Reduction of Agrochemicals and Environmental Load : A Current Development in Watershed Areas of Northern Thailand

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Abstract Topographically, mountainous area of northern Thailand is part of the foot hill of Himalayas. Here living 15 different hill tribes with the total population, in the year 2005, of 1.3 million people mostly migrated from China and neighboring countries around 100 years ago. People brought culture and agricultural practices ; which of mainly shifting cultivation with slash and burn land preparation technique. The system causes environmental degradation mostly on fragile land. Soil erosion and topsoil depletion occur very seriously on the high sloping land. Now a day, production system changes to more market-oriented purpose for getting enough income to cover the increasing family expense due to needs of modern services, *eg*. television, mobile phone or even car. Intensification of land use and increase of chemical fertilizer as well as chemical pesticide application are common practices. Need of more agricultural land to increase yield force to the deforestation, whereas over use of agrochemical causes depletion of topsoil, change the balance of soil microorganism, natural enemy and even residue as toxic substances in soil, water, and in farm produce.

Promotion of sustainable agriculture and environment has been launched worldwide since many decades, although with a less impact on saving our soil quality, water resources and biodiversity as it expected. Increase in environmental risk and natural disaster as the consequence of the global warming are the clear indicator. Globalization of market and economy together with the modern living style of consuming society play a significant role in increasing the problems of agrochemicals residue and environment depletion. This phenomena occurs worldwide, even in a remote area of mountainous regions of Thailand. A sustainable strategies to solve these problems have been achieved by The Royal Project Foundation from 38 years steadily community development, which is recognized worldwide and will be described briefly in this paper. Alternative agriculture, which balances household income with ecological sustainability and social immunity, is the key success of the Project. Recent development for sustainable land use in mountainous area of Thailand focus on the reduction of soil erosion through terracing and water harvesting as well as alley cropping with vetiver grass cultivation and fertilizer sausage is demonstrated. Reduction of agrochemical use has been researched on utilization of beneficial microorganism and plant diversity and transferred to the farmers by participatory research appraisal, demonstration plot, and on farm consultation.

Key word : safety food, biopesticide, rainwater harvesting, soil erosion, highland agriculture, sufficiency economy

1. Introduction

1.1. Importance of watershed area in northern Thailand

Mountainous regions in Thailand covers the area of around 10.75 million hectare, from which 70 percent locates in the northern provinces and varied in the altitude of 300-2,500 meter above mean sea level. Topographically, these highland and upland areas lie on the south-eastern foot-end of Himalayas and expanding between latitude 14° to 20° 30′ N. With the total amount of annual rain from 1,200-1,500 mm., most of the area commonly functions as watershed or water bank of the whole country, especially for water supply to low land agriculture in dry season. With steady humid and cool weather, these areas usually rich in flora and fauna, and high soil fertility. Temperate vegetable, flowers, orchids and fruits produced

Table 1. Value of imported agrochemicals into Thailand, 2002-2006

Agrochemicals	Year				
	2002	2003	2004	2005	2006
Fertilizers quantity (ton) value (mill. $US)	3,669,353 670.07	3,837,787 780.17	3,727,667 984.51	3,316,304 1,008.37	3,684,100 1,071.97
Pesticides quantity (ton) value (mill. $US)	 39,634 259.88	 50,331 194.47	 86,905 235.23	 80,166 259.11	 101,786 394.50
Total value (mill. $US)	929.95	974.64	1,219.74	1,267.49	1,466.47

Source : Fertilizers ; http://www.doa.go.th/ard/folder5.aspx?id = 90 (7 October 2007)
Pesticides ; http://oae.go.th/factor/PestNew.htm (7 October 2007)

in this areas feed to the whole country, and also exported.

The area also serve as living place for around 1.3 million hill people of 15 different tribes. Most of them have been migrated, or even still illegally migrating, from southern China and from neighboring countries, and carried with them the slash and burn agricultural practices and culture.

1.2. Problems of agrochemicals pollution and environmental depletion in watershed area

In the last decades Thailand has strongly promoted countrywide the export-oriented agriculture. Intensive agricultural practices with high input of chemical fertilizer and pesticide has been introduced to the farmer by government agencies and private companies with a good success of motto "Kitchen for the World". Lately, Thailand becomes one of the global major exporting countries of fresh and processed fruits, vegetable, cut flowers, orchids and fishery produces. As a consequence, Thailand also becomes one of the biggest agrochemicals importing countries of around 3.31 million ton chemical fertilizer and around 0.80 million ton pesticide in the year 2005, with a steady increasing every year (Table 1).

