# タイ国ランパチ川における
# 流域荒廃の因果連鎖の解明とその農林工学的修復

（課題番号：12575020）

平成12年度～14年度科学研究費補助金（基盤研究（B）（2））

海外学術調査　研究成果報告書

平成15年3月

研究代表者　眞板秀二（筑波大学農林工学系）

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# 緒言

タイ国における熱帯林の消失は農地の拡大によって起こっている。しかし、農業活動をはじめとする人為的圧力（Human Impact）が流域の生態環境容量の範囲内であれば、生態系に自律的修復機構が働き流域荒廃には至らない。過度の人的的圧力が継続的に加わるとき、生態系の修復機構が破壊され流域荒廃の臨界点を超え悪循環に陥る。悪循環に陥ると、加速侵食による土壌の劣化→生産の維持不能→農耕地の放棄という変化がおこる。この結果、新たな農耕地を得るために森林の伐採が行われ森林のさらなる消失という方向に向かう。このように流域荒廃には、降雨、地形、土壌、植生などの自然的条件だけでなく、農民のおかれている社会・経済的状況やかれらの行動心理などが因果の連鎖をなして強く影響する。流域の持続的土地利用を考えるうえでは、まずこの因果連鎖を読み解くことにより流域の現状を診断することが必要になる。

本研究では、タイ国の辺境地の一つであり、約３０年前からの他地域からの移住者によって開発されたメクロン川支流ランパチ川流域を調査地に選定し流域荒廃に関するケーススタディを行った。この流域はミャンマー国境に接しており、政治的にも重要な位置にあることから政府も農業開発（主としてサトウキビ）に力を注いできたが、地勢学的な理由などからその開発進度は早いとはいえない。しかし、近年タイ国が第１位の生産量を占めるパイナップル栽培が、ランパチ川上流域でも行われるようになるとともに、野菜栽培も活発になってきた。パイナップルは傾斜地にサトウキビ、野菜などは平坦地に栽培されること、パイナップル畑では苗の植栽から３年経つと整地（裸地の出現）を行いまた新しい苗を植えるという栽培法をとること、さらに整地や新苗の植え付けが雨季に入ってから行われることから、パイナップル畑は他の作目に比べて土壌侵食を受けやすいという特徴をもつ。このような自然的、社会・経済的そして農民の行動心理的な諸種の変動要因をもつランパチ川流域、特に上流域についてその持続的発展のための処方箋づくりをめざし、まず流域の現状診断を行った。そのために砂防学、農業土木学、農業機械学、水文学、森林学、生態学などの研究者が人為的圧力というキーワードのもとに統合・連携する手法（農林工学的手法）を模索しながら研究を進めた。このアプローチでは社会的文化的背景の理解が不可欠であるとの認識のもと、「アジアと農林工学」ファーラムというオープンな勉強会を開き開発人類学、参加型社会調査法などの専門家を招き社会・経済・文化的側面の把握についての考え方、手法などを学んだ。

各研究者は４回以上の現地調査を行った。このうち、第１回目は専門の異なる研究者がそれぞれの立場を相互に理解し同じ土俵で議論ができるようにするため、全員でランパチ川流域を訪れ同一の現場を見ながら意見交換を行った。また、カセサート大学、チュラロンコン大学、アジア工科大学、ＦＡＯアジア・太平洋オフィス、王室潅漑局などを訪れ、関連資料の収集を行うとともに、研究活動を円滑に進めるために各大学、各事務所の研究者および担当者と本研究に関する意見交換を行う機会をもった。その後の調査では、効率をあげるため必要に応じてグループを組み調査を行った。と同時に各地に

またがった研究分担者が少なくても年に一度は一同に会し、研究の進捗状況、研究方針などを相互に報告・討議した。これにより、これまでの異なる専門分野の単なる並列的な総合研究ではない、真の統合・連携研究の展開を目指した。最終年度（2002年度）には、バンコク（2002年11月）で本研究成果の発表およびその討議のためにワークショップを開催した。このワークショップにはタイの各大学の研究者・院生、王室潅漑局などの技術者、JICA日本人専門家など約70名の参加があり、熱心な討議が行われた。なお、巻末に付録として調査活動概要、「アジアと農林工学」フォーラム概要、ワークショッププログラムおよび現地写真を載せてある。

報告書を読んでいただくとわかるように本研究は当初目指した流域荒廃の農林工学的修復までには至っていない。これについては今回の研究成果を基に新たな研究費を申請し再度挑戦したいと考えている。（眞板秀二）

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科学研究費成果報告書

# タイ国ランパチ川における流域荒廃の因果連鎖の解明とその農林工学的修復

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KU (カセサート大学), UT (筑波大学), RID (タイ国農業共同省王室灌漑局), AD (タイ国農業共同省農業局), NU (新潟大学), GU (岐阜大学), SU (信州大学), MU (宮崎大学), NIRE (農業工学研究所)

Workshop on Watershed Degradation and Restoration of
the Lam Phachi River Basin, Thailand
Bangkok, November 29,2002

# Watershed Degradation and Hydro-ecological Role of the Western Forest Complex (WEFCOM) of Thailand

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***Abstract***

Factors contributing to watershed degradation in general and specific to southeast Asia and particularly to Thailand are described as background for connecting to the status of natural resources degradation in Thailand as well as the western region in terms of forest, land and water resources changes during the past decades. The results from observation and assessment as probable effect of watershed degradation caused by forest fragmentation and land-use practices and cabbage growing with pesticide application on water yields are briefly discussed. The general features and the hydro-ecological role of the WEFCOM are described and analysed based on the observed and assessed effects obtained from the northern and western regions. The conservation plan of the WEFCOM originally proposed by the project together with that stemed from this study was also presented.

**Keywords : watershed degradation, hydro-ecological role, western forest complex**

## 1. INTRODUCTION

Thailand, by nature, is a forest land. A century ago, over 80% of the country was covered with the forests which fed a vast natural network of rivers, lakes and streams, most of which had water year-round and myriad wildlife. It has been known that less than 25% has good forest cover recently. Many tributaries are drying up and much of its wildlife and indigenous plants has vanished. The worse is that most of its forests are fragmented, surviving in residual pitches like small terrestrial islands in a sea of human settlement. Only some of those patches are large enough to have fully functional ecosystems. The most are too small or too disturbed or have lost its hydro-ecological roles as well as many wildlife species. (SNF.et.al.,*undated*)

During the past four decades, Thailand have implemented eight National Economic and Social Development Plans (NESDP) in the hope that our national economy and social status could be improved in great prosperity. At the end of the 8th NESDP, the Government had learnt that the decades of economic development which proceeded the recent economic crisis in this country as well as in many others did not guarantee a good quality of life of Thai and a healthy environment. It seems to be realized by the recent and the coming regimes of government that environmental degradation will clearly jeopardize prospects for continued growth of economy and social security in this country as well as this region and would have severe consequences on the poor who suffer most from worsening environmental condition.

It was stated by the World Bank Group (http : // wbln 0018. worldbank.org/eap/eap.nsf/ cf 72f4c306958369852567c9007.......) that "in rural area, rapid loss of natural forest cover, scarcity of water, increased pressure on fisheries, and eroded soils directly impare the income and welfare of poor, who tend to depend on the environment of both their sustenance and livelihood. If the current trend continues, the key role of the agriculture, forestry, fisheries, and tourism could play in these diminished, both in terms of direct sources of livelihood for rural people and indirectly through to other value-added activities"

Thailand has experienced this suffering situation and it should be about time that Thai people have to turn his and her interests in only monetary aspect of country's development and play more role in taking care of their environment so that natural resources degradation could be reduced and it, in turn, would enhance their quality of life.

This paper aims at informing (1) factors contributing to natural resources degradation using watershed to reflect the consequential impacts, (2) degradation of natural resources in

Thailand emphasizing on the western region, (3) effects of forest and soil resources utilization on water resources degradation, and finally (4) the important role of the Western Forest Complex in eco-hydrological maintenance for the western region and the country as a whole.

## 2. FACTORS CONTRIBUTING TO WATERSHED DEGRADATION

As has been known by watershed scientists that there are many factors that act cumulatively and synergistically to contribute to watershed degradation. Revenga et.al. (1998) stated that these factors include : (1) physical modification, (2) habitat degradation, (3) water use, (4) pollution, and (5) loss of freshwater biodiversity. The FAO (1994) reported that watershed degradation in South Asia comprises elements of (1) deforestation, (2) soil erosion, and (3) adverse changes to river flow regimes and sediment content. Degradation caused by these factors was described by the World Resources Institute and could be summarized as follows :

### 2.1 Physical alteration of inland water systems

Structural modifications, such as dams, flood control, and channelization, change the dynamics of aquatic ecosystems, fragment existing systems, and join previously unconnected ones. In many cases these structural modification have made more land available for producing corps which have played a key role in global food security. However, altering the structure of a river can also bring about costly changes, such as decline in fish catches, loss of fresh biodiversity, increase in frequency and severity of flood, and loss of soil nutrients in the flood plain.

Reducing the flow of fresh water to the sea, dam can also lead to the intrusion of salt water into previously fresh surface water and groundwater-- rendering them undrinkable. It was also recorded that the recent floods along large rivers such as the Mississippi River have been substantially higher than they would have been before flood control structures confined the river a narrow channel (Watersheds of the World – Revenga et.al.,1998).

### 2.2 Habitat degradation and watersheds

It was stated by World Resources Institute (Revenga,et.al., 1998) that land utilization such as deforestation, mining, grazing, agriculture, industrialization, and urbanization all degrade rivers, lakes, wetlands, and the watersheds they drain in ways that make the less able to support life and of provide valuable ecosystem services.

Habitat degradation from logging and extensive agriculture, for example, increase soil erosion and therefore siltation of rivers, reservoirs, lakes and coastal waters. The excessive siltation then affect downstream communities by increasing the frequency of floods, imparing hydropower and navigations, and choking streams and coastal habitats.

Besides those afforementioned factors, Goodloe (2002) pointed out using this longer than 44 years experiences in New Mexico watershed management that excessive numbers of livestock and forest fires and the coming popular activity of off-road vehehicles are also of prime important factors causing watershed degradation.

### 2.3 Water use and watersheds

Human societies recently use more water for irrigation, domestic consumption, and urban and industrial uses, two-third of it for agriculture. It was reported in the Watersheds of the World (Revenga et.al.,1998) that the amount of freshwater withdrawn has risen 35-fold in the past 300 yrs for USA. In many areas, groundwater is now withdrawn far faster than it can be recharged.

So much water is diverted from large rivers like the Colorado and the Ganges that little if any reaches the sea during the dry season, with harmful effects on inland and coastal habitats, fisheries, and people. China's Huang He (Yellow River) is so heavily used that the lower reaches were without water for 2/3 of 1997. Lake Chad, in Africa's Sahel region, has shruk by

75 percent in the last 30 years because of drought and diversion for agriculture, to the detriment of this important inland fishery.

**2.4 Pollution and watersheds**

It was stated in the Watersheds of the World by Revenga et.al. (1998) that the increased load of wastes and exacerbated by the loss of water withdrawn by people's activities has reduced the capacity of rivers to assimilate or flush pollutants from the system. The water that finally returned streams and rivers after irrigation is severely degraded by increased toxicity, excess nutrients, salinity, higher temperature, pathogen population, sediments, and lower dissolved oxygen.

Fertilizer and pesticides from agriculture are major pollutants. Chemical pollutants are also released directly from industrial and municipal sites, and indirectly as runoff from farms, home, roads, and cities. Toxic chemicals are also carried long distances by air currents, and many ultimately find their way into rivers and lakes.

**2.5 Loss of freshwater biodiversity**

As mentioned above, physical alteration, habitat degradation, water withdrawal, and pollution all contribute directly or indirectly to declines in freshwater species. In addition, the incursion of non – native, or allien, species and the mismanagement of inland fisheries are other factors contributing to the loss of freshwater organisms. Allien species may prey on native species , compete for food and breeding space, disrupt food webs, and even introduce new diseases. The spread of these species is a global phenomenon, one that is increasingly aided by the growth of aquaculture and by shipping and commerce.

**2.6 The causes of watershed degradation in Thailand**

The Watershed Management Division of RFD (http://www.forest.go.th/nrco/english/wshmd.htm) reported that the main causes of watershed degradation in Thailand are conversion of forest lands to agricultural land, forest fire, logging operation and other activities such as road construction, mining, over grazing and pesticides and fertilizer application.

The ongoing losses of forest cover in Thailand over the last 3 decades from about 53 percent in 1961 to approximately 25 percent in 1998. The depletion of forest areas has mainly been caused by conversion of forest to agricultural lands to provide subsistence food for rapidly increased population as well as rapid agronomic expansion for commercial crops. Due to the areas in the lowlands are limited effecting form rapidly increasing population, lowland Thai population have encroached forest areas into the mountainous land. In addition, Hilltribes settled in the mountainous watersheds have been practiced shifting cultivation (slash and burn practice) for their livelihood. Shifting cultivation has been the main cause of watershed degradation resulting on soil erosion, soil fertility reduction, sedimentation on downstream areas and reservoirs.

In the past, the cultivated land in the upper watershed areas were mainly for subsistence food. However, in the last few decade, the cultivated lands have been converted to commercial crop incorporation with increasing population which have rapidly caused forest destruction, The population living in the highland mountainous areas in 1997 were 991,122 people in 4,374 grouping villages within 20 provinces mainly in the northern region (Public Welfare Department at : http://www.hadf.org/thailand.htm). About 1 million was recently approximated to reside in those mountainous lands. (http://hadf.org/enlish/hilltribe/hilltribe.html).

The agricultural practices particularly the rapid expansion for commercial crops on the sloping upper watershed areas are major cause of watershed degradation. The widespread deforestation for commercial agriculture caused not only increasing surplus runoff, soil erosion, siltation in rivers and other damaging downstream areas, but also water contamination. The forest fire is mainly caused by slash and burn for shifting cultivation, collecting forest products, hunting etc. It is not only damaged forest trees but also ground covers and surface soil. These will decrease infiltration capacity and resulting in surplus runoff and soil erosion.

Road construction particularly on the upper slopping watershed area is also one of the major cause of soil erosion, landslide, sedimentation, and water quality in the downstreams. In addition, local landless people penetrated into the forests along the roadside and encroaching forests for agricultural practices, and finally settledown in the forest areas.

## 3. DEGRADATION OF NATURAL RESOURCES IN THE WAESTERN REGION

### 3.1 The degradation of the forest resources

Trace back to 1961, western region of Thailand was covered by 71.50 percent of forest area. At that time, inland forest area remained in Ratchaburi, Kanchanaburi, Supanburi, Petchaburi and Prachubkhirikan as detected by landsat imageries at about 64.81, 91.32, 37.72, 76.0 and 79.12 percents of the respective provincial areas. Twelve years later, the inland forest area of the respective provinces calculated basing on the landsat-5 remained at 36.10, 69.54, 13.96, 58.41 and 50.22 percent of its provincial area, a tremendous decrease of forest resources which ever occurred during the past 3 decades. The western region has lost more than 50 percent of its forest resources from 1961 to 1998. For the rugged terrain of headwater source of Mae Klong watershed, about 41% of forest in Kanchanaburi boundary have been lost during the mentioned period. Degradation of forest land during the past 3 decades is shown in Table 1. Besides the legal logging by the concessionair in early 1960 – 1980, the illegal land encroachment by those ethic groups migrated from the neighboring country as well as the increasing local population were those factors affecting forest degradation (Pragtong, 2001).

### 3.2 The degradation of the soil resources

Study on soil resource degradation was rather limited in the experimental area or in some part of the western region. Also it was concentrated on agricultural area of the lowland with very few information for the upland agriculture. Intensive study on the physical and hydraulic properties of soil under various kinds of land use in Mae Klong watershed experiment area was carried out by Deesaeng et.al. (1997). Only partial study results are summarized in Table 2. It was concluded by the investigators that conversion of forest for agricultural practices caused the top soil to loss and left only subsoil which inherently has a finer texture and subsequently resulted in lower BD and higher in total porosity.

Regarding soil hydraulic properties, at any matric potential energy, water content in soil under cultivation was higher than that under other land use condition due to its finer texture and greater porosity. However, soils under cultivation contains micro-pores which, in turn, cause less amount of available water to plants while those soils in the forest and plantation contain medium and macro-pores which soil water could be made available for plant more than that in cultivated soil. Plowing top soil could increase saturated hydraulic conductivity but the lower rate of $K_s$ beneath the plowing depth could be existed as shown in Table 2 (Bt2). Converting forest for agriculture without improving its physical properties could degrade $K_s$ in which greater amount of runoff could occur in cultivated land.

Preliminary study on the effect of change of tropical forest on soil environment by Chunchaay et.al. (1993) also revealed that top soil thickeness, color and hardness of cultivated area were distinctly different form forest soils. Numbers of root in forest land was observed to be more than that in cultivated area. More rainwater was retained by agriculture soil than that in forest soil. The moisture in soil can be more utilized by eucalyptus than by cassava. It was also found that subsoil of cultivated area in Kanchanaburi was reduced 1-3 folds due to greater in bulk density while rather uniform for soils in northern provinces. The CEC of Ca, Mg, K and Na of upper soil layer of forest soil both in northern and in Kanchanaburi are higher than those of cultivated land.

It can be therefore concluded that soil properties in terms of physical, hydrological, hydraulic and chemical have been degraded in some extent whenever forest land have been converted for agricultures. Fortunately, most of the forest lands in this region are under national parks and wildlife sanctuaries systems, slow rate of change is thus expected. Unless intensive conservation could be strictly implemented, soil resources in this region would be then sustainable.

