can discuss that if landslide was occurred in early years of rehabilitation (from year 1st to year 7th) Measure 2 and Measure 3 would help to reduce the damage more than status qua. This is due to the same reason of vetiver grass planting in Measure 2 and Measure 3 and incomplete process of natural rehabilitation in status qua. Contradictory, if the landslide was to occur in the late time of rehabilitation (from year 8th to year 20th) status qua would become the most effective to prevent landslide compare with Measure 2 and Measure 3 because of deep root system of native pioneer species, such as bamboo grass, cogon grass, and *Helicteres lanata, Nephelium melliferum*.

Table 8 Summary of NPV in sensitivity analysis for rehabilitation measures, and ranking place. (Baht per Rai; 1 USD=30.55 Baht; 1 Rai = 0.16 ha.)

Measure	Discount rates				Scenarios			Ranking
	3%	6%	8%	10%	unusual climate condition[a]	increase in prices of materials[b]	combined conditions[c]	(based on 6% discount rate)
1	221,518	138,242	101,282	74,262	78,133	123,381	63,272	4
2	537,986	386,976	314,357	257,561	245,617	355,005	213,646	1
3	512,786	370,857	302,518	249,005	221,479	331,504	182,126	2
4	224,590	141,087	104,043	76,974	80,978	125,610	65,501	3

Note: Scenarios were set at conditions of 6% discount rate; [a]under conditions of drought, cold wave, and summer storm cause decline in fruit yield at 30%; [b]under conditions of increase in prices of materials by 30%; [c]under combined conditions of unusually climates and increase in prices of materials; Parentheses indicate values of B/C ratio.

3.8 Cost and benefit distributions among stakeholders

From in-depth interview and focus group of stakeholders, the distribution of cost and benefit could be drawn. It was found that high power upstream stakeholders (Chief executive and administrative persons of Maephoon Subdistrict administration office (SAO), Members of the SAO Council, and Mayor and administrative persons of municipality of Hua Dong) would be responsible for 50% cost of measure 1. And the cost of all measures (Measures 1, 2, 3 and status quo) was distributed to only stakeholder groups in upstream region which are high power/leadership persons and land owner and

farmers (non-member of any social groups), equally. This due to local administrative office would take responsibility for land rehabilitation together with the farmers and land owners. In addition, Measure 4 cost was attributed to cost of removing sediment in drainage which is fully taken care by the local administrative office.

The benefit distribution revealed that all stakeholders, upstream and downstream, would obtain the benefit from all measures for land rehabilitation except status quo (Measure 4). It can be seen clearly that land owner and farmers in MaePhoon Sub district (upstream stakeholder) would get the most benefit from Measure 3 (75%), Measure 2 (75%), and Measure 1 (50%), accordingly. It can be explained that farmer can gain income from fruit and banana produces in all Measures. In addition, Measure 4 would provide 90% benefit to land owner and farmers since the natural rehabilitation by native pioneer plants, such as *Thysanolaena maxima* Ktze, *Eupatorium odoratum* Linn., *Imperata cylindrical* Beauv., and *Musa acuminata* Colla, can increase the organic matters content in surface soil.

In addition, off-site stakeholders could also obtain 20% benefit in measure 1 and 10% in Measure 2, Measure 3 and 4. Measure 1 would provide more benefit to downstream stakeholders because vetiver grass was supposed to enhance soil erosion control. It can also explain that soil erosion control will result in reduction of yearly budget of Subdistrict administration offices for removing sediments in drainage or streams. Additionally, soil erosion control in upstream region would also provide sufficient amount of water for household and agricultural uses in downstream region. Therefore, all measures would benefit to off-site stakeholders, particularly communities and farmers and chief executive and administrative persons.

3.9 Policy implication

For practical implementation of land rehabilitation on sloping agricultural areas damaged by landslide, the research outputs are needed to be considered from Mae Phoon Subdistrict Administrative Organization Council (SOA) for three year developing plan of Mae Phoon Subdistrict (Year 2012-2014). In addition, annual assessment of all implemented projects and detailed activities should also be performed. This would help to follow the changes of local environment and economic situation in each year. Although, it was found that the Measures 2 (by planting of vetiver grass with intercropping of durian seedling and sunnhemp, and constructions of waterway) provided the highest value of NPV because the farmers or land owners would spend less money for investment and could gain high incomes from durian produces. This measure can also increase the higher contents of major elements (Nitrogen and Potassium) into the topsoil than other measures. Moreover, if there is unusual climate conditions occurred which would result in fruit yields declination Measures 2 can still play as an appropriate option for land rehabilitation in Mae Phoon Subdistrict. However, stakeholders were happened to choose Measure 3 based on in depth interview and questionnaire responses. Therefore, Measure 2 and 3 can be alternative measures for Mae Phoon SOA to implement to landslide affected area.

Since the public policy is performed based on participation of local community and stakeholders, the conflicts during practical implementation in order to solve the problems in term of land rehabilitation could be less. Moreover, the evaluation of implemented public policy for selected measured of land rehabilitation should be necessarily concerned. The evaluation process can indicate whether or not the activities are according to policy makers expected, conducted approach is efficient, and it can be a good practice for applying in other areas.

4. Conclusions

Based on brainstorming of stakeholders and researchers three alternative measures for land rehabilitation considering a concept of the vegetative-based approaches were designed and compared to status quo. Using 6% discount rate with 20 year project period the highest Net Present Value can be obtained from Measure 2. Considering the total costs of all measures it suggests that less investment for land rehabilitation can be taken by Measure 1 and Measure 4. The sensitivity analysis brings about the conclusion of Measure 2 provides the highest NPV in all cases of uncertain discount rates and scenarios. Additionally, deep root system of vetiver grass planted in Measure 1, 2 and 3 and that of native pioneer species naturally grown in status quo can conserve topsoil layer and prevent soil erosion. This suggests that all measure options would probably reduce the damage from landslide and provide high benefit to the stakeholders in soil fertility improvement and agricultural production yield and income, if the landslides were to reoccur in the future.

The cost and benefit distribution was also analyzed based on in-depth interview of both On-site and Off-site stakeholders. It can conclude that the cost of all measures was distributed equally to high power/leadership upstream stakeholders in Maephoon Subdistrict and land owner and farmers in upstream region. In case of benefit distribution, land owner and farmers in MaePhoon Sub district would get the most benefit from Measure 3. From the result of cost-benefit analysis it can also be seen clearly that income benefits from banana and fruits produces would be ones of the important incentives for upstream farmers and landholders to rehabilitate agricultural land damaged by landslide in Meaphoon Subdistrict. Lastly, in order to solve the problems of land rehabilitation the most agreed option needed to be considered by Mae Phoon Subdistrict Administrative Organization Council for three year developing plan of Mae Phoon Subdistrict (Year 2012-2014) and implemented practically. The public policy is therefore recommended to perform based on participation of local community and stakeholders. This can provide effective output with less conflict to MaePhoon Sub district.

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