Based on a big demand in raw material for food and feed industries in Thailand, intensive agricultural practices also extended into the northern highland-watershed areas. Hilltribe people changes their land use pattern from self-sufficient agriculture to market-oriented agriculture. Cropping system changes from rice and corn for household consumption to temperate vegetable and cut flowers for marketing. Even corn growing areas also increased drastically due to the high demand in animal-feed industry, and ethanol production. Deforestation together with intensive slash and burn practices on sloping land causes serious soil erosion and significantly deplete the soil fertility and biodiversity richness of those watershed areas. Farmers have to gradually increase their fertilizer application rate and also pesticide spraying frequency to maintain a good yield and to fulfill a market demand of high quality produces. These high input has raised up the unit cost and lastly lowered the competitiveness of the highland produce in the world market. With a smaller market and through an uncertain price, farmers lastly lost their invest, unable to pay back their bank loan and even fall into the uncertainty of food security and poverty situation (Figure 1).

1.3 Additional negative impact of the new global development

1) Global warming

In Thai highland-watershed area, global warming also increases the ambient temperature, but at the same time heavier precipitation. More erosion occurs and, in more often cases, land slice and heavy flooding in low land farm areas in the villages have been annually registered. For agriculture, long duration of cloudy sky in rainy season limits the leaf photosynthesis and weakens the plants especially against disease and insect. In addition, high temperature with high humidity (in

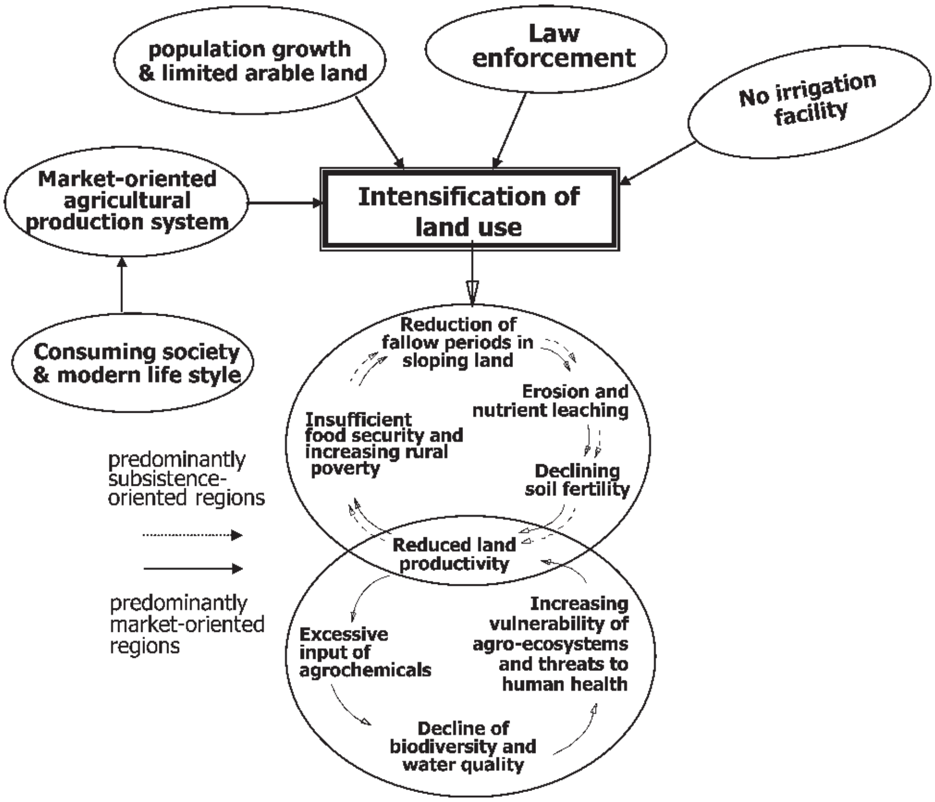

Figure 1. Viscous circles of unstable food security and poverty

soil and ambient) preferment a serious insect pests and diseases outbreak, which then require more pesticide use.