**Table 1 : Forest resorures degradation in western region of Thailand during 1961 to 2000**

| Provincial Area | Province | | | | | | | | | | | | | | | | Western Region | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ratchaburi | | Kanchanaburi | | Supanburi | | Samut Sakorn | | Nakhan Pratom | | Petchaburi | | Prachubkhirikhan | | Sumut Songkhram | | | |
| Sq. km : | 5169.02 | | 19,408.20 | | 539.66 | | 858.41 | | 2165.24 | | 6220.65 | | 6366.92 | | 409.01 | | 41,137.11 | |
| Million Rai : | 3.25 | | 12.18 | | 3.35 | | 0.54 | | 1.36 | | 3.89 | | 3.98 | | 0.26 | | 28.81 | |
| Remaining forest area in year 1951-1998 was interpreted from Landsat-5 (TM) : scale 1 : 250,000 | | | | | | | | | | | | | | | | | *Excluding Mangrove Forest | |
| Year ; | M.Rai | % | M.Rai | % | M.Rai | % | M.Rai | % | M.Rai | % | M.Rai | % | M.Rai | % | M.Rai | % | M.Rai | % |
| 1961 | 2.11 | 64.81 | 11.12 | 91.32 | 1.26 | 37.72 | - | - | 0 | 0 | 2.96 | 76.00 | 3.15 | 79.12 | - | - | 20.6 | 71.50 |
| 1973 | 1.17 | 36.10 | 8.47 | 69.54 | 0.47 | 13.96 | - | - | 0 | 0 | 2.27 | 58.41 | 1.99 | 50.22 | 0.37 | 14.40 | 14.37 | 49.87 |
| 1975 | - | - | - | - | - | - | 0.1156 | - | - | - | - | - | - | - | - | - | - | - |
| 1976 | 0.95 | 29.34 | 8.38 | 68.86 | 0.46 | 13.73 | - | - | 0 | 0 | 1.97 | 50.60 | 1.46 | 36.73 | 0.3 | 10.79 | 13.22 | 45.88 |
| 1978 | 0.81 | 24.84 | 8.33 | 68.41 | 0.45 | 13.59 | - | - | 0 | 0 | 1.77 | 45.40 | 1.10 | 27.75 | 0.022 | 8.40 | 12.46 | 43.25 |
| 1979 | - | - | - | - | - | - | 0.0901 | - | - | - | - | - | - | - | - | - | - | - |
| 1982 | 0.66 | 20.34 | 7.76 | 63.73 | 0.422 | 12.60 | - | - | 0 | 0 | 1.56 | 40.11 | 0.899 | 22.60 | 0.020 | 7.68 | 11.30 | 39.22 |
| 1985 | 0.91 | 28.31 | 7.23 | 59.34 | 0.386 | 11.53 | - | - | 0 | 0 | 1.42 | 36.50 | 0.869 | 21.84 | 0.038 | 11.53 | 10.82 | 37.55 |
| 1988 | 0.89 | 27.41 | 7.02 | 57.66 | 0.380 | 11.34 | - | - | 0 | 0 | 1.397 | 35.91 | 0.860 | 21.61 | - | - | 10.54 | 36.62 |
| 1989 | 0.888 | 27.36 | 7.011 | 57.58 | 0.379 | 11.33 | - | | 0 | 0 | 1.396 | 35.90 | 0.859 | 21.60 | - | - | 10.53 | 36.56 |
| 1991 | 0.835 | 25.72 | 6.769 | 55.59 | 0.376 | 11.24 | - | | 0 | 0 | 1.387 | 35.66 | 0.829 | 20.84 | - | - | 10.20 | 35.39 |
| 1993 | 0.823 | 25.35 | 6.714 | 55.14 | 0.372 | 11.10 | 0.0113 | 2.09 | 0 | 0 | 1.367 | 35.14 | 0.794 | 19.96 | 0.0057 | 2.22 | 10.07 | 34.95 |
| 1995 | 0.820 | 25.23 | 6.671 | 55.09 | 0.369 | 11.01 | 0.0113 | 2.09 | 0 | 0 | 1.357 | 34.88 | 0.787 | 19.77 | 0.0054 | 2.07 | 10.00 | 34.72 |
| 1998 | 0.816 | 25.10 | 6.579 | 54.01 | 0.353 | 10.53 | 0.0106 | 1.96 | 0 | 0 | 1.340 | 34.45 | 0.767 | 19.27 | 0.0071 | 2.73 | 9.85 | 34.21 |
| 2000 Landsat TM) (1:50,000) | 1.038 | 31.93 | 7.374 | 60.54 | 0.391 | 11.67 | 0.0211 | 3.96 | 0 | 0 | 2.105 | 54.11 | 1.435 | 36.05 | 0.0153 | 5.88 | 12.38 | 42.97 |

Source : Royal Forest Department (2002). Forestry Statistics. Planning Division, RFD. Ministry of Agriculture and Cooperatives.

**Table 2 : Summarized Soil resource degradation investigated in the Mae Klong headwatershed Experimental Station Kanchanaburi , Western Thailand**

| Soil properties : of surface soil at $Bt_1$ | Natural forest | Teak Plantation | Epil-epil *(Leuceana leucocephala)* Plantation | Cultivated area |
|---|---|---|---|---|
| Physical properties : | | | | |
| - Depth (cm) | 20-30 | 20-42 | 12-32 | 11-22 |
| - PD. ($Mg.m^{-3}$) | 2.54 | 2.45 | 2.41 | 2.55 |
| - BD. ($Mg.m^{-3}$) | 1.49 | 1.39 | 1.30 | 1.10 |
| - Porosity (%) | 41.35 | 43.36 | 46.11 | 56.69 |
| - Texture | SC | SCL | SL | C |
| Pore size distribution : | | | | |
| - < 0.2 $\mu$ | 0.19 | 0.17 | 0.21 | 0.33 |
| - 0.2 – 60 $\mu$ | 0.10 | 0.06 | 0.09 | 0.05 |
| - > 60 $\mu$ | 0.18 | 0.26 | 0.19 | 0.21 |
| **Hydrologic capacity : (vol.of $H_2O$,% in 0- $Bt_1$ depth at potential energy : )** | | | | |
| - 0 kPa | 46.84 | 48.12 | 49.60 | 58.67 |
| - 1 kPa | 32.56 | 31.45 | 33.37 | 40.94 |
| - 3 kPa | 29.59 | 28.73 | 31.27 | 38.48 |
| - 10 kPa | 29.26 | 23.41 | 27.89 | 36.81 |
| - 33 kPa | 21.80 | 19.33 | 24.12 | 34.24 |
| - 100 kPa | 19.15 | 16.84 | 21.71 | 32.65 |
| - 1500 kPa | 18.55 | 16.53 | 21.47 | 32.50 |
| $\theta_{AWC}$ (% by vol) | 6.71 | 6.88 | 6.42 | 4.31 |

**Hydraulic properties $K_s$ ( $10^{-6}$ $ms^{-1}$) at soil horizon :**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Horizon : | A | 22.17 | Ap | 35.65 | Ap | 12.55 | Ap | 124.74 |
| | $Bt_1$ | 10.80 | $Bt_1$ | 3.60 | $Bt_1$ | 9.18 | $Bt_1$ | 111.79 |
| | $Bt_2$ | 8.92 | $Bt_2$ | 4.79 | $Bt_2$ | 21.56 | $Bt_2$ | 4.62 |
| | $Bt_3$ | 7.74 | $Bt_3$ | 2.10 | C | 115.30 | $Bt_3$ | 0.15 |
| | $Bt_4$ | 0.93 | $Bt_4$ | 1.83 | | | $Bt_4$ | 0.08 |
| | $Bt_5$ | 0.34 | $Bt_5$ | 9.26 | | | $Bt_5$ | 0.05 |
| | $Bt_6$ | 0.90 | | | | | $Bt_6$ | 0.07 |

Source : modified from Deesaeng et.al. (1997)

### 3.3 The degradation of water resources

Water resources degradation can be considered in terms of water quantity, quality and flow timing. As has been known that removal of forest or other vegetation can sharply reduce water retention and increase erosion which results in reduced water availability in dry seasons and more silttation downstream as well as more frequency of floods in wet season. Excessive chemical substances form agricultural activities as well as pollution from urbanization and also industrialization can degrade water qualities and even make unusable for human needs.

It has been fortunately for those who are residing in the western regional watersheds of Thailand since there have been relatively abundant water resources after 1994 when the water resources systems in the Mae Klong basin have been highly developed (Satoh, et,al.,1999). Analysis of the relationship between suspended sediment yield and forest cover situation in the Mae Klong river basin led Maita et.al (1999) to conclud that "if the forest land upstream is converted to agricultural land and other land use, more sediment would be produced in upstream areas than in downstream areas because sediment production is more active in the headwater region that contains many steep slopes than the downstreams." Among the three sub – basins of Mae Klong watershed, Lam Phachi – the highest crop land ratio with most finely divided stream network, produced roughly twice the annual mean suspended sediment yield (540 ton/mcm) while the Khwae Noi and Khwae Yai yielded about 244 and 273 ton/mcm annually.

## 4. PROBALE EFFECT OF WATERSHED DEGRADATION ON WATER YIELD

### 4.1 Effect of forest fragmentation on flow regulation

Investigation on forest fragmentation effect on water quantity and quality is rarely found for the western region of Thailand. Many researches on the effect of deforestation on water yield have been carried out and published but mainly using existing forest area in a watershed as variable in determinining water yields in terms of water quantity, quality and timing. Among these researches, Warapongsittikul (2002) determined the effect of forest fragmention on water yield regulation on the purpose of attempting to find out optimal size of massive forest cover which can regulate water yield under watershed management policy for maintaining watershed ecosystem functions. Based on the lag time from 437 storm hydrographs which were influenced by patches of forest area in watershed , rainfall characteristics and physiography of watershed under wet and moist soil condition, the derived models for determining lag time under moist soil condition are as follows:

$$LT_m = 468.44 MFC^{0.0845} SL^{-0.2541} Dd^{-1.1648} \; ; R^2 = 0.7704 , F = 50.32^{**} \qquad \text{.......(1)}$$

$$LT_m = 3239.1 PA^{-0.1867} Pn^{-0.2717} SL^{-0.1450} Dd^{-2.8005} \; ; R^2 = 0.7814 , F = 39.33^{**} \qquad \text{.......(2)}$$

and $$LT_m = 33.5488 PA^{-0.7523} Pn^{-0.0921} SL^{-0.7887} DA^{1.1502} \; ; R^2 = 0.7699 , F = 36.81^{**} \qquad \text{.......(3)}$$

where,

$LT_m$ = lag time according to the definition of The Mirago Geography Grosary (is the time diference between when heavy rainfall occurs and when peak discharge occurs) for moist soil condition (in minutes)

MFC = massive forest cover in percent of watershed area.

SL = watershed mean slope (%) = $\sum S/N$
= (summation of slope in each pixel (%) calculated from Erdas Imagery software / number of pixels)

Dd = drainage density ($km.km^{-2}$)

PA = patch area under cultivation in percent of watershed area (%)

Pn = numbers of patch under cultivation

DA = watershed area (sq.km) determine using GIS techiques

In order to determine the effect of human activity in using upland for farming and living as patches that cause fragmentation of forest area , equation (3) was suggested since all independent parameters can be simply determined by GIS techniques.

Considering from the affornentioned equations , it could be stated that with respect to a particular watershed number of patch size utilized for farming on upland watershed would shorten the lag time of flow which could be affected on flash flood and / or increasing flood peak rate. Although the investigation was based mainly on watershed in the north , physiographic features and the ways of using upland in the western region would reflect the same manner.

### 4.2 Effect of watershed degradation on peak flow

when watershed resources in from of forest and soil were degraded, the hydrological behavior could be changed in some extent. Effect of deforestation on such hydrological function have been investigated in northern Thailand but rather few in the western region especially for small watershed where it could be feasible to develop small reservoirs in the future. The following study although does not directly reflect hydrological change for the western region caused by watershed degradation , the results obtained from various locations of selected watersheds could be beneficial for discussion on watershed degradation in relation to peak flow characteristics for watersheds in western region.

Based on 13 small watersheds of different landform and landuse, Klinkularb (2002) analysed the relationship between peak flow rate and parameters representing drainage morphology and land use practices through the CN curve originally developed by USDA and rainfall characteristics via rainfall intensity, the multiple non linear model for high mountain watersheds, hilly watersheds and hill-undulating watersheds were derived. They are :

- High mountain watersheds : (when CN > 50)

  $q_p = 6.42x10^{61} A^{0.23869} CN^{-36.544} I^{0.55693}$ ; $R^2 = 0.4496$ ; F = 5144.32**

- Hilly watersheds : (when CN = 40-50)

  $q_p = 7.89x10^{23} A^{0.34849} CN^{-14.852} I^{0.3143}$ ; $R^2 = 0.8167$ ; F = 19.31**

- Hill – undulating watersheds : (when CN < 40)

  $q_p = 7.284x10^{3} A^{0.72557} CN^{-4.} 50879 I^{1.665633}$ ; $R^2 = 0.7129$ ; F = 6.62**

where ,

$q_p$ = peak discharge ($m^3.s^{-1}$)

A = drainage area ($km^2$)

CN = curve number

I = rainfall intensity ($mm.hr^{-1}$)

### 4.3 Effect of Headwater Catchment Degradation on Water Qualities

4.3.1 Effect on water physiochemical quality and aquatic macroinvertibrates communities

It has been perceived by scientists as well as the farmers that converting headwater forest resources for annual crop cultivation without any conservation measures produces tremendous amount of suspended sediment. Study on the effect of such activity on chemical qualities of water and on aquatic life in rather few. Sangpradub et.al.(1997) carried this kind of research in the Nam Choen head watershed in the northeast of Thailand where forest and soil resources degradation have been recognized by the northeast people. The investigators found that degradation of Nam Choen headwater was evident by water physiochemical parameters and benthic macroinvertibrates. The water quality in the forest land sites was less degraded than at bared sites. The apparent degradation of water quality in this catchment was caused by clearing for agriculture. The streams covered by forests were less affected by surface runoff, resulting in high DO and low BOD level.The macroinvertibrate analysis more accurately reflected these impacts. The species richness and abundance in the disturbed sites was less diverse than those in the pristine sites. The degree of fauna composition in disturbed areas varied according to the extent of land clearing. More detail on richness and abundance of aquatic life can be found in the above mentioned reference.

4.3.2 Effect of cabbage growing and pesticide application on soil and water quality degradation

Cabbage growing on upland area of northern as well as western Thailand has been controversial on water quality degradation aspect. There have been few investigation on the effect of cabbage growing, which usually needs pesticide application, on water quality of headwater sources. Ounok (2002) carried out the research with the aim at modeling the movement of pesticide (cypermethrin) from cabbage growing area to stream channel and downsteam. Based on 26 storm rainfalls observed at small watershed of Mae Chaem basin in northern Thailand, the model derived for estimating storage of cypermethrin in soil for the first and second application was expressed as :

$$[\triangle s_i]_1 = 2.56\, R^{-7.39\times10^{-6}}\, \triangle s_{i-1}^{\,0.0843}\, D_1^{\,2.86\times10^{-6}}\, e^{-1.47\times10^{-6}\lambda} \; ; R^2 = 0.96$$

$$[\triangle s_i]_2 = 797.91\, R^{-3.21\times10^{-5}}\, \triangle s_{i-1}^{\,-1.48\times10^{-3}}\, D_2^{\,-3.88\times10^{-6}}\, e^{-3.72\times10^{-6}\lambda} \; ; R^2 = 0.922$$

where ,

| | | |
|---|---|---|
| $[\triangle s_i]_1$ and $[\triangle s_i]_2$ | = | amount of cumulative cypermethrin in soil at the day i for the first and second date of application (gm/ha) |
| R | = | cumulative rainfall amount after date of application (mm) |
| $\triangle s_{i-1}$ | = | storage of cypermethrin in the previous day (gm/ha) |
| $D_1$ and $D_2$ | = | day after cypermethrin application for the first and second application date |
| $\lambda$ | = | slope length of cypermethrin movement (meters) |

To estimate pesticide contamination in streamwater, the ratio of Cypermethrin observed at outlet (1200 meters from the cabbage growing area) and amount of cypermethrin storage in soil and cabbage (which is named as Cypermethrin delivery ratio ; CyDR ,%) was modeled using storm rainfall amout (mm),day after cypermethrin application (days) and storage of Cypermethrin in cabbage growing area of the previous day ($\triangle s_{i-1}$; gm/ha). The model was derived as ;

$$CyDR = 6.324\times10^{-4}\, R^{1.485}\, D^{-1.062}\, \triangle s_{i-1}^{\,0.640} \quad ; R^2 = 0.772$$

The results indicated that with about 400 gm/ha of cypermethrin application, It contaminated in surface runoff and sediment in the range of 0.003-0.0498 mg and transported to the outlet at a range of 0.2820 – 639.8 mg . The maximum storage of cypermethrin in cabbage was 224 mg and in soil of about 4532 mg.

**4.4 Effect of irrigation on water quality**

As has been previously mentioned that water that finally returned to rivers after irrigation could severely degraded by increased toxicity and excess nutrients. In the Mae Klong basin, Kwanyuen et.al.(1999) investigated the effect of Thamaka Irrigation Project on 12 water quality parameters namely : temperature , EC , turbidity , pH , concentration of nitrate , ammonia , phosphate , and chloride ,TS ,TDS , BOD and SAR. It was found that the water quality was acceptionally good and the drainage water quality was deteriorated just a little but the overall quality was still much above the standard of water quality for natural water resources and irrigation water. It was also stated that the main source of pollution for the Mae Klong basin is from wastewater from community , town , and city along the riverbanks followed by agriculture and industrial wastewater.

## 5. HYDRO-ECOLOGICAL ROLE OF THE WESTERN FOREST COMPLEX (WEFCOM)

### 5.1 Thailand's Largest Forest Conservation Area

Covering 18,730 sq.km., the Western Forest Complex (WEFCOM)- situated at Lat :13°00'-18°00' and Long : 96°15'-100°15' in western region, It is Thailand 's largest surviving tract of forest land as well as being the largest conservation area in mainland S.E. Asia. It retains most of its native flora and fauna (only rhinos and vulture are known to be extinct) and it encompasses many waterways which supply three of Thailand 's six river systems;- the Chao Phraya, the Mae Klong and the Salween. The complex comprises 17 conservation areas (11 national parks, 6 wildlife sancturies) and span six provinces: Kanchanaburi, Kampaengphet, Uthaithani, Nakhonsawan, Supanburi and Tak.(Sueb Nakhasathien Foundation, *undated*)

### 5.2 Biophysical Features of the WEFCOM

The WEFCOM contains all the forest formation (except the coastal one) of continental Southeast Asia: hill-evergreen, seasonal (or dry) evergreen, mixed deciduous and dry deciduous forest as well as variations such as pine forest, bamboo grove and savana.Most precipitation comes from the southwest monsoon and ranges from 2,500 mm on the western side where rain falls longer than 6 months to 1,200 mm in the east where it rains for 4-5 months. Soils vary from red-brown clays in the west where the substrate is mostly limestone to sandy podzolic soils in the east where the substrate is mostly granite.

The topography is seldom level with altitudes ranging from 150 m(MSL) to highest peak 1,960 m. Temperature vary from 0 $^{0}$C in the highland at night in the cold season to a daytime high of 40 $^{0}$C in the hot season. Because of this physical diversity, these western forests support a mixed mosaic of habitats with a correspondingly diverse flora and fauna.

### 5.3 The Ecological Role of the WEFCOM

5.3.1 Forest types and distribution

The most recent data on the forest area in the WEFCOM interpreted from **Landsat** by the Technical Division of the WEFCOM Management Project, RFD is shown in Figure 1 and Table 3. Based on the above mentioned source of data, mixed deciduous forest is the largest proportion in the WEFCOM boundary (30.4%) followed by the degraded (hill + dry) evergreen forest (24.8%) and secondary growth/bamboo forest (23.8%), the other smaller patches of forests consist of dry evergreen (7.2%), hill evergreen (5.4%), dry dipterocarp (2.1%) and savannah (1.6%). The pine and swamp forests, even a very small area (0.10% and 0.02%) occurring, but they are very interesting and not much is known for these two forest type. For the pine forest, it was stated by the WEFCOM Project, after the rapid ecological assessment (REA) of the vegetation that , these forests seem to be on the brink of disappearing because of the forest fire and the change in climate. It is a fact that several thousand years ago, the climate was drier and pine forest were wide spread in Thailand. The swamp forest is more or less flooded all year round so trees have adapted to the most conditions and formed large buttresses Calophyllum sp. and and tandanus still roots.

These evergreen mountain forests on elevation above 1,700 MSL are subject to strong winds and harsh condition results often in stunt growth and the forming buttress. It makes these forests very fragile and disturbances, espectcially fires might result in the collapse of these stil little knowm ecosystems and will be replaced with secodary growth and grassland. This type becomes more and more fragmented as result of encroachment. So far over 900 species of trees, shrubs and herbs have been categorized in database. A few species are, so far, not found outside the WEFCOM.

At the figure of 19,648.3 sq.km as total area of the WEFCOM, about 875.1 sq.km. or about 4.44 percent is agricultural area. The agricultural area will be extended more and more in the future by many reasons, e.g., more development projects, contradictory land-use policies, civil strife in Mynmar that gives rise to refugees, by illegal land encrochment, hunting and logging and also by the failure to involve local people in forest and wildlife protection.

5.3.2 A Source of wildlife and natural wealth

With variety of forest vegetation and the ecological diversity, this area endows with a wealth of animals. Among them, 1,000 vertebrates species or a half the number known for Thailand exist in the WEFCOM. These vertebrates include: 156 mammal species, 490 birds species, 41 reptiles and over 180 species of fish. These figures do evoke the areas awesome biodiversity and ecological wealth. In addition, this area supports the world 's largest and smallest land mammals (the elephant and the bumblebee).

5.3.3 The role in maintaining people's quality of life

The WEFCOM can be viewed as a place to be appreciated by visitors in many ways. It is a natural library or recreation and spiritual sustenance. For those who are living and farming in the west and west-central Thailand, it is also valuable for its role in maintaining the local climate (including air and water quality) which improves the quality of life. More important, the western watersheds help regulate the local supply of fresh water, ensuring that it is available year-round from surface waterways and underground aquifers. The later role will be deseribed in the next sections.

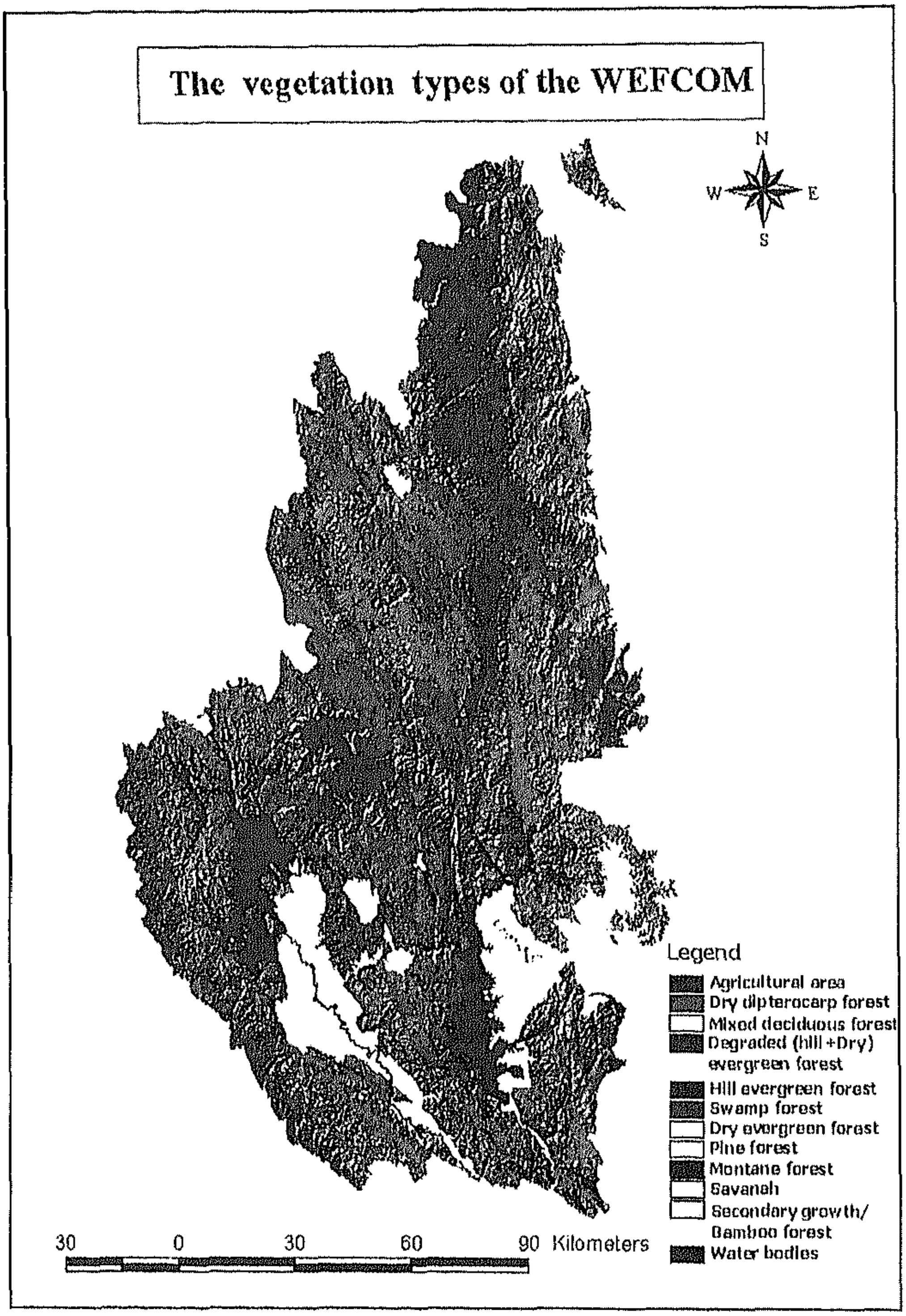


**Figure 1: The vegetation type of the Western Forest Complex interpreted from Landsat taken in year 2000 with groundcheck in 2001.**

Source : The Wastern Forest Complex Ecosystems Project

**Table 3: Forest area in the WEFCOM interpreted from Landsat taken in 2000 with groundcheck in 2001**

| Forest type | Areal distribution | | |
|---|---|---|---|
| | (Sq.km) | Million Rai | Percent |
| Agricultural area | 872.08 | 1.40 | 4.44 |
| Degraded (Hill+Dry) evergreen forest | 4882.18 | 7.81 | 24.85 |
| Dry dipterocarp forest | 410.00 | 0.66 | 2.09 |
| Dry evergreen forest | 1410.76 | 2.26 | 7.18 |
| Hill evergreen forest | 1053.17 | 1.69 | 5.36 |
| Mixed deciduous forest | 5982.79 | 9.57 | 30.45 |
| Montane forest | 14.33 | 0.02 | 0.07 |
| Pine forest | 20.22 | 0.03 | 0.10 |
| Savannah | 314.20 | 0.50 | 1.60 |
| Secondary growth/Bamboo forest | 4684.57 | 7.50 | 23.84 |
| Swamp forest | 3.91 | 0.01 | 0.02 |
| Total area | 19648.36 | 31.44 | 100.00 |

Source : Technical Section, WEFCOM Management Project, RFD

**5.4 The Hydrological Role of the WEFCOM**

5.4.1 The important source of water supply for the western region

Besides ecological role of western forest complex in terms of the diverse in wildlife and tropical vegetation , it encompasses many waterways which supply three of Thailand six river systems; the Chao Phraya (via the Sakaekrang),the Mae Klong (via the Khwae Yoi and Khwae Noi),and the Salween (via the Mae Kasat and Suriya)

The Sakaekrang river enclosed by 5,142 sq.km watershed area covering the main portion of Uthai Thani province and some part of Nakhon Sawan and Kampang Petch provinces. The four tributaries consisting of Huay Mae Wong (2,171sq.km) , Klong Poh (1,211sq.km) ,Huay Tab Salao (1,253 sq.km) and lower Sakaekrang sub watershed (1,557sq.km) drain 1,297 MCM annually to the Chao Phraya River. At present only one large reservoir of 160 MCM namely Tab Salao with others medium and 78 small reservoirs have been operated by the RID. The total area benefited from these projects is about 721,650 rai (6.25 rai = 1 ha)

The Mae Klong basin of 30,837 sq.km covering 8 provinces namely: Kanchanaburi , Ratchaburi, Samut Songkram, partly Supanburi, Nakhon Phrathom, Samut Sakorn, Uthaithani and Tak contributes about 7,973 MCM annually. This treatmendous amount of water drains from 10 sub-basins, they are : Khwae Yai basin (1,445 sq.km), Huay Mae Lamoong (910 sq.km), Huay Mae chan (862 sq.km), middle Khwae Yai (3,380 sq.km), Lower Khwae Yai (4,094 sq.km), upper Khwae Noi (3,947 sq.km),Huay Khayeng (1,015 sq.km), Huay Mae Nam Noi (947 sq.km), Lam Pha chi (2,453 sq.km), and lower Mae Klong floodplain (4,318 sq.km).

The Salween basin in the upper northern covers 29,500 sq.km in which about 17,920 sq.km is in Thailand and some part of Mynmar. Drainage area in Thailand covers 3 provinces: Mae Hongson, Tak and Chiang Mai. Annual runoff discharged from total area of Salween basin is about 112,561 MCM with the rate of 120.8 liters/second/sq.km. The sub-watersheds in Thailand contributes about 85.66 MCM/ annum with the rate ranges from 4.7 -5.5 liters/sec/sq.km. Recently, there have been few projects of reservoir and water pupping for irrigation which feed about 187,000 rai of cropping areas.

All these three main basins in the western region contributed totally about 9,321 MCM/annum to those living and farming downstream area. Althouth treatmendous amount of runoff (112,562 MCM/annum) discharged from 17,920 sq.km of Salween basin, only 86 MCM is discharged from small basin in Thailand. With the high annual rainfall and good condition of forest cover in headwaters which are mainly in the WEFCOM boundary, good quality water and proper timing have been regulated by the WEFCOM ecosystems an the two large reservoirs of Mae Klong basin.

## 6. THE CONSERVATION PLAN OF THE WEFCOM

The results obtained from research on the effect of watershed degradation caused by converting forest for agriculture without any conservation measures clearly reflect the important role of forest cover on water yield regulation. With the more demand of good water for domestic use as well as for irrigation in the future, conserving upstream under good condition is of prime important. Fortunately the conservation plan for the WEFCOM has been implemented. The plan comprises of 5 main parts, i.e., (1) Landuse zoning and implementation, (2) strengthen manpower efficiency, (3) research and database development, (4) ecological value promotion and (5) people's participation. The conservation plan is illustratied in Figure 2.

Land suitability classification as has been recommended by Tangtham et.al.(1994) shoud be considered for implementation. For those agricultural areas outside the WEFCOM , intensive conservation practices as well as water management by appropriate irrigation system should be developed for increasing efficiency in using both land and water resources so that the need for upland, which is now under forest cover, for cropping would be less from the increasing regional population.

## 7. CONCLUSION

Compare to the other regions, watershed degradation in the western region is relatively less even though there have been almost the same driving factors. The rugged terrain and harsh road access in the past resulted in remaining higher percentage of forest cover than other main basins in Thailand. This consits of 18,776 sq.km forest area under the WEFCOM conservation area. Of this figure,it is fortunately that about 18,730 sq. km. are under 11 National Parks and 6 Wildlife Sancturies. Besides the important ecological role in preserving one of the most abundant biodiversity of the world named as " ***The Tenasserim Hill Biogeographic Unit*** " , the WEFCOM also plays an essential role in regulating water yield with proper quantity, good quality and flow timing to the two main basins-the Mae Klong and Sakaekrang and a part of Salween basin. The existing conservation plan of the WEFCOM will help protect the superlative eco-hydrological roles of the western regional watershed. The plan, however, should be modified to meet the increasing population and the global changes in both environmental and economic aspects in the future.

## The WEFCOM Conservation Plan

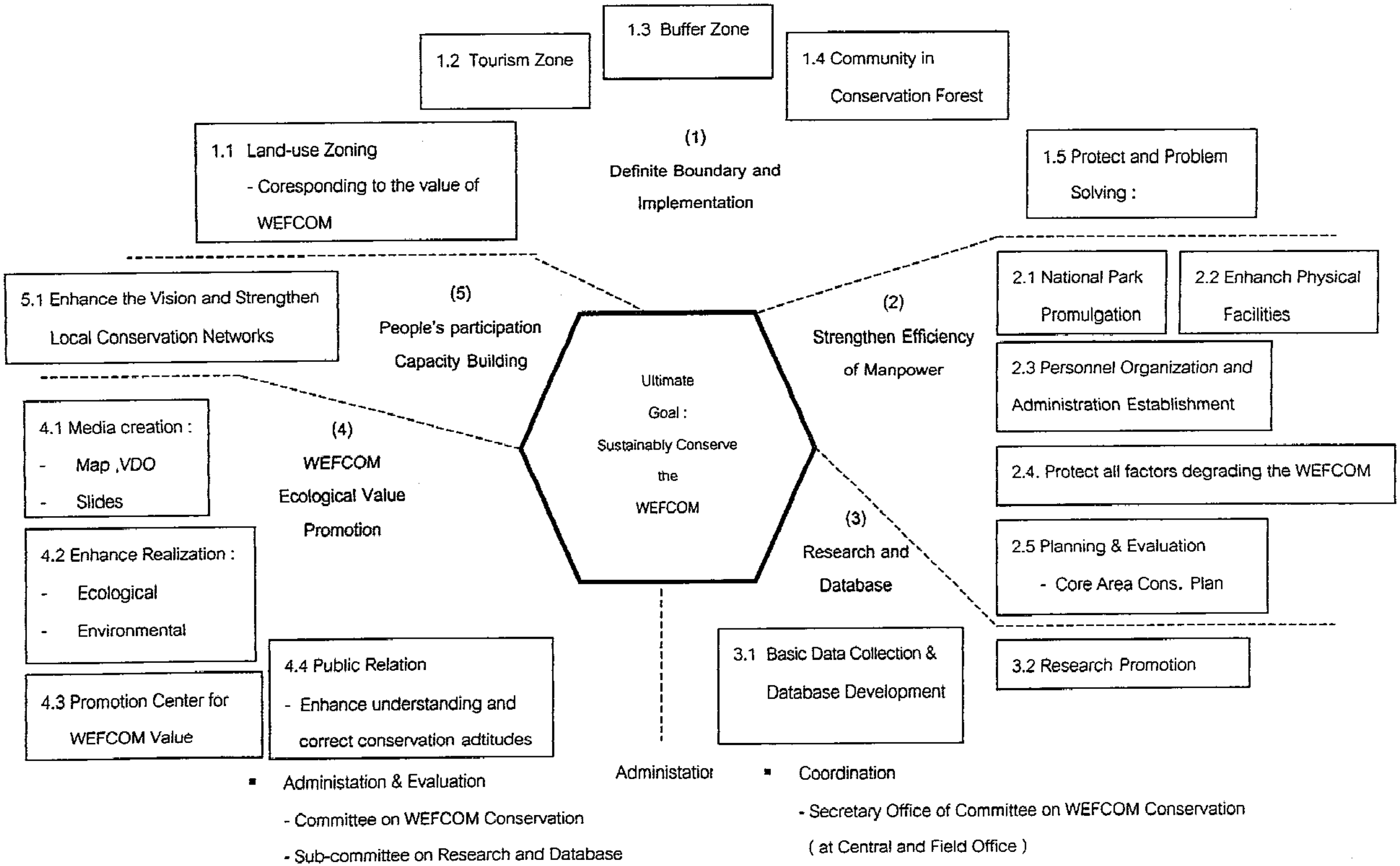


**Figure 2 : The WEFCOM Conservation Plan and implementation strategies proposed by the WEFCOM Management Project, RFD**

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Workshop on Watershed Degradation and Restoration of
the Lam Phachi River Basin, Thailand
Bangkok, November 29, 2002

# Current Status and Future Prospects of Farm Mechanization in Thailand*

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**Current Status and Future Prospects of Farm Mechanization in Thailand**

Suraweth Krishnasreni

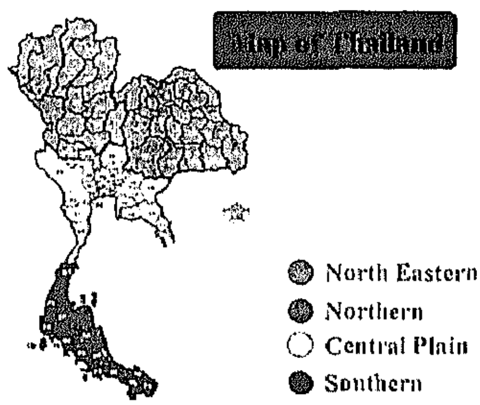
1

- Thailand is one of the world suppliers in agricultural production.
- 57 million population live in the rural areas
- Total area of 514,000 qu. Km of the country is under agriculture
- 17.5 million hectars of cultivated land

2

- 14 million hectars are rainfed
- Rice most important crop approximately 60% of total land
- Maize is the second crop 10% of total land
- other crop are rubber, cassava, sugarcane, mungbean, soybean, kenaf, groundnut and fruit crops etc.