2) New global economy

Globalization has not only promoted the market and industrial agriculture but also the tourist industries. Growth of both service and industrial sectors in town requires a lot of manpower. Migration of working age youths from highland villages down to the town increases drastically year to year. Some population survey results concerning mountain population showed the old people and children to be the dominant group living back in the villages. Lacking of agricultural labor in highland farms will become the next serious problem, for which replacement by mechanization will be in rare case possible.

3) Green energy policies

Development of alternative energy source, especially ethanol- and bio-diesel industry, has become a new opportunity for agricultural produces. Recently, ethanol production using corn-starch as raw material has doubled the corn price. With new dream, hill tribe farmers intensify slash and burn on sloping land again. As a consequence, a health hazard smog level in many towns locate in the valley was alarmed, and a heavy herbicide application in corn plantation due to labor shortage was observed. Most of the herbicide has a long half-life in water and soil then causes a serious environmental load.

2. Research on reduction of agrochemical residue and environmental load : a review

2.1 Erosion control and rain water harvesting

Beside the erosion problem as mentioned above, the sloping land of Thai watershed areas also have the problem of water scarcity in dry season. Most of the arable lands have no irrigation facility. Farmers grow crop once a year and only in rainy season (rain-fed agriculture). By poor weather condition, eg. too heavy rain, land slice and flooding may completely damage the annual income of the household. By growing the second crop in late month of rainy season, farmers will face the big risk of drought and poor growth

Table 2. Effect of anti-erosive cultural practices (CP, CF-AL, CF-M-AL and CP-AL-VG) on CR＝Cumulative Runoff and CSL＝Cumulative Soil Loss (site A data)

Date	Cum. Rain (mm)	Anti-erosive cultural practices							
		CP		CF-AL		CF-M-AL		CP-AL-VG	
		CR	CSL	CR	CSL	CR	CSL	CR	CSL
23-May-06	296	11.2	21.2	9.0	4.5	8.5	3.7	8.9	9.5
15-Jun-06	441	19.8	33.7	14.2	7.7	12.8	4.9	14.1	11.4
20-Jun-06	484	26.7	44.3	17.3	9.9	16.0	6.1	17.4	13.4
25-Jun-06	557	38.8	55.5	26.5	12.1	24.6	7.0	25.9	18.1
6-Jul-06	722	59.5	835.2	42.6	575.8	39.7	446.6	41.8	580.0
25-Jul-06	860	68.5	854.1	48.1	579.9	45.5	447.3	47.6	582.4
30-Jul-06	975	83.9	893.8	61.0	599.6	56.1	455.9	59.9	594.3
17-Aug-06	1,135	102.9	962.7	71.3	619.2	66.2	470.1	70.8	614.9
23-Aug-06	1,198	111.5	1022.1	76.0	625.5	71.1	471.7	75.7	622.1
20-Sep-06	1,412	121.1	1031.0	83.2	627.5	78.2	474.1	82.9	624.8
6-Oct-06	1,535	140.8	1059.0	94.8	628.0	90.8	474.7	95.1	637.8
9-Oct-06	1,617	160.3	1106.7	110.0	631.2	105.7	478.9	111.3	641.2
18-Oct-06	1,681	169.3	1127.3	113.5	633.3	110.2	479.5	115.2	643.9

Panomtaranichagul, 2007

CR＝Cumulative Runoff ($m.^3$ ha^{-1})
CSL＝Cumulative Soil Loss ($m.^3$ ha^{-1})

CP＝Contour Planting,
CF-AL＝Contour Furrow＋Alley Cropping
CF-M-AL＝Contour Furrow＋Mulching＋Alley Cropping
CP-AL-VG Contour Planting＋Alley Cropping＋Vetiver Grass

performance.

Soil management to decrease soil erosion and increase rain water harvesting for extending crop season to the late months of the year has been studied by our group for three years in a row (Panomtaranichgul, 2007). The experimental plots were selected from the 3 farmer's fields in 2 basins for the 2 main experimental plots set as Site A and Site B, at hill slope of 80% and 50% respectively. Each main plot consisted of 12 sub plots (5 x 30 m) with rotations of the three main growing cash crops and the mixed fruit trees in the hedgerows of alley cropping. The mixed fruit-tree hedgerows consisted of Mango (*Mangifera indica Linn.*), Lemon, (*Citrus aurantifolia*) and Jujube (*Zizyphus jujuba Mill.*) plus ground cover with Graham Stylo (*Stylosanthes guianensis*). The main cash crops are rotations of Sweet corn (*Zea mays*) during early rainy season, followed by Upland rice (*Oryza sativa*) during mid-late rainy season and followed by Lablab bean (*Lablab purpureus*) during late rainy season-summer respectively.