3

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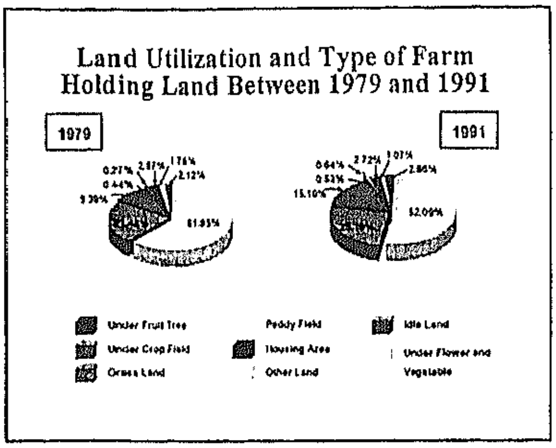
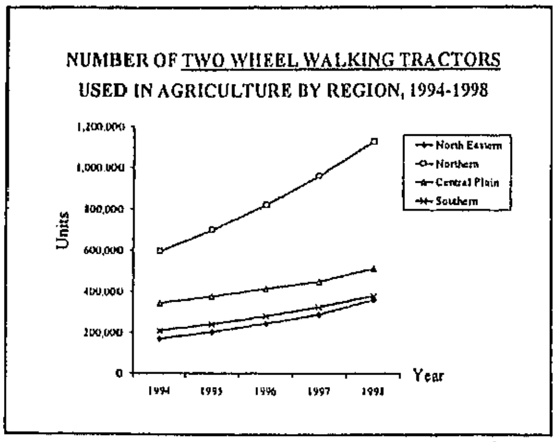
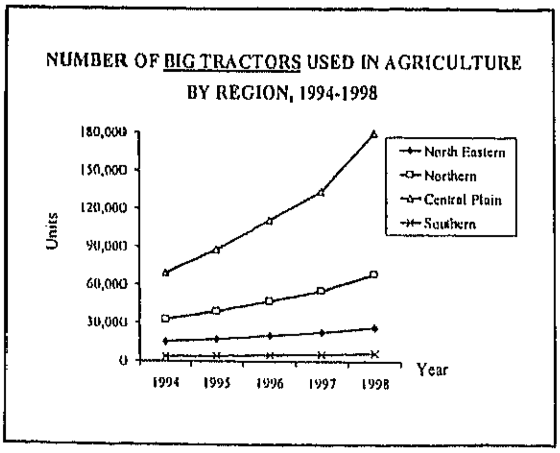

Land Utilization and Type of Farm Holding Land Between 1979 and 1991
1979
1991
Under Fruit Tree
Under Crop Field
Grass Land
Paddy Field
Housing Area
Other Land
Idle Land
Under Flower and Vegetable

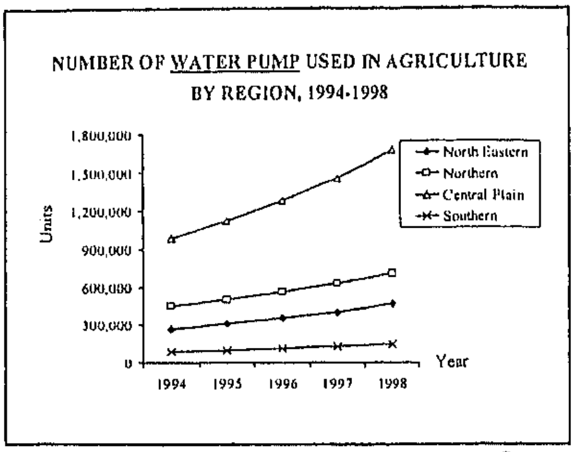
5


NUMBER OF TWO WHEEL WALKING TRACTORS USED IN AGRICULTURE BY REGION, 1994-1998
Units
Year
North Eastern
Northern
Central Plain
Southern

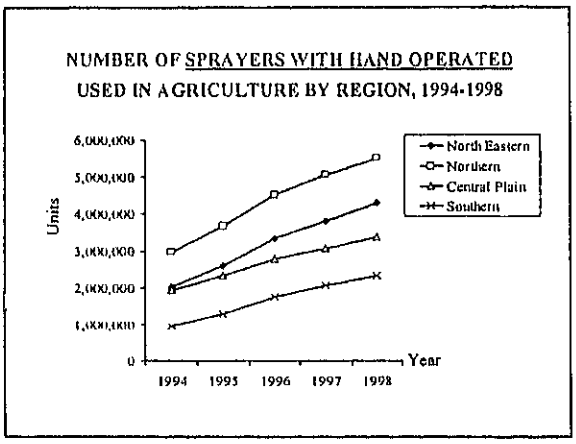
6


NUMBER OF BIG TRACTORS USED IN AGRICULTURE BY REGION, 1994-1998
180,000
150,000
120,000
90,000
60,000
30,000
0
Units
1994 1995 1996 1997 1998
Year
North Eastern
Northern
Central Plain
Southern

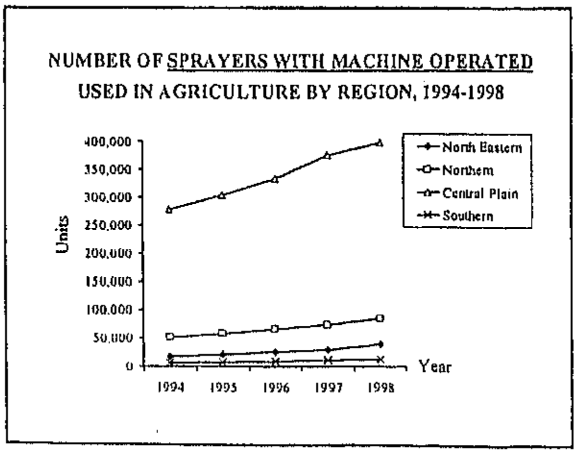
7


NUMBER OF WATER PUMP USED IN AGRICULTURE BY REGION, 1994-1998
1,800,000
1,500,000
1,200,000
900,000
600,000
300,000
0
Units
1994 1995 1996 1997 1998
Year
North Eastern
Northern
Central Plain
Southern

8

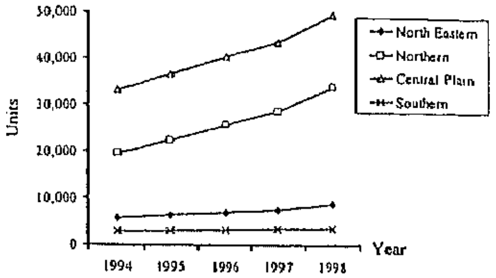

NUMBER OF SPRAYERS WITH HAND OPERATED USED IN AGRICULTURE BY REGION, 1994-1998
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
Units
1994 1995 1996 1997 1998
Year
North Eastern
Northern
Central Plain
Southern

9


NUMBER OF SPRAYERS WITH MACHINE OPERATED USED IN AGRICULTURE BY REGION, 1994-1998
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Units
1994 1995 1996 1997 1998
Year
North Eastern
Northern
Central Plain
Southern

10

NUMBER OF THRESHING MACHINE USED IN AGRICULTURE BY REGION, 1994-1998

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## Stages of farm mechanization development in Thailand

1. Primary Stage (1910 - 1950)
2. Development Stage (1951 - 1970)
3. Extension Stage (1971 - Present)

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## 1. Primary Stage (1910-1950)

- In 1910 tractors were imported for demonstration and dissemination
- New pattern of agriculture was intiated by Siltiporn Krisdukorn
- Mae Joe Agriculture Schools was established in Chiang Mai Province

13

## 2. Development Stage (1951-1970)

- Introduction new crops to farmers; maize, cotton, watermelon, vegetable and fruit etc.
- Large size tractors were imported

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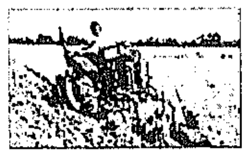
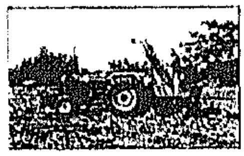
- Rice Department was established in 1954
- Agricultural Engineering Division was established in 1955.
- Large size tractor (70-80 hp) was used for land preperation





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## 3. Extension Stage (1971-present)

- High yield variety (HYV) of rice (high yield and non-photosensivity) was introduction by Rice Department
- Farmers in irrigated areas started planting rice 2 crops/year

16

- Two wheel tractor (powertiller) and four wheel tractor (6-25 hp) were locally made.
- Other agriculture machinery such a tilleage equipment, planter, thresher, harvester, dryer were used milling machine, etc.

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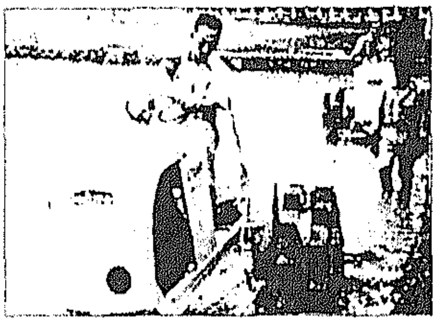

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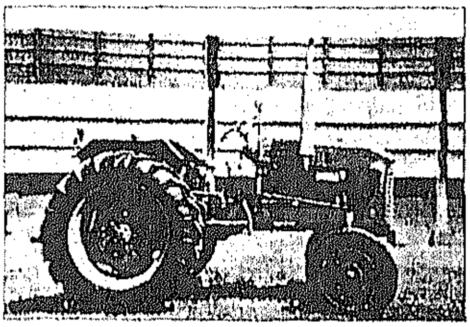

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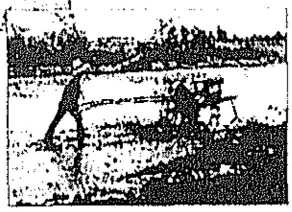

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Development of Planter, thresher, harvester, dryer for rice

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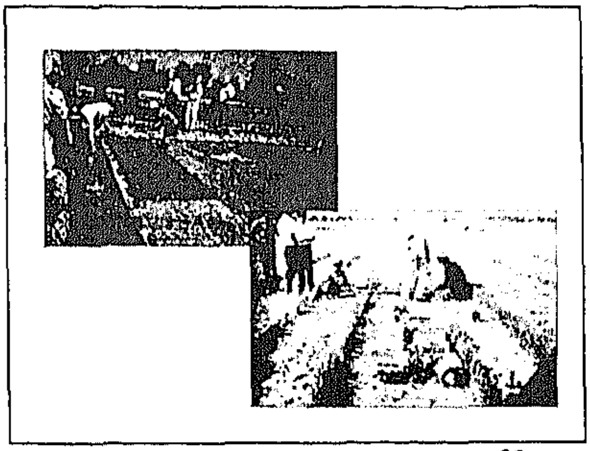

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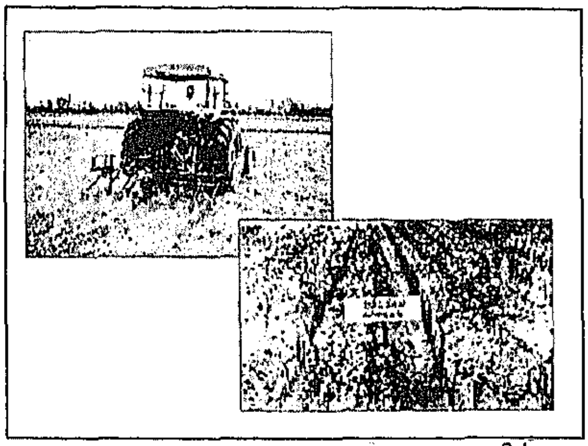

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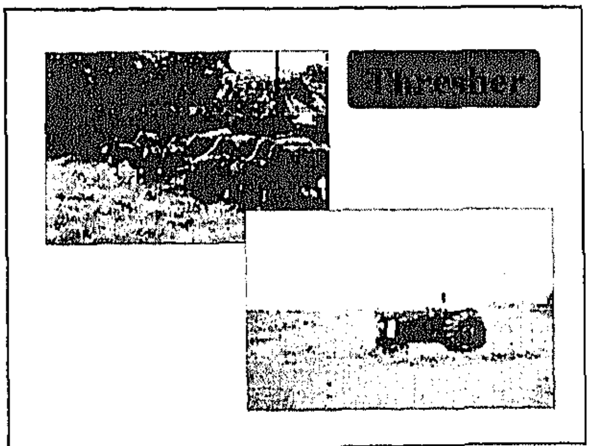


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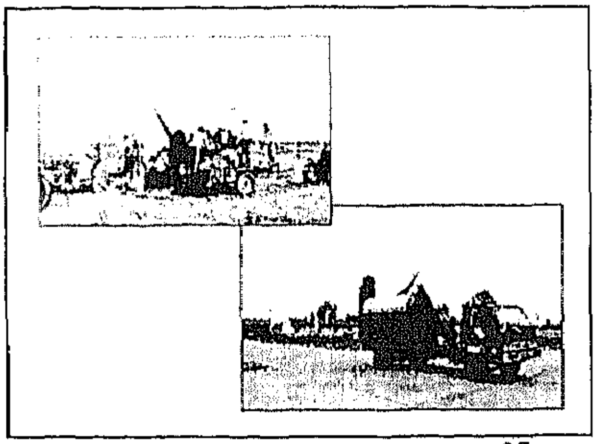

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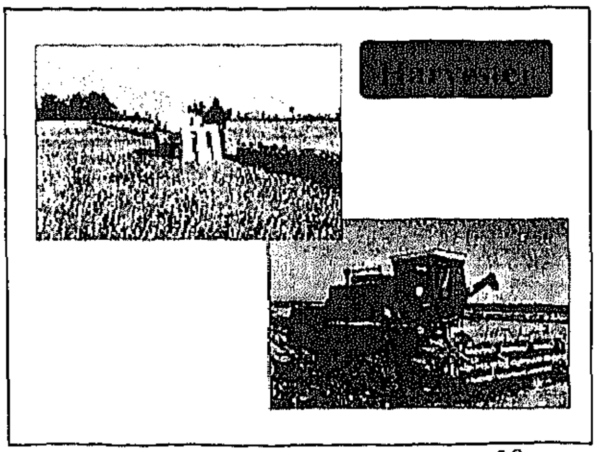


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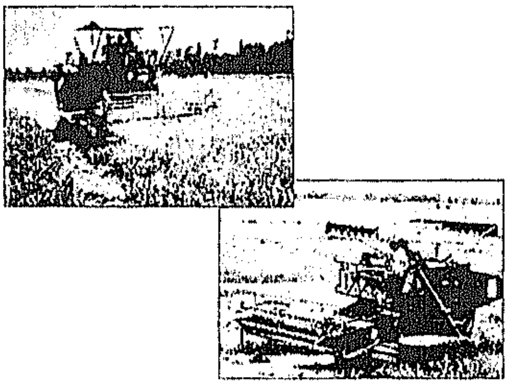

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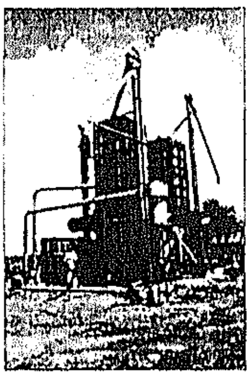

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## Agricultural Machinery Manufacturing Status

Manufacturers has been grouped is to 3 grouped

1) Small
   - up to 10 employees
   - 94 manufacturers or 40 %
2) Medium
   - more than 10 and 30 employees
   - 72 manufacturers or 34 %
3) Large
   - more than 30 employees
   - 40 manufacturers 20 %

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## Extension of Agricultural Machinery

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## Standardization

Standardization of Agricultural Machines has been established in powertiller, thresher, rice mill and combine harvester etc. However, the existing role in standardization had been emphasized on standard parts of powertiller in order to reduce cost of manufacturing and spare parts. The standard parts of transmission system (gear box) has been development to be used by local manufacturers.

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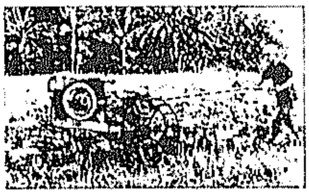
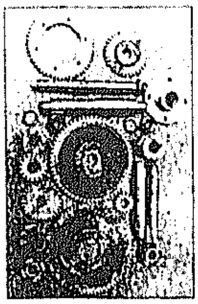

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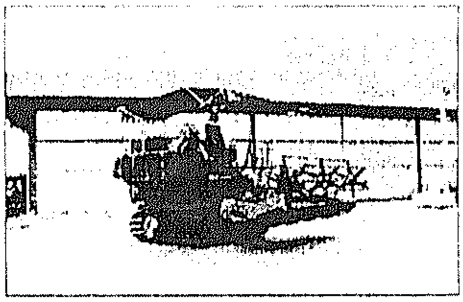

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## Thai Association of Agricultural Engineering (TSAE)

- Established in 1975
- Members 461

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## TSAE Activities

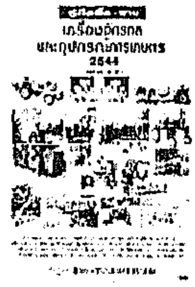
Annual National Seminars has been continuouly counducted

- 2000 in Bangkok (hosted by TSAE)
- 2001 in Khon Kaen (hosted by Khon Kaen University)
- 2002 in Chiang Mai (hosted by Mae Joe University)
- 2003 in Bangkok (hosted by Kasetsart University)

38

- Hand book for Buy-Sell Agricultural Machinery was biannually published in 1999 and 2001

- Joint with JODC (Japan Overseas Development Cooperations) and Ministry of Science, Technology and environment of Training course for local manufacturers



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## Trend of Farm Mechanization

During this period of economic crisis, farm mechanization still has important role in improving agricultural production. The research and development aims to these activities :

1. Collaborations among researchers from government sectors, educational institutes and manufacturers are the important aspects to ensure that the research works will be continuously implemented to marketing production.

40

2. Cost reduction in manufacturing by using standard parts among different manufacturers. Standard parts will be benefit to not only cost reduction for manufacturers but also more convenient for farmers to buy spare parts. Powertiller standard parts (gear box) project is the example of a successful project. This project, supported by the Thai Research Fund (TRF), is a collaboration among AED and 13 local manufacturers.

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3. Production value-added by improving machinery for postharvest technology and processing.

4. Researches under government fund are grouped into projects. Each project must be evaluated by the National Research Council. In the past, research proposals were evaluated by each organizations. By this new evaluation, researchers must propose the project concerning government policy.

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**Workshop on Watershed Degradation and Restoration of**
**The Lam Phachi River Basin, Thailand**
**Bangkok, November 29, 2002**

# Factors Affecting Hydrologic Characteristics in the Lam Phachi River Basin

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***Abstract***

Extraction of hydrologic characteristics in a watershed area having limited hydrologic data is needed for the conservation and sustainable use of soil and/or water resources. In this paper, hydrologic characteristics are extracted and discussed using data in the upper reach of the Lam Phachi River basin through the master recession and flow duration curves. The reliable baseflow contribution and lowflow regime aspect depend on the amount of annual rainfall. And the result of annual water balance means that the groundwater storage is consumed with the evapotranspiration function over the drought water year. Also the statistical analysis is used to determine whether climate change has occurred. Here we use rainfall data observed from 1952 to 2001 in the No.47022 site. Finally it is found that rainfall for a given non- exceedance (probability year) gradually decreases, and in addition the probability year for a given rainfall is larger than previously (1952-1976).

Keywords: water balance, climate change, water resources, Gumbel distribution

## 1. INTRODUCTION

In studying the conservation and the sustainable use of soil and/or water resources in a watershed area, it is fundamental to examine and discuss which factors affect hydrologic characteristics in a given area. Especially, in the case of discussing on the conservation and development of water resources, the relationship between climate change and hydrologic characteristics, and water balance have to be examined.

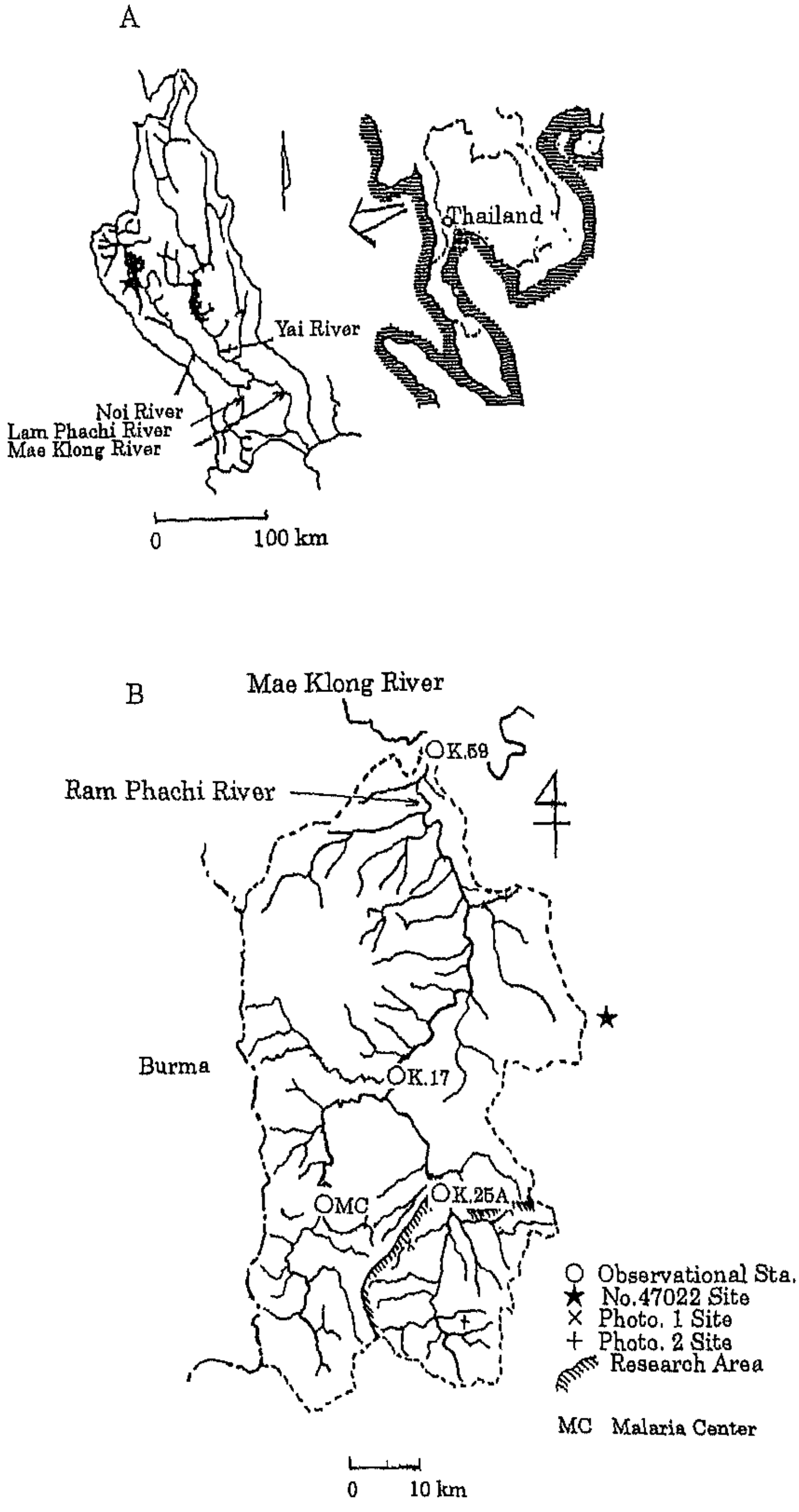



Figure 1. Location (top) and outline (bottom) in the research area.

It has been shown by many scientists that the potential storage capacity of water resources and drought and/or flood event characteristics in a watershed area may be changed with global climate change and forest deforestation in East –South Asia. So far various interesting reports have been shown on the climate change (for example, Hurd et al. (2000), Kanae et al.(2001), Chikamori & Nagai (2002)).

This paper focuses attention on the upper reaches in the Lam Phachi River, and addresses the following questions: (1) To what extent can the short term data be used to discuss water balance and hydrologic characteristics? (2) Does climate change occur in this study area?

## 2. DESCRIPTION OF THE RESEARCH WATERSHED AREA

### 2.1 Outline

The Lam Phachi river is a tributary of the Mae Klong river which is located in western Thailand and borders with Burma (Figure 1A). The watershed area is 2,590 $km^2$, and it is bordered by a mountain range with altitudes of about 1,000 m. The topography in the western part of the basin is mainly mountainous and hilly, and in addition several falls are found in the upper reaches (located by × site in Figure 1B, Photograph 1). In contrast, the land use in the eastern part of the basin is mostly low land, and there are a lot of ponds for irrigation and drinking from the upper reaches to the middle reaches of the basin area (located by + site in Figure 1B, Photograph 2) .

### 2.2 Data collection and observational system

The hydrologic observational locations used for analysis are shown in Figure 1B. The K.25A , K.59 and K.17 sites are managed by RID, and rainfall in the malaria center are observed by the Rajanagarindra Tropical Disease International Center (RTDIC). Water levels are observed at K.25A, K.17 and K.59, and record term at K.25A and K.17 sites are comparatively long. Evaporation is measured with the Class A-pan in K.59A and K.17 sites. Also the No.47022 rainfall station used for climatic change analysis (Section 5) has been managed by the Meteorological Department for over 50 years. The observed rainfall, flow, and evaporation are arranged using daily values.

The following analysis is mainly carried out by using hydrologic data in the K.25A watershed area (380 $km^2$). Table 1 gives record lists of hydrologic data used for the following hydrologic analysis.

Table 1. List of data used

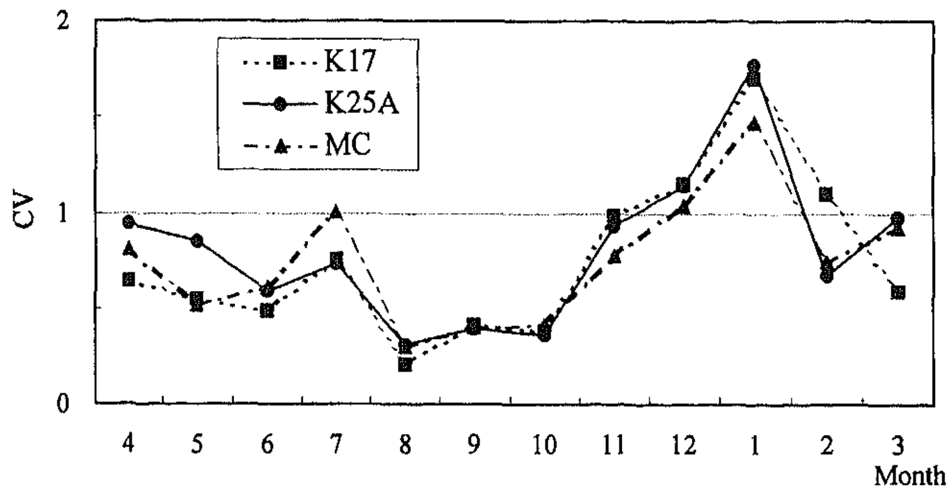
| Station | Rainfall | Discharge | Evaporation* | Record length |
|---|---|---|---|---|
| K.25A | ○ | ○ | ○ | 1995～2001 |
| K.17 | ○ | ○ | ○ | 1995～2001 |
| Malaria Cen. | ○ | × | × | 1995～2001 |
| No. 47022 | ○ | × | × | 1952～2001 |

* Observed with A Class Pan.

## 3. HYDROLOGIC CHARACTERISTICS

### 3.1 Spatial distribution of rainfall

The coefficient of variation (CV) for monthly average rainfall, calculated for the period of record, in K.25A, K.17 and Malaria Center is compared in Figure 2. Although the CV fluctuation for the three rainfall sites is similar from August to October, the CV values for other months are different respectively. This aspect suggests that the spatial distribution of rainfall in each site is homogeneous during the three months from August to October. On the other hand, during the dry season it is very heterogeneous.




### 3.2 Discharge time series

Figure 3 shows the autocorrelation function (ACF) for discharge time series in K.25A site. Examples of a droughty year* (solid line) and a heavy rainy year** (dotted line) are respectively compared. That comparative aspect indicates that the reliable baseflow contribution in the rainy year is stronger than that for the doughty year. From this respect, it is apparent that the reliable baseflow contribution depends on the amount of rainfall. Therefore, it is essential for water resources management and/or planning to examine how climatic change affects the rainfall situation. In section 5, this issue is discussed at length.

### 3.3 Extraction of droughty characteristics

It is important for the development and preservation of water resources how to extract useful information from the low flow data. The master recession curve and flow duration curves are very representative expressional forms for low flow recession characteristics. Then we discuss the characteristics of low flow with the above mentioned two curves.

The recession limb of the discharge hydrograph, if no recharge is taking place, is termed as the recession curve. This curve represents the total effect of various

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* water year annual rainfall is smallest during the given record term.

** water year annual rainfall is largest during the given record term.

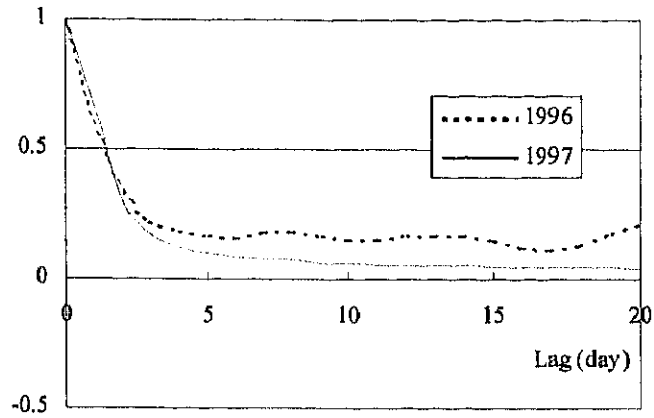



Figure 3. ACF of daily discharges

physical recession characteristics, and the curve constructed by combining individual recession limbs is usually termed the master recession curve. The recession constant may be defined as the total index of low flow characteristics.

The following equation is quoted by many hydrologists as the expressional equation that represents the recession limb during a long period without rain:

$$Q_t = Q_0 \exp(-\lambda t) \qquad (1)$$

where $Q_t$ is the discharge at time T, $Q_0$ is the initial discharge, and $\lambda$ is the recession constant.

The recession constants were automatically and objectively estimated by the construction method presented by Sugiyama (1996) .

Figure 4 shows the master recession curve for K.25A site. The recession constant in this study area is 0.025 $d^{-1}$, and this value is larger than that in Srinagarind Dam basin area (0.013 $d^{-1}$), and is similar in value (0.024 $d^{-1}$) to Vajiralongkorn Dam (old name is Khao Leam Dam) (H. Sugiyama et al., 1999). This result indicates that the reliable baseflow contribution in K.25A basin area is a little less than that in the S Dam basin area.

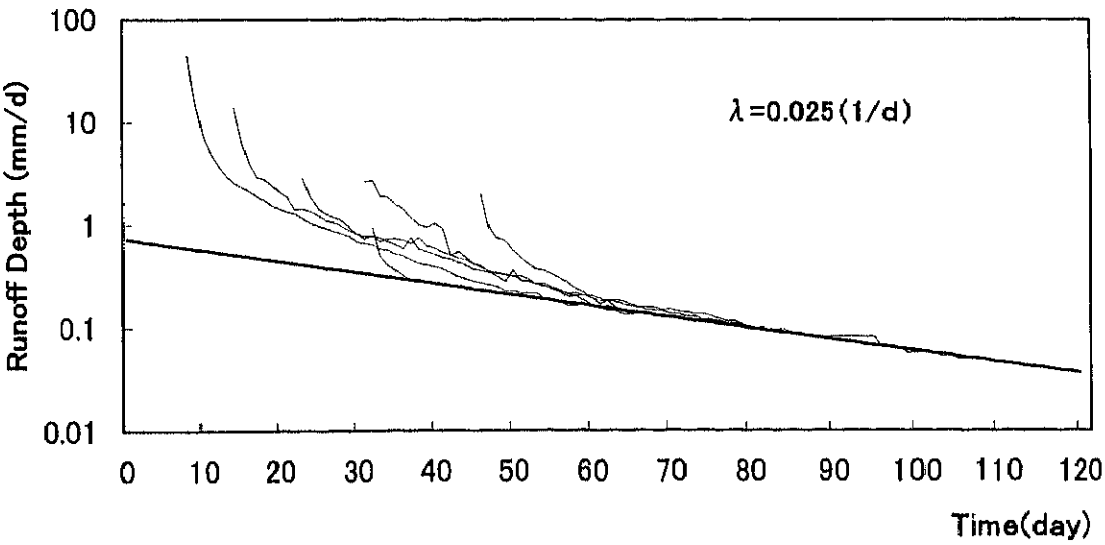



Figure 4. Master Recession Curre for the K.25A Site

The Flow duration curves for K.25A site are shown in Figure 5. This figure is drawn with discharge arranged in order of descending magnitude. The magnitude of stream discharge is plotted as ordinate against the corresponding percent of time, the probability that an arbitrary discharge will be equaled or exceeded, as abscissas. The average FD curve is constructed using daily discharge of successive years. From this figure, the runoff depth exceeded 80 percent of time, recognized as an index of low flows in Thailand, is 0.06 mm/d in rainy water year, 0.02 mm/d in drought year. These values are small because the persistence of flow in this study area is low (Figure 4, $\lambda$=0.025(d-1). And that difference is about three times, demonstrating that flow regime is dependent on the amount of annual rainfall.

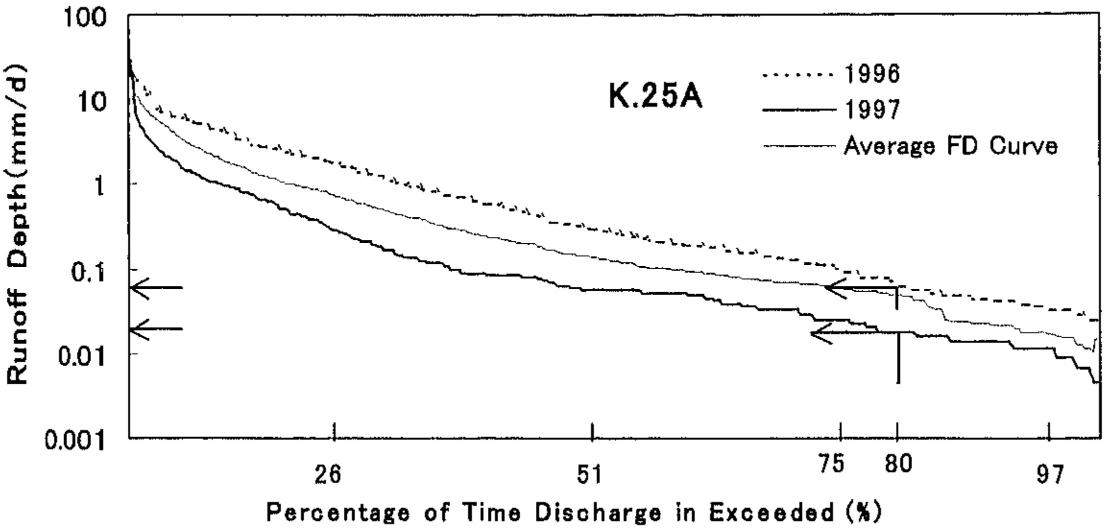



Figure 5.Flow duration curve for K.25A site.

## 4. WATER BALANCE

The water balance in the K.25A basin area was examined over 1996 and 1997 water years. Here we use average areal rainfall estimated by the Theisen method, and water level observed in K.25A site. Evapotranspiration is estimated multiplying evaporation observed in K.25A site by 0.7. Monthly water balance is given in Table 2 respectively. From the comparison of water years 1996 (annual rainfall 1,848 mm) and 1997 (annual rainfall 1,057 mm), it is understood that the percentage of evapotranspiration components to rainfall in July through November is low in 1996, high in 1997, and the percentage of runoff component is high in 1996, low in1997. Also the percentage of the change in storage components are almost similar to each water year.

The annual water balance is shown in Table 3. It is revealed comparing the result in water year 1996 that in water year 1997 the percentage of storage to annual rainfall is minus 36.7 %, and the value of evapotranspiration is over 100 %. And also it is indicated that although the change of storage is generally neglected in the estimation formula (Equation (2)) for annual water balance, the calculation of change in storage is especially needed in drought years. In other word, it means that the groundwater storage is consumed with the evapotranspiration function over the drought water year.

$$P = Q + Evap. \pm \triangle S \quad (2)$$

where, P is rainfall, Q runoff, Evap. evapotranspiration, $\triangle S$ change of storage.

Table 2. Monthly water balance in the K.25A basin area

Unit: mm

| Water year / Month | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | P | Q | Evap | $\pm\triangle S$ | P | Q | Evap | $\pm\triangle S$ |
| Apr | 110.2 | 2.9 | 121.3 | -14.0 | 73.4 | 1.0 | 128.4 | -56.0 |
| May | 266.7 | 12.0 | 139.5 | 115.2 | 27.4 | 0.9 | 122.1 | -95.6 |
| Jun | 125.1 | 18.3 | 104.8 | 2.0 | 35.4 | 0.4 | 125.8 | -90.8 |
| Jul | 348.9 | 52.5 | 64.9 | 231.5 | 103.1 | 0.6 | 95.9 | 6.6 |
| Aug | 124.2 | 27.4 | 89.2 | 7.6 | 151.0 | 1.6 | 107.9 | 41.5 |
| Sep | 357.7 | 173.6 | 69.8 | 114.3 | 257.2 | 16.7 | 72.8 | 167.7 |
| Oct | 295.4 | 188.4 | 63.2 | 43.8 | 175.6 | 39.5 | 81.8 | 54.3 |
| Nov | 175.3 | 95.1 | 61.6 | 18.6 | 226.6 | 135.0 | 67.3 | 24.3 |
| Dec | 9.4 | 13.1 | 64.2 | -67.9 | 0.0 | 8.5 | 81.7 | -90.2 |
| Jan | 0.8 | 3.7 | 84.1 | -87.0 | 0.6 | 3.2 | 101.7 | -104.3 |
| Feb | 13.3 | 1.5 | 95.5 | -83.7 | 0.8 | 2.0 | 105.2 | -106.4 |
| Mar | 20.9 | 1.1 | 130.4 | -110.6 | 5.4 | 1.5 | 142.4 | -138.5 |
| Total | 1847.9 | 589.6 | 1088.5 | 165.8 | 1056.5 | 210.9 | 1233.0 | -387.4 |

Table 3. Annual water balance in the K.25A basin area

| Water year | Rain fall | Discharge | Evap. | Change of storage |
|---|---|---|---|---|
| 1996 | 1,847.9 | 589.6 | 1,088.5 | 165.8 |
| 1997 | 1,056.5 | 210.9 | 1,233.0 | -387.4 |

Unit:mm/y

* Estimated by the Theisen meyhod.