The results showed similar trends during the 3 year trials but only the results of the year 2006 will be demonstrated as shown in Table 2. In general, it can be seen that cumulative soil loss occurred at smallest number in the plot with mulching and alley cropping (CF-M-AL) compared to the only contour planting (CP, Table 2). For water harvesting ability (Table 3) ; alley cropping, mulching, and vetiver grass could increase the water harvesting of the soil when compare to only contour planting (CP) ; but only when slope was 50 percent. At slope 80 percent, mulching plus alley cropping showed a positive trend to increase rain water penetration to the soil.

For the effect of soil management on moisture retention (soil water content at 1 m. soil depth), it was also clearly seen that mulching plus alley cropping with fruit tree or fruit tree plus ground cover gave the best result. In the dry month of January and February (no cumulative rain), water

Table 3. Effect of anti-erosive cultural practices on water harvesting ability of soil (three year studies)

Date	Cum. Rain (mm)	Anti-erosive cultural practices							
		CP		CF-AL		CF-M-AL		CP-AL-VG	
		A	B	A	B	A	B	A	B
12-Jan-06	0	240	260	246	286	289	311	232	279
22-Mar-06	0	181	210	172	268	188	285	143	264
5-Jun-06	563	297	326	312	404	314	427	300	403
5-Jul-06	646	273	401	300	422	302	429	292	410
17-Sep-06	1,362	381	417	352	448	398	439	358	413
27-Oct-06	1,681	276	430	300	499	294	468	286	459
21-Nov-06	1,681	224	415	255	404	256	428	239	397
11-Jan-07	0	183	268	192	284	207	300	185	273
2-Feb-07	0		245		264		280		249

Panomtaranichagul, 2007

A = Site A

B = Site B

CR = Cumulative Runoff (m.^{3} ha^{-1})

CSL = Cumulative Soil Loss (m.^{3} ha^{-1})

CP = Contour Planting,
CF-AL = Contour Furrow + Alley Cropping
CF-M-AL = Contour Furrow + Mulching + Alley Cropping
CP-AL-VG Contour Planting + Alley Cropping + Vetiver Grass

retention in the soil up to 1 m. depth were higher than that of only contour planting (CP).

2.2. Reduction of nutrient lost by using "fertilizer sausage"

Our group worked, under the support from JICA, on Appropriate Technology for Reduction of Agrochemical in Northern Thailand (ATRACT) Project, on five years old tangerine trees to compared the effect of different fertilizer application on leaf and shoot growth. The treatments were as following :

(1) Application of 16-16-16 at the rate of 1 kg/tree/month for 5 months (conventional method)
(2) Application of 16-16-16 at the rate of 1 kg/tree/year,
(3) Application of 16-16-16 coated with polysilicone at the rate of 1 kg/tree.
(4) Application of 16-16-16 fertilizer in plastic bags (fertilizer sausage) with 40 pin holes/bag at the total application rate of 1 kg/tree or 4 bags each with 250 g of 16-16-16 per tree (fertilizer sausage)
(5) Application of 16-16-16 fertilizer in plastic bags (fertilizer sausage) with 56 pin holes/bag at the total application rate of 1 kg/tree or 4 bags each with 250 g of 16-16-16 per tree.

At the end of experiment, the remaining fertilizers in PE bag were dried and weighted. The average amount fertilizer remained in PE bag with 40 pin holes were 419.8 g while that in PE bag with 50 pin holes were 560.7 g. The use of 16-16-16 fertilizer in PE bags at 1 kg/tree only once at the beginning of the field trial in March had beneficial effect on improvement of the size of tangerine leaves and shoot formation at 150 days (August) compared to the control treatment (conventional practice). Furthermore there were some fertilizers remained in PE bags suggesting that the application rate lower than 1 kg might be possible.