## 5. DOES CLIMATE CHANGE OCCUR IN THIS STUDY AREA?

It is important for the preservation and management of water resources to examine how hydrologic characteristics are affected by global climate change. We attempted to extract information for climate change by examining rainfall data with statistical analysis. In this analysis, the daily rainfall record observed in the No. 47022 rainfall site (Figure 1B, ★) outside of the study area was used. We firstly defined rainfall during a series of rainy days as total rainfall, and secondly record length (from 1952 to 2001) was divided into 25 year terms respectively. Finally, the frequency and distribution of each given term was examined.

Although several extreme value distributions are presented, Gumbel distribution is applied for annual maximum of total rainfall and daily rainfall in each given term. The Gumbel distribution is given as follows.

$$F(x) = \exp(-e^{-y})$$

$$f(x) = a \cdot \exp(-y - e^{-y}) \qquad (3)$$

$$y = a(x - x_0), \ -\infty < x < \infty$$

where the notation F(x) and f(x) denote the probability cumulative function and density function, respectively, of the random variable x, and a and $x_0$ are parameters.

The relationship between annual maximum of total rainfall of a storm and non-exceedance probability for the two periods of 25 years is respectively shown in Figure 7. Non-exceedance probability is estimated with the following Weibull Plot (Equation (4)).

$$F_j = N+1-j / N+1 \qquad (4)$$

where $F_j$ is non-exceedance probability, j order, N data number.

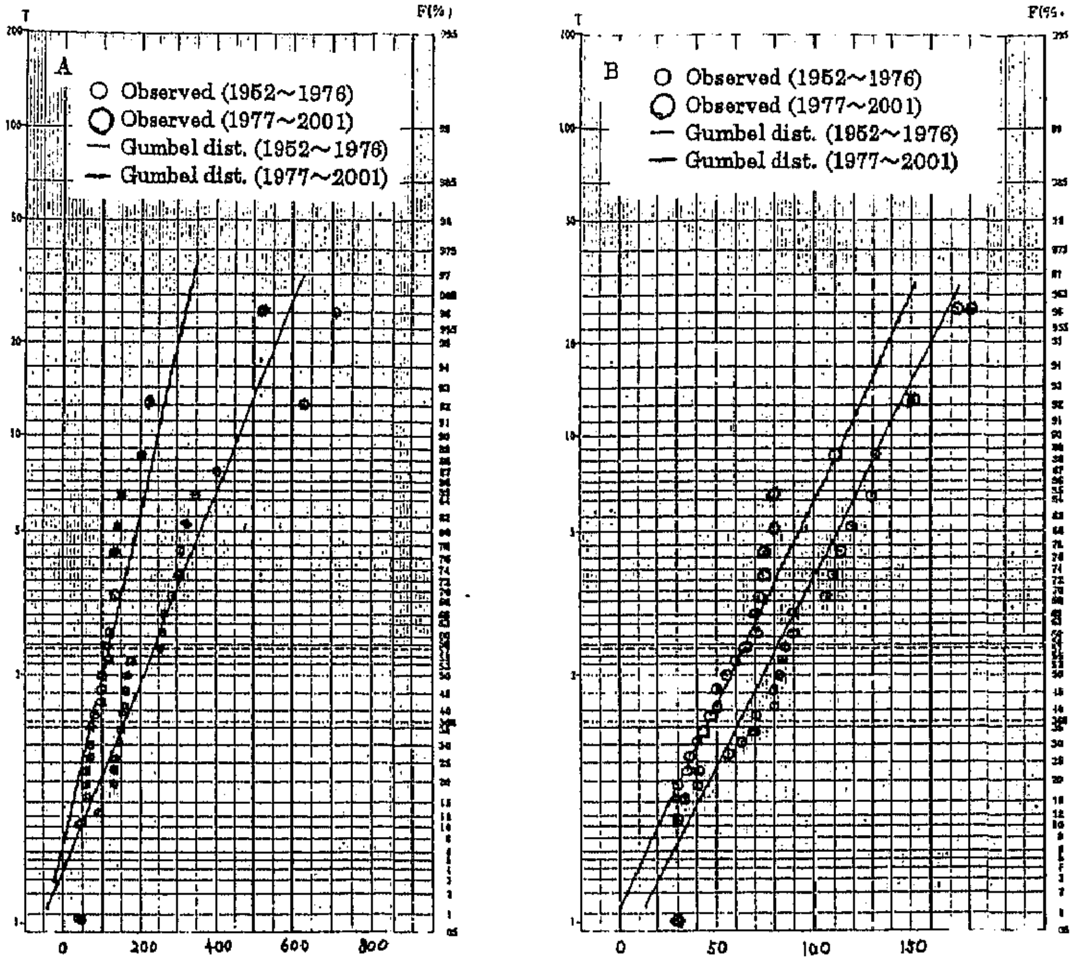
Figure 6A shows that plotting position for the recent 25 year term (1977-2001) moves to the left side. This aspect indicates that rainfall for a given non- exceedance (probability year) gradually decreases, and in addition the probability year for a given rainfall is larger than previously (1952-1976). Also the straight slope of the Gumbel distribution is larger than previously.

In Figure 6B, the distribution for the annual maximum daily rainfall is drawn with the same procedure. Although a changing trend of distribution is not so obvious as in the case of total rainfall, it is possible to conclude that the rainfall situation is inclined to change.

## 5. CONCLUSIONS

Hydrologic characteristics and climate change in the Lam Phachi River basin were discussed by using hydrologic data in K.25A site. By using hydrologic data of short record term, fundamental information for hydrologic characteristics can be extracted through the master recession curve and flow duration curve. It was shown that the reliable baseflow contribution depends on the amount of annual rainfall, and information for water resources can be extracted with the flow duration curve.

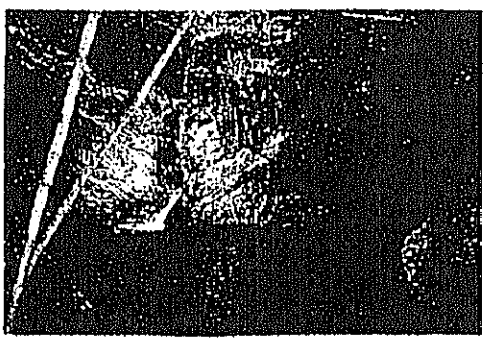
The annual maximum of total rainfall during a series of rainy days and daily rainfall for the same probability year decreases. So reconsidering magnitude of design floods and/or droughts for constructing hydraulics structures may be needed.



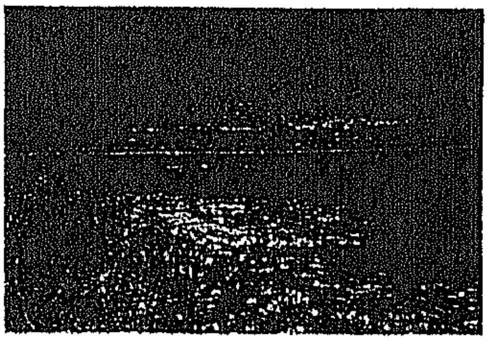

(a) Annual maximum of total rainfall (mm).

(b) Annual maximum of daily rainfall (mm/d).

Figure 6. Plotting on Double exponential distribution paper.



Photograph 1. Fall view.



Photograph 2. Pond view.

ACKNOWLEDGEMENTS.

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# Human Impact on Soil Erosion of the Lam Phachi River Basin
## - From a Viewpoint of Infiltration Capacity -

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***Abstract***

This paper focuses on soil erosion problems in the Lam Phachi River basin. The10-minute interval rainfall data in the target area of the upper basin suggested that the rainfall pattern was characterized by strong intensity and short duration. As a result of infiltration tests, the forestlands had higher final infiltration rates (44-160 mm/hr) than the pineapple and cassava fields (5-39 mm/hr), though they had considerable rate variation depending on the soil characteristics. Thus, strong rainfall intensities and low infiltration rates caused severe soil erosion (69, 163 t/ha/yr) in some areas of the pineapple fields on gentle slopes in the target area. Vegetation surveys revealed that forests on the fringe of croplands were secondary forests caused by frequent and intensive disturbance due to human activities such as logging and fires. This study indicated two stages for soil erosion problems in the basin. The first stage is that the forest conversion to cultivated lands was practiced in the entire basin during the past two or three decades. The second stage is that dynamic cultivation changes have occurred on the converted land related to a shift to a more cash-crop-oriented culture since the 1990s. Recent dynamic changes in cultivation might have already caused the vicious cycle of watershed degradation in some areas of the basin, e.g., pineapple fields on gentle slopes of the upper region. We now need protection measures against accelerated erosion, and appropriate agricultural practices in the context of sustainable agricultural production and environmental protection to maintain the sound watershed.

**Keywords: soil erosion, infiltration capacity, human impact, pineapple field**

## 1. INTRODUCTION

The conversion of forests to cultivated lands can lead to soil erosion and declining yields, and agricultural changes shifting from subsistence to cash crops can also lead to increasing erosion and declining productivities. These conversions and changes result from natural degradation hazards, the direct and underlying causes of watershed degradation. The natural degradation hazards are conditions of the natural environment which lead to high susceptibility to degradation, e.g., steep slopes, high intensity rainfall and drought in the dry season. The direct causes include deforestation of fragile land making it unsuitable for sustained agricultural use, shifting cultivation without adequate fallow periods, and failure to adopt soil conservation management practices. The underlying causes are land shortages, land tenure, economic pressures, poverty, and population pressures (FAO, 1994). Thus human-induced impacts are strong driving forces for watershed degradation. Soil erosion can be the most serious mechanism of watershed degradation because it adversely affects not only agricultural productivity through reducing the availability of water, nutrients, and organic matter, but it also causes serious off-site effects, i.e. eroded sediments fill riverbeds, lakes, and reservoirs, significantly reducing their roles for floods, irrigation, hydropower, fisheries, and the environment. In the Lam Phachi River basin, forests were converted to cultivated lands in the entire basin during the past two or three decades. Recently, dynamic cultivation changes have occurred on the converted land related to a shift to a cash-crop culture. These changes might have caused soil erosion problems in croplands, particularly pineapple fields on gentle slopes in the upper region of the basin.

This paper describes the infiltration capacity, soil characteristics, and erosion rates in adjacent plots of the forestland and the cropland, particularly pineapple fields, and the human impact on soil erosion to clarify the mechanism of the watershed degradation of the Lam Phachi River basin.

## 2. STUDY AREA

The Lam Phachi River drains a 2620 $km^2$ basin whose ridge is the Myanmar border in the western part of Thailand (Fig. 1). It runs north and joins the Huai Tha Khoei River, the largest tributary at Ban Tha Khoei, the center of the basin. The relief of the basin declines from 1020 m in the headwaters to 30 m at the confluence with the Khwae Noi River. The basin receives an average of 1130 mm rainfall annually, 90 percent of which falls during the rainy season between May and November, and 10 percent falls during the dry season between December and April (Maita et al., 1998). Igneous rocks of the Mesozoic Period and sedimentary rocks of the Paleozoic Period underlie the headwaters and the ridge along the Myanmar border of the basin. Sedimentary rocks of the Quaternary Period underlie the lowland of the basin. The analysis, using remotely sensed data in 1994 and 1995, indicated that the forestland ratio to the entire basin was 56 percent, and the agricultural land ratio was 37 percent (Maita et al., 1999).

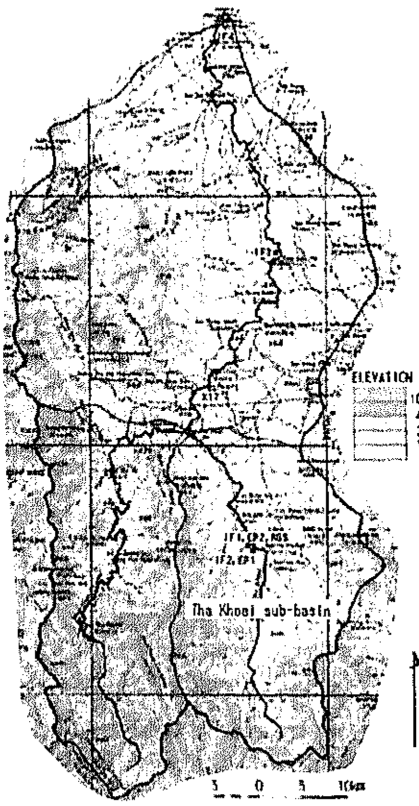


Fig. 1 Map showing the study area,
IF1-IF4; Infiltration capacity test site,
EP1-EP2; Soil erosion measurement plot,
RGS; Rain gage station,
K17; Hydrological monitoring site of RID

## 3. INFILRATION CAPACITY, RAINFALL INTENSITY AND SOIL EROSION

Soil erosion in the cropland mostly resulted from the Horton overland flow that is produced when the rainfall rate exceeds the ability of the soil to absorb water (Kirkby, 1978).

Therefore, the infiltration capacity of soil and rainfall intensity are the most important physical factors for soil erosion.

**3.1 Site Selection**

3.1.1 Infiltration capacity test, soil and vegetation surveys

To compare the infiltration rate of the forestland with the cropland, we selected four sites (IF1 to IF4) along the Lam Phachi River and the Huai Tha Khoei River that is the main tributary (Figs. 1 and 2). Each site has two adjacent plots to test infiltration rates of forestland and cropland, with the exception of the IF4 site. Main crops of the basin are pineapple, sugarcane, cassava, maize and vegetables. Pineapple is cultivated on the gentle slope areas such as foothills, rather than the flat areas such as flood plains, whereas the other crops are cultivated on the flat areas. In the IF1 and the IF2 sites that are on hilly areas, pineapple fields were selected to compare with the infiltration rate of the forestland, whereas in the IF3 site on the flood plain, sugarcane fields were selected. In the IF4 site on the flood plain, only the infiltration rate of the cassava field was tested.

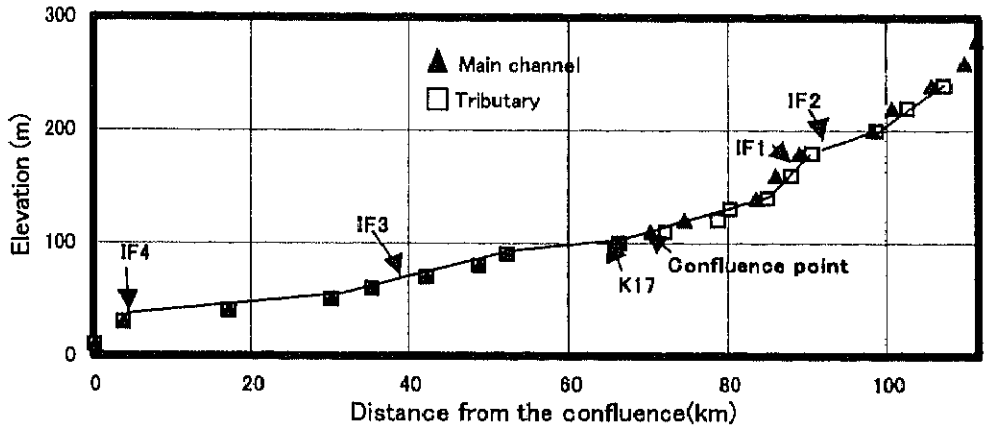


Fig. 2 Longitudinal profile of the Lam Phachi River

We also conducted a soil survey (IF1 to IF4) and a vegetation survey (IF1 to IF3) to investigate the influences of soil and vegetation characteristics on the infiltration capacity. Since forest surrounds the crop fields, pineapple fields are thought to have a similar soil condition to the forest before logging, and their structure might give us the intensity and the frequency of artificial disturbances in the forests. The tests and surveys were carried out from late July to early August 2001.

3.1.2 Rainfall intensity and soil erosion

We set the rain gage station (RGS) in the center of the Huai Tha Khoei sub-basin in early October 2000 to obtain the short interval rainfall data (Fig. 2). Main crops of the upland areas in the Huai Tha Khoei River sub-basin, the research target area for investigating the human impact on soil erosion, are pineapple, sugarcane, and cassava. Since we can find soil erosion in a lot of the pineapple fields on the sloping areas, we set two plots (EP1, EP2) on such sites near the RGS and surveyed the rill and gully erosion in late November 2000, the end of the rainy season (Fig. 1).

**3.2 Methods**

3.2.1 Infiltration capacity test, soil and vegetation surveys

We measured the infiltration capacity using a cylinder type infiltrometer. To avoid divergent flow, a 40 cm diameter infiltration ring was put inside a 60 cm ring. The outer ring was flooded simultaneously with the inner ring to serve as a buffer to help ensure one-dimensional vertical flow from the inner flow. The rate of water depth decrease in the inner ring was then measured and maintained at a roughly constant depth for the duration of the test.

However, the infiltration rate measured by the infiltrometer was generally higher than that of natural rainfall.

We also surveyed the soil profile, texture and hardness by digging a trench near the infiltration capacity measurement site. The soil hardness of each horizon in the soil profile was measured using a push-cone type soil hardness meter. The soil was then sampled from each horizon, and its particle size was analyzed in the laboratory to classify the soil texture, which was determined using the classification standardized by the U.S. Department of Agriculture.

We set up three vegetation survey plots in the forest adjacent to the pineapple fields (IF1 and IF2), one survey plot in the forest adjacent to a sugarcane field (IF3), and one survey plot in the forest in the mountain area considered to be covered by the original forest (MD). In each survey plot, all stems higher than 1m were identified to the species level, and the heights of these stems were measured. Stems with a height over 1.3m were measured at DBH (1.3m height).

3.2.2 Rainfall intensity and soil erosion

To automatically obtain the short-interval rainfall, we used a tipping bucket rain gage and a data logger that was set to 10-minute intervals. To investigate the form and the volume of soil erosion that occurred in the pineapple fields, we surveyed the patterns, and the width, the depth, and the length of the rills and gullies in the about 20×20 m plots.

**3.3 Results and Discussions**

3.3.1 Infiltration capacity and soil characteristics

The results of soil profile, texture and hardness surveys at the trench near the infiltration capacity test site are shown in Figs. 3 to 9. The results of infiltration capacity tests using a cylinder-type infiltrometer are shown in Figs. 10 to 13. Though many factors influence the shape of the infiltration capacity curve, the most important controls are rainfall characteristics (intensity, duration, and drop size), soil characteristics (texture, structure, initial moisture content, clay mineralogy, and condition of the soil surface before rainfall), vegetation and land use. As shown in the infiltration capacity curves obtained by the tests (Figs. 10 to 13), the infiltration rate is high in early stages, but tends to decrease monotonically and asymptotically approach a constant rate that is often termed the final infiltration rate. The early stage of curves shows that water penetrates as fast as it arrives, and the water supply rate determines the infiltration rate; i.e., the process is supply-controlled (Hillel, 1998). In contrast, the latter and final stages show that the soil controls the rate of infiltration, either at the surface or within the profile, and the process becomes soil-controlled (Hillel, 1998). Thus, the latter process determines the actual infiltration rate.