2.3 Bio-pesticide from plant-and microbial-biodiversity

The successful utilization of plant extract and/

Table 4. Effects of slow release fertilizer treatments on the width and length of tangerine leaves and flushing number

Form of 16-16-16 fertilizer application	Application		Leaf width (cm)	Leaf length (cm)	Flushing number/month
	method	rate (kg /tree)			
1. conventional method*	Broadcast	1 kg/m²	2.68a	6.27a[1/]	0.80c
2. readily available	,,	1	2.44b	5.62b	1.00bc
3. coated with polysilicone	,,	1	2.62a	5.88ab	1.20bc
4. in PE bag with 40 pinholes	Buried	1	2.70a	6.05a	2.20ab
5. in PE bag with 56 pinholes	,,	1	2.87a	6.28a	2.67a

Faculty of Agriculture, CMU (2006)
*control treatment
[1/] Means in the same column followed by different letters are differ significantly at P=0.05

Table 5. Efficiency of ethanol crude extract from *Acorus calamus* to control *Cercospora* sp., *Phytophthora* sp. and *Fusarium* sp.

Concentration (ppm)	Percent inhibition of mycelium growth		
	Cercospora sp.	*Phytophthora* sp.	*Fusarium* sp.
Control	0.00c[1/]	0.00c	0.00d
500	0.00c	0.00c	31.11c
1,000	16.67b	11.11b	68.89b
2,500	100.00a	100.00a	100.00a
5,000	100.00a	100.00a	100.00a
10,000	100.00a	100.00a	100.00

Naphrom and Ponjunt (2007)
[1/] Means in the same column followed by different letters are differ significantly at P=0.05

or beneficial microorganism to replace agro-chemicals have been reported here and there, whereas some products even commercialized *eg*. Neem, *Bacillus subtilis*, *Bacillus thuringensis*. Watershed area of northern Thailand is well-known from its biodiversity richness; not only plant, but also insect, animals and microorganism. A research group of Chiang Mai University has been actively launching the research for developing bio-pesticide from plant and microorganism, from which this paper will pick up and demonstrate some positive results as follows:

1) Bio-pesticide from plant

The group succeeded in developing ready to use fungicide from galanga (*Alpinia* galanga) crude extract, which presently well adopted by farmers and exporter for controlling anthracnose disease (*Colletotrichum gloeosporioides*) in exporting mango. Product has the shelf-life of 1 year with still 90 percent effectiveness compared to fresh produced product. (Sruamsiri *et al*, 2005)

After screening the highland medicinal plants for sometime, the group decided to select and develop the bioinsecticide for highland organic farmers by using *Derris* sp. and *Piper retrofractum*. For biofungicide; *Artemisia vulgaris*, a weed species on highland, and *Acorus calamus* L. were selected out with the outstanding efficiency to control leaf spot (*Cercospora sp.*) and rot disease (*Phytophthora sp. and Fusarium sp.*) even at the concentration of only 0.25 percent. Both plants also showed a very high efficiency to control aphid at the concentration of only 0.05 percent.

2) Use of Endophytic actinomycetes and soil microorganism

Endophytic actinomycetes are mycelium-producing bacteria, which normally live together with plant. With the ability to produce secondary metabolite like enzyme, vitamins, antibiotics (Jonete *et al*., 2000), these bacteria can sometime

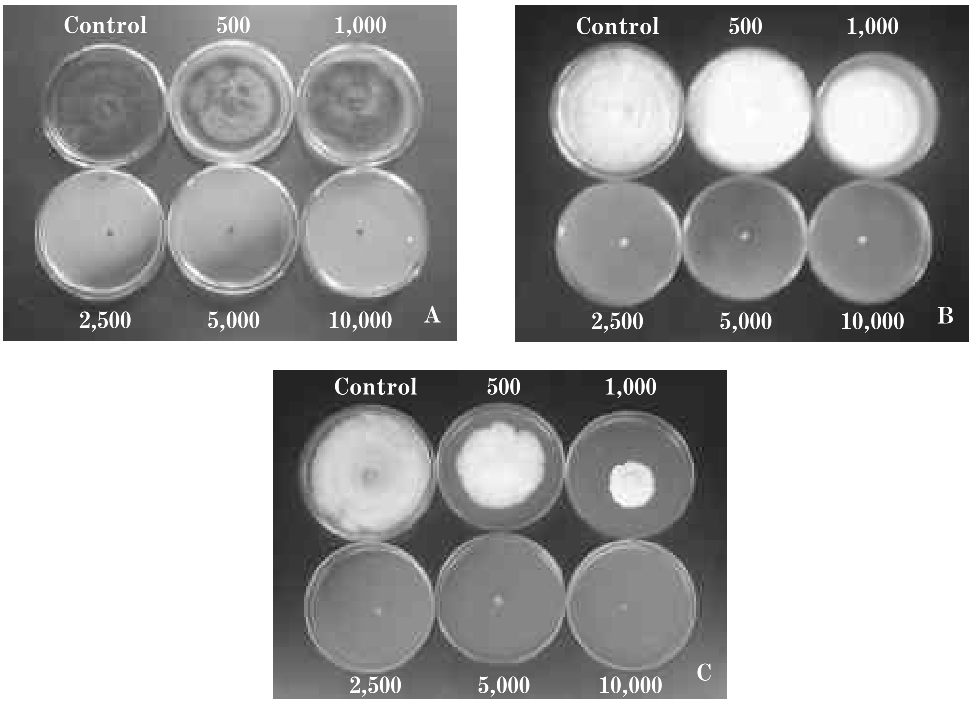

Figure 2. Efficiency of ethanol crude extract from *Acorus calamus* to control *Cercospora* sp. (A) *Phytophthora* sp. (B) and *Fusarium* sp. (C)

promote plant growth or strengthen self-defensive mechanism of plant. Research to make use of these beneficial micro-organisms in agriculture still being in the developmental stage. Preliminary results, however, suggested the possibility to use endophytic actinomycetes from many Thai medicinal plants to control *Sclerotium rolfsii, Alternaria brassicicola, Fusarium* sp. and *Choenaphora* sp. (Kunasakdakul, 2007). *Endophytic actinomycetes* from crucifer vegetable also showed promising efficiency to control leaf spot disease caused by *Alternaria brassicicola* and *Cercospora* sp (Boonchitsirikul, 2007)

In the case of soil microorganism, the effects of mixed *Arbuscular mycorrhizal* fungi (AM), rhizobacteria *Pseudomonas aeruginosa*, *Bacillus subtillis* and antagonistic fungus *Paecilomyces lilacinus* (provitan) on growth and gall development of tomato infected by root-knot nematodes (*Meloidogyne spp*.) was studied under greenhouse conditions. These tested organisms not only enhanced the growth of tomato plants but also significantly suppressed root-knot infection and nematode population densities resulting in less gall development in the root system (Prakob, 2007).

3. Community participation : a key tool for reduction of agrochemicals and environmental load

Actually, the technology development mentioned above is not the real innovation. Many works have been reported locally and internationally, although only some works were successfully adopted at farm level. Many factors influenced the adoption of those alternative methods or natural substances to replace agrochemical use. Technology may be too sophisticate, or not relevant to normal habitat of the farmer, or not effective under different environmental conditions, or may be too expensive for farmers, or may require more intensive work skill, *etc*. In Thai watershed area, strategies for reduction of agrochemical use and for promotion of environmental awareness are locally developed in accordance to each socio-geographical situations. The following are some best practices :

3.1 Price guarantee strategy

One question, farmers usually ask in the training or seminar program, is the profitability of the technology. Unfortunately, they interested in more the economic turn over than the positive impact on environment and their health. Farmers decide to spray more pesticide to get a marketable produce, although they understand the toxicity of agrochemical residue in produce and in soil and water.

Marketing of only safety produce based on contract farming, value-chain mechanism, or value create farmers' group are the strategies recently launched in many villages in mountainous area of Thailand. Farmers received market access and price guarantee upon agreed quality and amount whereas knowledge and skill improvement will be provided by partner companies or organizations. This strategy works successfully in The Royal Project Foundation, especially the promotion of Good Agricultural Practice (GAP), EurepGAP, and Organic Vegetable certification. Farmers earn sufficient income, while the agrochemical applications are reduced.

3.2 The Royal Project's Sustainable Development

Working strategies of the Royal Project in sustainable development can be classified as "area-based multiage working process". In each targeted village, information on socio-economic and enviro-geographical characters will be firstly surveyed and anticipatorily analyzed to identify the necessity to improved (what to develop??), and prioritize the working procedure (how to develop??). New appropriate technologies and knowledge will be introduced and tested on farm-trial basis. Participatory approach research (PAR) is the key method of all stages of development, to integrate the local wisdom into the development process. Good adaptive and successful technique and technologies are then transferred to the hill tribe through many means ; *eg*. repeatedly practical training, demonstration plots and other visualized means. This whole development procedure sometimes called "research-based development methodology" or Research for Development Technology, which of course is one of the royal suggestions of His Majesty.