Comparing the final infiltration rate of forestland with that of the pineapple field at the IF1 site, the rate of forestland (160 mm/hr) is considerably higher than that of pineapple field (28 mm/hr)(Fig. 10). The IF1site is located at the foot of hilly land. Both soils are considerably deep (more than 80 cm in depth) and are similar in soil profile, texture and hardness (Figs. 3 and 4). At the IF2 site, the rate of forestland (44 mm/hr) is not so different from the pineapple field (39 mm/ hr) as compared with the IF1 site (Fig. 11) The IF2 site is located at the top of hilly land. Neither soil is so deep (30-40 cm in depth), and soils are similar in soil profile, texture and hardness (Figs. 5 and 6). At the IF3 site, the rate of forestland (130 mm/hr) is considerably higher than that of the sugarcane field (20 mm/hr) (Fig. 12). The IF3 site is located on the floodplain near the river. Judging from the soil texture and hardness, the forest plot for the infiltration test may be selected on a sand dune of the former river channel (Fig. 7). Soil characteristics of the forest plot are considerably different from those of the sugarcane plot, although the soil of both plots is quite deep (more than 80 cm in depth) (Figs. 7 and 8). The IF4 site containing the plot to conduct the infiltration test for the cassava field, is located on the floodplain just above the confluence of the Khwae Noi River. The rate of the cassava field (5 mm/hr) is quite low (Fig. 14). The soil profile, texture and hardness of the field suggest that indurated layers (called hardpans) might be formed in the layer below 20 cm depth from the surface (Fig. 9). Hardpans cause a low final infiltration rate.

As previously mentioned, at the IF1 site the final infiltration rate of the forest plot is considerably higher than that of the pineapple plot. At the IF2 site, however, the difference of the final rate between the forest plot and the pineapple plot is not significant. Since the IF1 site differs from the IF2 site in soil depth, but not in the other soil characteristics, this might suggest that the first factor controlling the final infiltration rate is soil depth.

**Soil prifile of secondary forest at IF1F**
**Survey date: July 27, 2001**
**Slope angle: 11.5 degree**

**Soil hardness**

| Soil layer | | Soil hardness |
|---|---|---|
| A0 | Humus | |
| A1 | Organic matter | 7 kg/cm² |
| A2 | Gravel<30% | 8.5 kg/cm² |
| B | Gravel<90% | 8.5 kg/cm² |

**Soil texture**

| Sample No. | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|
| A0(0-3) | 70.72 | 20.68 | 8.60 | Sandy Loam |
| A1(3-10) | 72.34 | 10.17 | 17.49 | Sandy Loam |
| A2(10-25) | 72.67 | 17.58 | 9.75 | Sandy Loam |
| B(25-45) | 72.78 | 17.76 | 9.46 | Sandy Loam |
| B(45-65) | 77.29 | 13.46 | 9.25 | Sandy Loam |
| B(65- ) | 77.05 | 13.95 | 9.00 | Sandy Loam |

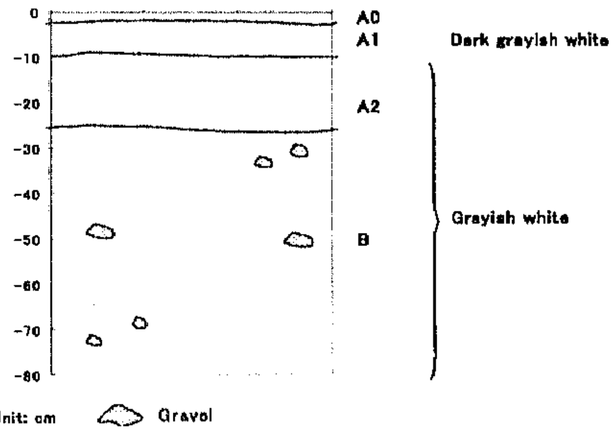


Fig. 3 Soil characteristics of the secondary forest at the IF1 site

**Soil prifile of pineapple field (first year growth) at IF1P**
**Survey date: July 25, 2001**

**Soil hardness**

| Soil layer | | Soil hardness |
|---|---|---|
| A | Gravel<5% | 2.9 kg/cm² |
| B1 | Gravel<10% | 9.0 kg/cm² |
| B2 | Gravel=80% | 3.3 kg/cm² |

**Soil texture**

| Sample No. | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|
| A(0-25) | 75.60 | 15.59 | 8.81 | Sandy Loam |
| B1(25-40) | 73.37 | 17.08 | 9.55 | Sandy Loam |
| B2(40-60) | 73.24 | 13.89 | 12.87 | Sandy Loam |
| B2(60-80) | 78.18 | 10.27 | 11.55 | Sandy Loam |

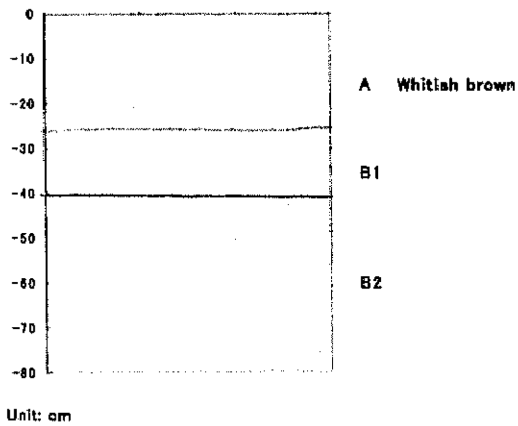


Fig. 4 Soil characteristics of pineapple field at the IF1 site

**Soil prifile of secondary forest at IF2F**
**Survey date: July 30, 2001**

**Soil hardness**

| Soil layer | Soil hardness |
|---|---|
| A | 30 kg/cm² |
| B1 | 9 kg/cm² |
| B2 | 12 kg/cm² |

**Soil texture**

| Sample No. | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|
| A(0-10) | 71.87 | 18.09 | 10.05 | Sandy Loam |
| B1(10-20) | 74.22 | 16.56 | 9.22 | Sandy Loam |
| B2(20-30) | 75.36 | 16.36 | 8.28 | Sandy Loam |

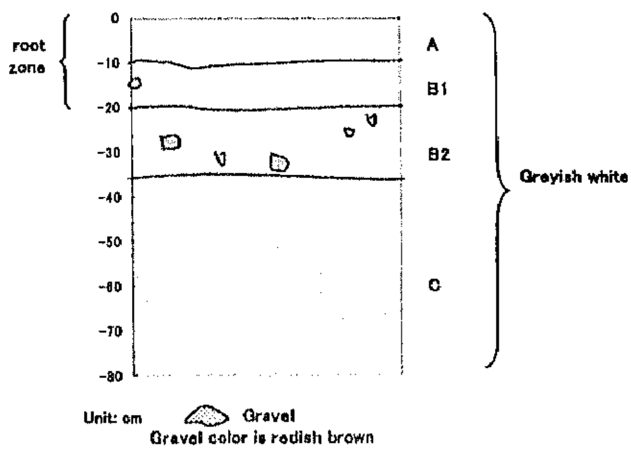


Fig.5 Soil characteristics of the secondary forest at the IF2 site

Soil prifile of pineapple field
(second or thied year growth) at IF2P
Survey date: July 30, 2001
Slope angle: 5 degree

**Soil hardness**

| Soil layer | Soil hardness |
|---|---|
| A | 10 kg/cm² |
| B1 | 20 kg/cm² |
| B2 | 15 kg/cm² |

**Soil texture**

| Sample No. | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|
| A(0-7) | 70.88 | 18.38 | 10.75 | Sandy Loam |
| B1(7-15) | 70.79 | 24.71 | 4.50 | Sandy Loam |
| B2(15-25) | 72.35 | 17.71 | 9.94 | Sandy Loam |
| B2(25-35) | 75.88 | 15.72 | 8.40 | Sandy Loam |

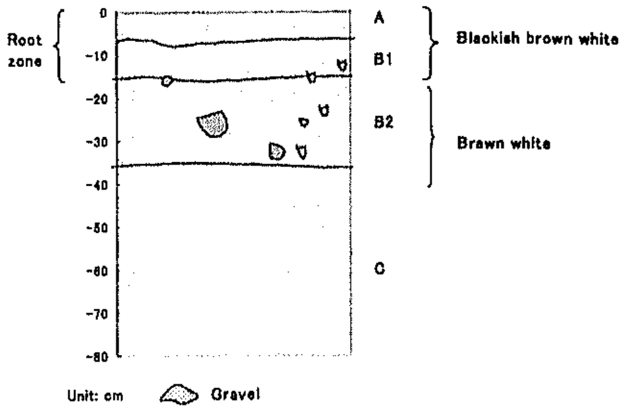


Fig. 6 Soil characteristics of the pineapple field at the IF2 site

Soil prifile of secondary forest at IF3F
Survey date: July 31, 2001

**Soil hardness**

| Soil layer | Soil haradness |
|---|---|
| B1 | 0.5 kg/cm² |
| B2 | 1.9 kg/cm² |
| B3 | 0.9 kg/cm² |

**Soil texture**

| Sample No. | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|
| A(0-6) | 88.309 | 6.579 | 5.112 | Sand |
| A2(6-10) | 92.087 | 4.128 | 3.785 | Sand |
| B(10-30) | 97.404 | 0.795 | 1.801 | Sand |
| B(30-35) | 97.514 | 0.285 | 2.201 | Sand |
| B(50-70) | 97.887 | 0.12 | 1.993 | Sand |
| B(70-90) | 97.199 | 0.035 | 2.767 | Sand |

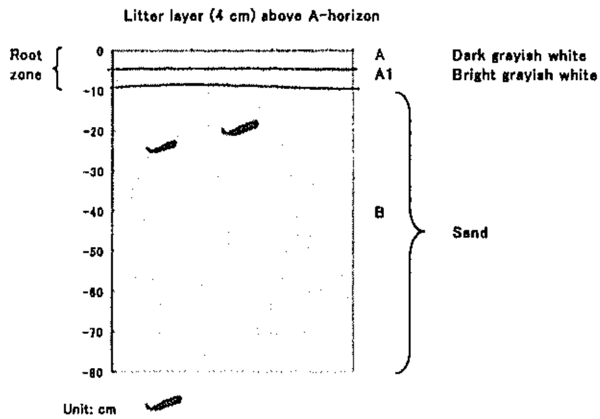


Fig. 7 Soil characteristics of the secondary forest at the IF3 site

Soil prifile of sugarcane field at IF3S
Survey date: July 31, 2001

**Soil hardness**

| Soil layer | Soil hardness |
|---|---|
| B1 | 2 kg/cm² |
| B2 | 10 kg/cm² |
| B3 | 22 kg/cm² |

**Soil texture**

| Sample No. | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|
| B1(0-10) | 79.95 | 13.67 | 6.38 | Loamy Sand |
| B2(10-35) | 81.82 | 12.39 | 5.79 | Loamy Sand |
| B3(35-55) | 66.89 | 23.82 | 9.29 | Sandy Loam |
| B3(55-75) | 58.83 | 28.86 | 12.31 | Sandy Loam |

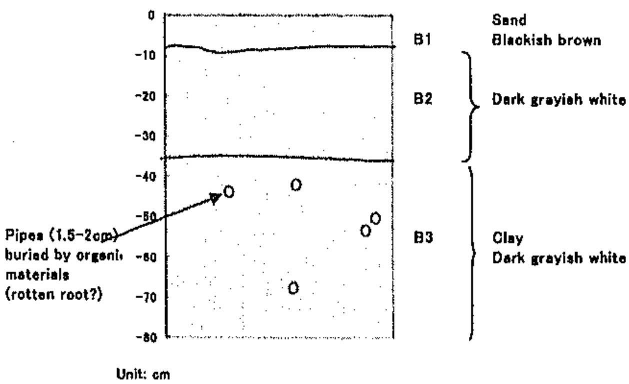


Fig. 8 Soil characteristics of the sugarcane field at the IF3 site

Soil prifile of cassava field at IF4C
Survey date: August 1, 2001

Soil hardness

| Soil layer | Soil hardness |
|---|---|
| A(0-20) | 4 kg/cm² |
| B(20-30) | 38 kg/cm² |
| B(30-50) | 50 kg/cm² |

Soil texture

| Sample No. | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|
| A(0-20)Brigh | 77.85 | 16.97 | 5.19 | Loamy Sand |
| A(0-20)Dark | 78.19 | 16.03 | 5.78 | Loamy Sand |
| B(20-30) | 77.41 | 17.63 | 4.96 | Loamy Sand |
| B(30-50)Blac | 75.00 | 16.58 | 8.42 | Sandy Loam |
| B(30-50) | 78.11 | 16.48 | 5.41 | Loamy Sand |

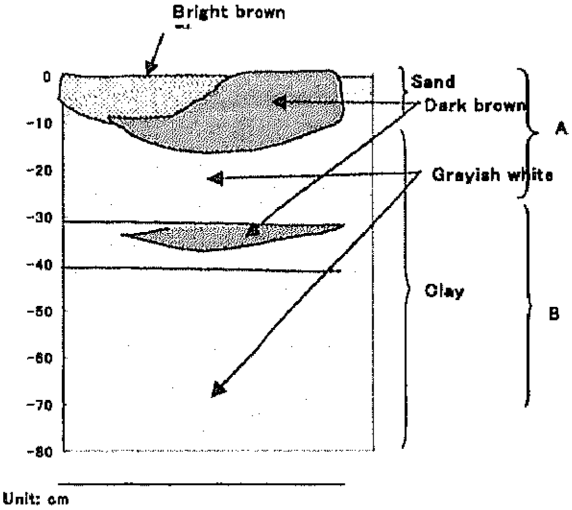


Fig. 9 Soil Characteristics of the cassava field at the IF4 site

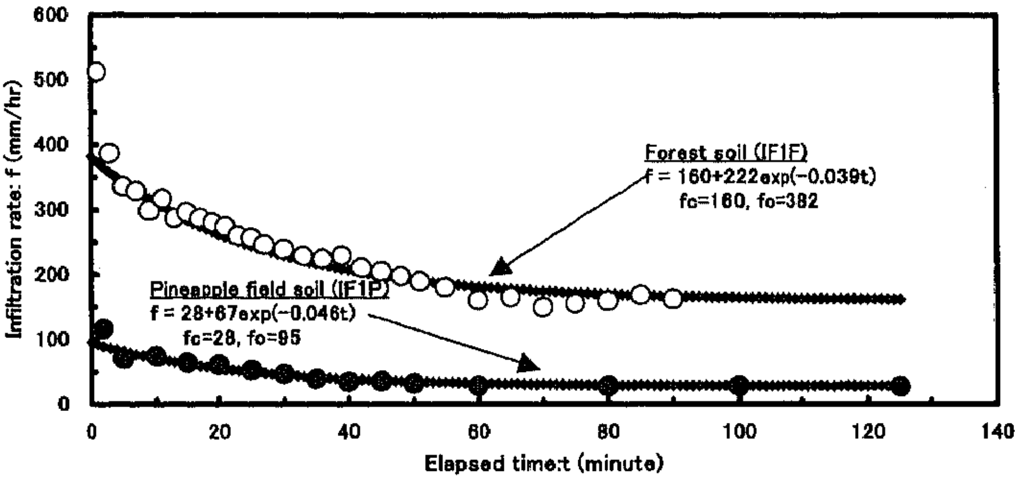


Fig. 10 Infiltration capacity curves of the forestland and the pineapple field at the IF1 site
f: Horton equation, fc: final rate, fo: initial rate

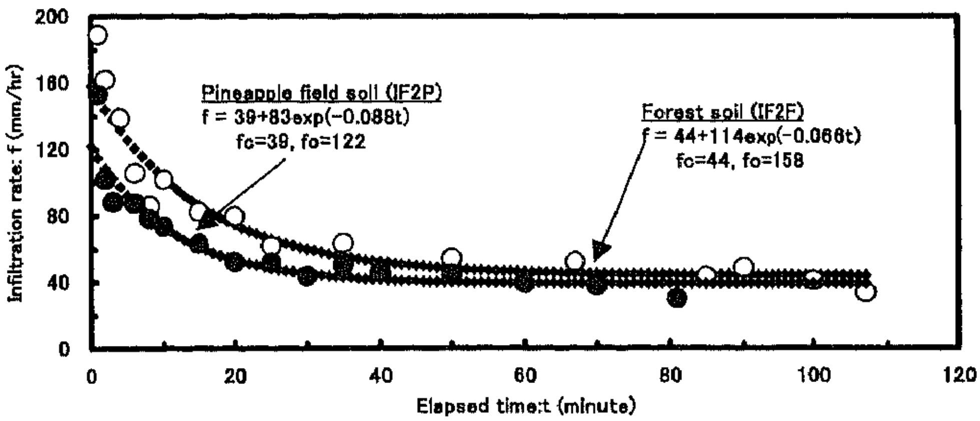


Fig. 11 Infiltration capacity curves of the foretland and the pineapple field at the IF2 site
f: Horton equation, fc: final rate, fo: initial rate

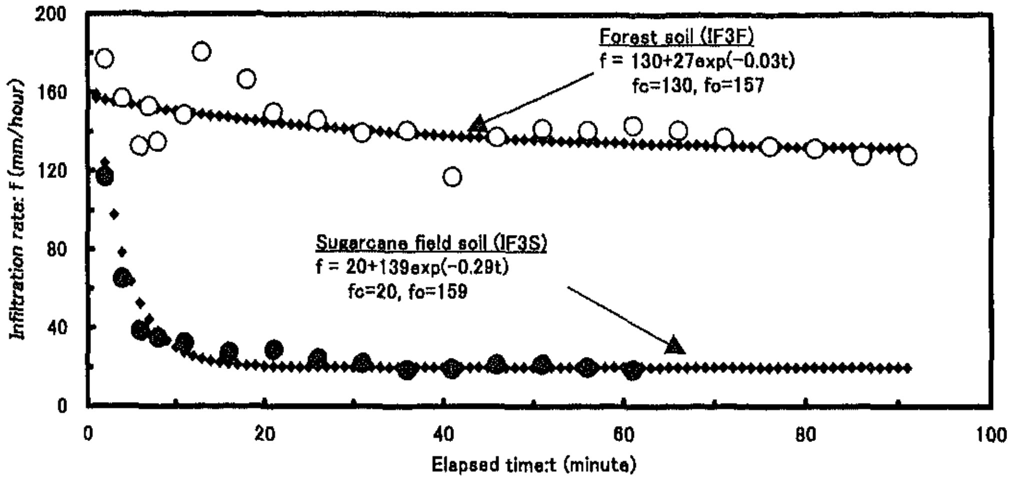


Fig. 12 Infiltration capacity curves of the forestland and the sugarcane field at the IF3 site
f: Horton equation, fc: final rate, fo: initial rate