The multifunctional development in each village can be divided into 4 major fundamental pillars which strongly link together as jigsaw : economic development, physical development, social development and ecological development (Figure 3).

1) *Economic development* means the promotion of household income, in the sense of amount, year-around distribution, and equity to receive the income. Major activities of The Royal Project are developing technologies ; *eg*. for agriculture production, management, tourist ; promote the marketing system and off-farm income, and backing up the farmers to get access to capital and soft loan for investment from bank or local government organizations.

2) *Physical development* is usually supported by government partner-organization such as road for produce transport and village connection, irrigation system and water reservoir, as well as electricity supply. The Royal Project arranges the post-harvest and marketing building and facilities. In some cases, even cooling system and cooling transport chain are also provided.

3) *Social development* is emphasized as the most important main stream of development. Working tasks focus at different layers ; individual person, family, youth group, community, villages, networks and country level. Major activities compile of promoting education, health care, youth activities, housewife group small business, cultural conservation activities, as well as improving the self-help group management skill. Sustainable social development is encouraged by promoting the full participatory of villagers in community development from planning stage up to operating and evaluation.

4) *Ecological development* According to His Majesty, the most important outcome of the sustainable highland development is the good balance of livelihood uplift and natural resource, especially soil, water and forest conservation. Sustainable agriculture with environmental friendly crop/livestock management is introduced together with promotion of fruit tree as recommended crops. Fruit tree canopy could replace forest tree in the

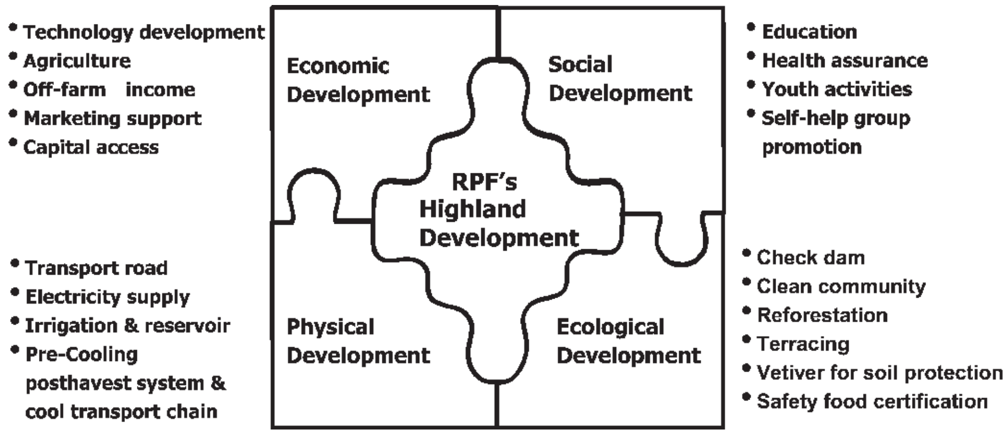

Figure 3 : The Royal Project's 4 pillars of sustainable development

sense of soil and water conservation and microclimate improvement. Safety food certification and organic certification are actively implemented to promote reduction of agrochemical use in watershed areas.

According to The Royal Project's development philosophy, all the four pillars must be parallel developed or in necessary case, one by one but with a very short time difference. For example firstly promote the income from agriculture to make the hill tribe believe and collaborate in agrochemical reduction program or ecological development activities.

This success story showed the possibility to promote a parallel agrochemical reduction and environment and natural resource improvement through knowledge transfer and income generating activities.

4. Conclusion

Promotion of sustainable agriculture and environment has been launched worldwide since many decades, although with a less impact on saving our soil quality, water resources and biodiversity as it expected. Increase in environmental risk and natural disaster as the consequence of the global warming are the clear indicator. Economy globalization together with the modern living style of consuming society play a significant role in causing the problems of agrochemicals residue and environment depletion. This phenomena occurs worldwide, even in a remote area of mountainous regions of Thailand. A sustainable strategies to solve these problems in watershed areas have been recently introduced and adapted to each socio-geographical situation and specifically to each hill tribe's culture. In general, the success begins with research for alternative production system. Development must, however carefully balance the household income with ecological sustainability and social immunity. Community participation is the key of sustainable success.

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