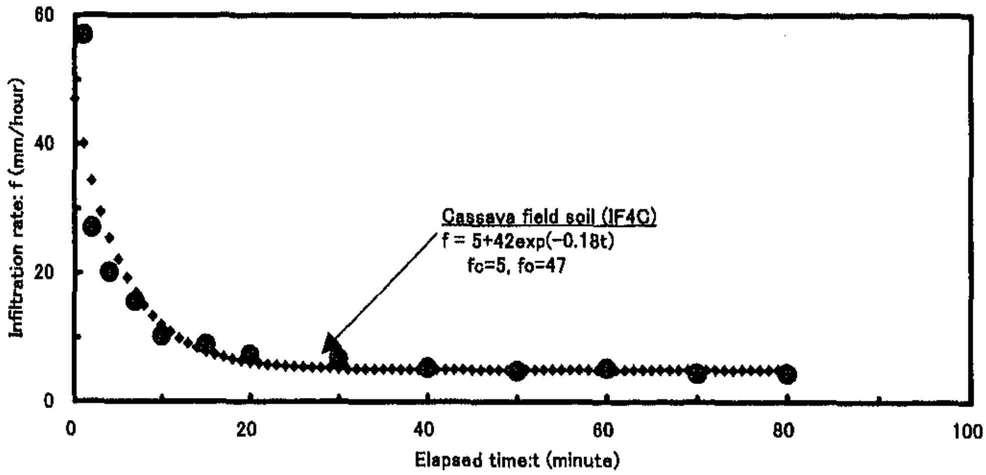


Fig. 13 Infiltration capacity curve of the cassava field at the IF4 site
f: Horton equation, fc: final rate, fo: initial rate

Overall, the forestlands have higher final infiltration rates than the pineapple and cassava fields, though they have considerable variation in the rate depending on the soil characteristics. This tendency can be found in many other measurements of infiltration capacity. According to Inthasothi and Chunmao (1976), the final infiltration rate of the evergreen forest area was 48 mm/ hr, compared to the old cultivated area, which means that the shifting cultivation was practiced, resulting in the smaller value of 20 mm/hr in the final rate. These values were obtained using the method of applying water in the field plot at Mae Thalai watershed, Chiengdao, Thailand. Nakano (1976) summarized the results of the infiltration test in Japan using the method of applying water in the field plot in various land use areas of Iwate Prefecture. According to his summarization, the final infiltration rate of forestland was 250-270 mm/hr. Conversely, the final rate of the landslide scar and the unpaved road were 99 and 11 mm/hr respectively. Many field tests suggest that the forestland generally has a higher final infiltration rate than cultivated land and bare land. Thus forest cover has a strong influence on the infiltration capacity. However, we need to conduct further research to understand the mechanism causing the difference.

3.3.2 Rainfall intensity

In the Lam Phachi River basin, 90 percent of the annual rainfall falls during the rainy season between May and November. Rainfall in September and October is much higher than other months of the rainy season. Figure 14 shows hourly rainfall at the RGS from September 10 to October 20, 2000, and Fig. 15 illustrates 10-minute rainfall at the RGS from September 27 to October 1, 2000. The rainfall pattern is characterized by strong intensity and short duration. This suggests that croplands, which have the lower value in the final infiltration rate, are susceptible to soil erosion because the Horton overland flow occurs easily due to strong rainfall intensity, but that the eroded sediment load could be not transported any distance due to short rainfall duration.

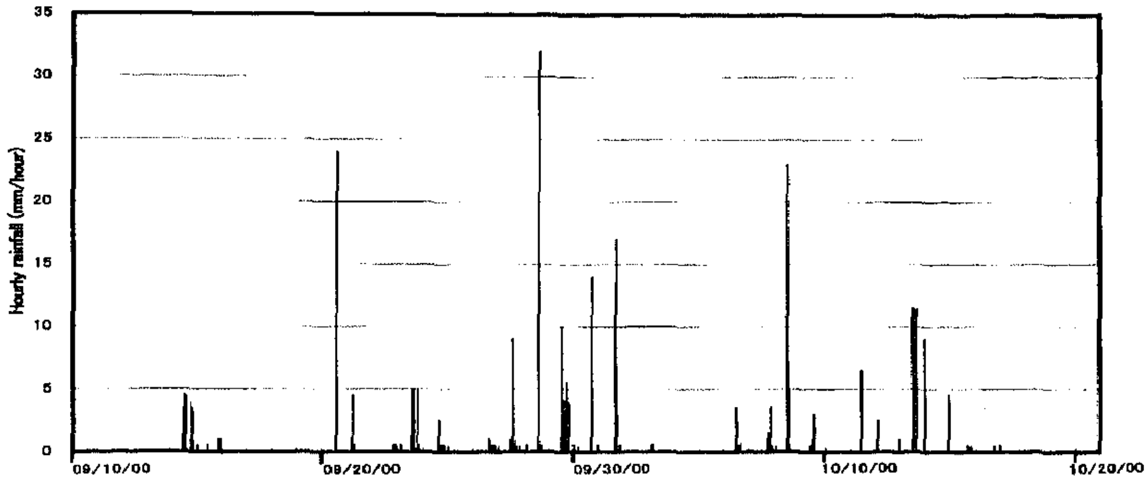


Fig. 14 Hourly rainfall from 10 September to 20 October 2000 at RGS

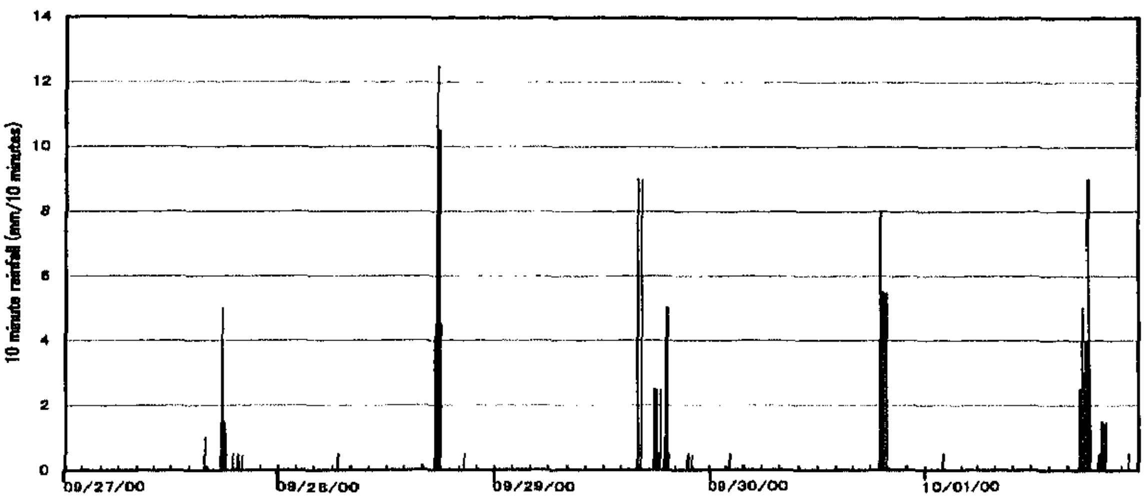


Fig. 15 10 minute rainfall from 27 September to 1 October 2000 at RGS

3.3.3 Soil erosion

Figure 16 shows rill erosion at the EP1 plot, a one-year growth pineapple field with 11 percent maximum slope, and Fig. 17 shows rill and gully erosion at the EP2 plot, a three-year growth pineapple field with 18 percent maximum slope. Both plots are selected in the most severe soil erosion area in the target research area. The pineapple growth age is a time indicator showing how often its field experienced rainy seasons, and when the soil erosion in its field began. Every three years, old pineapples are removed from the fields, and simultaneously field preparation using a tractor is completed to plant young pineapple plants at the beginning of the rainy season. This preparation results in an almost flat field condition. It was estimated that the EP1 plot experienced one rainy season and that the EP2 plot experienced three.

The mean width of rills and gullies in the EP1 (EP2) plot is 0.55 m (0.76 m). The mean depth of rills and gullies in the EP1 (EP2) plot is 0.12 m (0.31 m)(Table 1). Considering the range of width and depth (Table 1), rill erosion in the first-year-growth pineapple field caused by the rainfall of the first rainy season could develop into gully erosion by the rainfall of the second and the third rainy season. This change could promote the extension and the connection of rills and/or gullies and result in higher density of rills and gullies (Figs. 16 and 17, Table 1). If we divide the volume of rill and gully at the EP1 and the EP2 plots by the number of rainy seasons, we can roughly estimate the annual soil erosion. Thus we estimated the soil erosion rate at the EP1 plot to be 49.4 $m^3$/ha/yr and that at the EP2 plot to be 116.3 $m^3$/ha/yr (Table 1). These soil erosion rates also can be shown to be 69 t/ha/yr (EP1) and 163 t/ha/yr (EP2) if the bulk density of the soil is assumed to be 1.4 t/$m^3$.

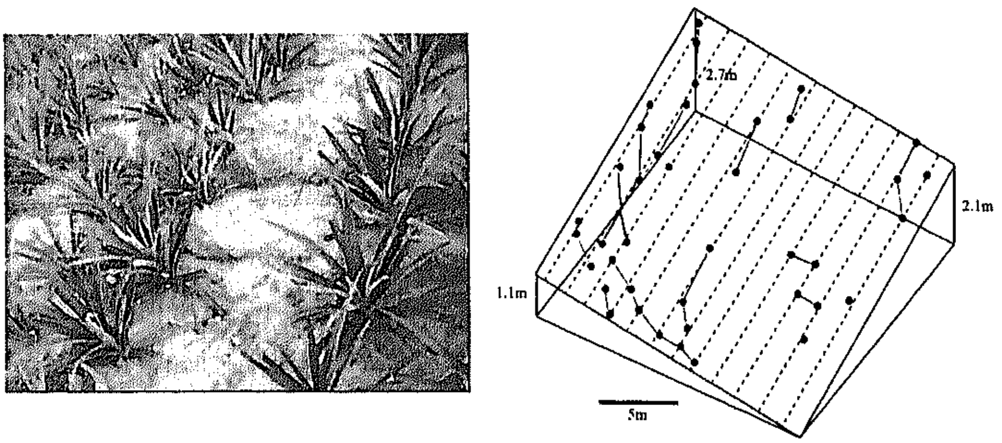


Fig. 16 Rill erosion at the pineapple field of one year growth (EP1)
●—● Rill erosion, ........ Middle of planting rows

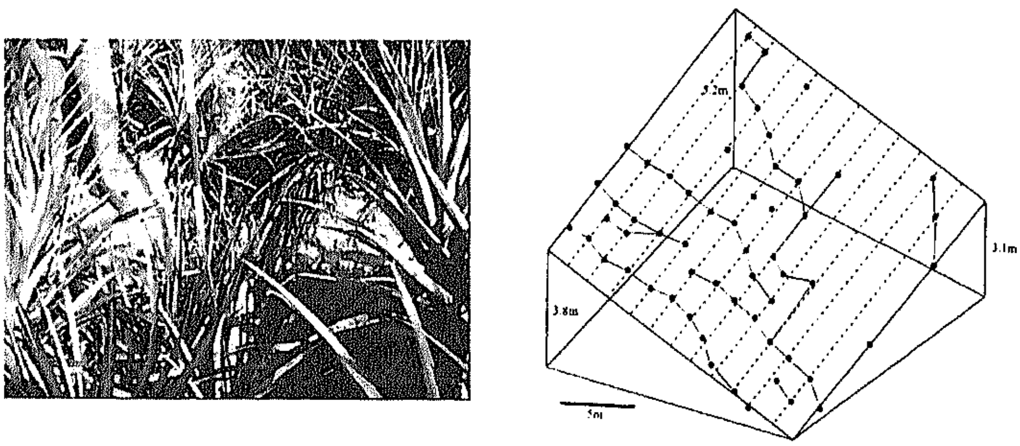

Fig. 17 Rill and gully erosion at the pineapple field of three year growth (EP2)
●—● Rill or gully erosion, ........ Middle of planting rows

According to Sidle (2002), soil losses from conventional hillslope agriculture practices in

Southeast Asia are high. For example, for vegetable crops grown on moderate to steep hillsides, the highest levels of soil loss were 38-140 t/ha/yr. This occurred when cultivation was oriented up and down the hillslope, a typical practice in the region. According to Edwards (1993), soil loss in the bare land in Australia is reported to be 31- 87 t/ha/yr. Comparing these soil loss rates in Southeast Asia and Australia, soil erosion rates in the EP1 and EP2 plots of pineapple fields, which may show the most severe erosion in the research target area, can be ranked as the highest level. Another type of soil erosion caused by inappropriate agricultural practices can be seen in the downstream areas. For example, the bank erosion near the IK4 site was caused by the accordance of the direction in both floodplain's slope and cassava rows coupled with quite low infiltration capacity due to hardpans (Photo 1, Fig 9).

Table 1 Width , depth, density and volume of the rill and/or gully

| Plot name | Crop age | Maximum slope (%) | Rill and gully | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Density ($m/m^2$) | Width(m) | | Depth(m) | | Volume($m^3/ha$) |
| | | | | Mean | Range | Mean | Range | |
| EP1 | Pineapple(1year) | 11 | 0.145 | 0.55 | 0.32–0.69 | 0.12 | 0.05–0.25 | 49.4 |
| EP2 | Pineapple(3years) | 18 | 0.231 | 0.76 | 0.27–2.20 | 0.31 | 0.08–0.68 | 348.9 |

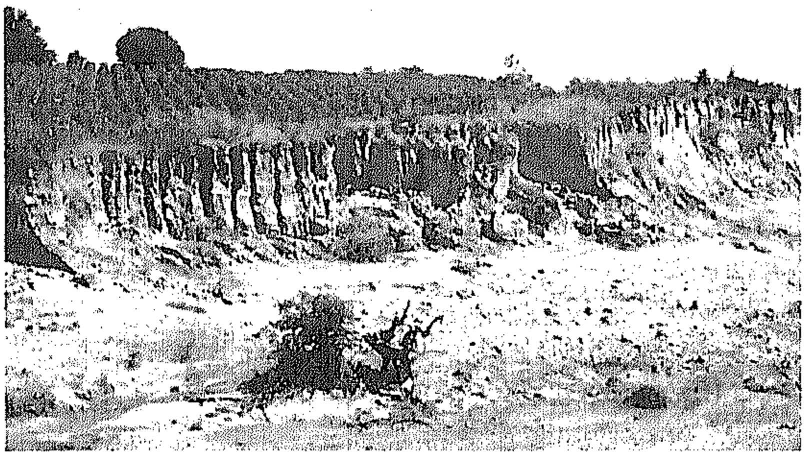

Photo 1 Bank erosion caused by inappropriate agricultural practices near the IF4 site

3.3.4 Vegetation survey

The density of trees varied among plots from 622 trees/ha to 25,600 trees/ha (Table 2). BA was varied among plots. Both the density and BA were lowest in the MD plot. The mean BA, which seemed to reflect the successional stage, was lower in the IF2(1) plot and in the IF2(2) plot, and highest in the MD plot. The MD plot had the highest values of mean DBH and maximum DBH, while the IF2(1) and IF2(2) plots had lower values than other plots (Table 2). The same results were obtained for mean H and maximum H. The species composition was different among plots (Table 3). In the IF2(1) plot *Acacia* and *Clestanthus denudatus* were dominant, and in the IF2(2) plot *Acacia* sp. and *Croton roxburghii* were the dominant tree species. *Callicarpa longifolia* (*Dalbergia volubilis*) dominated the stand in the IF1 plot (IF3 plot). Only two species, *Dalbergia volubilis and Fernandoa adenophylla*, were recorded in the IF3 plot. *Ficus hispidata* and *Harrisonia perforata* exhibited the higher density in the MD plot. The number of species per plot was higher in the MD plot, in which seven tree species were identified. Other plots had only two to four species per plot. All stand had the uni-modal DBH frequency distribution (Fig. 18). The mode of DBH frequency was 1-2cm, for the IF2(1) plot, 1-2cm for the IF2(2) plot, 4-6cm for the IF3 plot, 4-5cm for the IF1 plot, and 10-15cm for the MD plot. The MD plot exhibited a less prominent peak of DBH frequency than other plots.

Table 2 Stand characteristics of each plot setup in the secondary stand

| | | IF1 | IF2 (1) | IF2 (2) | IF3 | MD |
|---|---|---|---|---|---|---|
| Plot size($m^2$) | | 100 | 25 | 25 | 25 | 225 |
| n(/ha) | | 1700 | 25600 | 12800 | 13200 | 622 |
| BA($cm^2$/ha) | | 28136.88 | 145311.2 | 70142.32 | 389972.1 | 80679.2242 |
| Mean BA($cm^2$) | | 16.55111 | 5.67621875 | 5.47986875 | 29.5433409 | 129.663039 |
| DBH(cm) | Mean | 4.38 | 2.38 | 2.26 | 5.75 | 11.1785714 |
| | Max | 7 | 5.4 | 7.8 | 11.6 | 23.7 |
| Height(m) | Mean | 4.59 | 3.22 | 3.48 | 7.39 | 9.77142857 |
| | Max | 6 | 5 | 5 | 10 | 16 |

Table 3 Species composition of each plot in the secondary forest

| | Number of stems (/ha) | | | | |
|---|---|---|---|---|---|
| Species | IF1 | IF2(1) | IF2(2) | IF3 | MD |
| *Diospyros coaetanea* | 200 | | | | |
| *Gmelina asiatica* | 500 | | | | |
| *Caesalpinia sappan* | 1000 | | | | |
| *Callicarpa longifolia* | | 400 | | | |
| *Acacia* sp | | 16000 | 2800 | | |
| *Clestanthus denudatus* | | 8400 | 400 | | |
| *Ehetia laevis* | | 400 | | | |
| *Wrightia arborea* | | | 1600 | | |
| *Croton roxburghii* | | | 7600 | | |
| *Dalbergia volubilis* | | | | 12400 | 89 |
| *Fernandoa adenophylla* | | | | 800 | |
| *Bridelia curtisii* | | | | | 44 |
| *Dalbergia volubilis var. volubilis* | | | | | |
| *Ficus hispidata* | | | | | 178 |
| *Harrisonia perforata* | | | | | 133 |
| *Lagerstroemia tomentosa* | | | | | 44 |
| *Polyalthia suberosa* | | | | | 89 |
| Other species | | 400 | 400 | | 44 |
| Total | 1700 | 25600 | 12800 | 13200 | 622 |

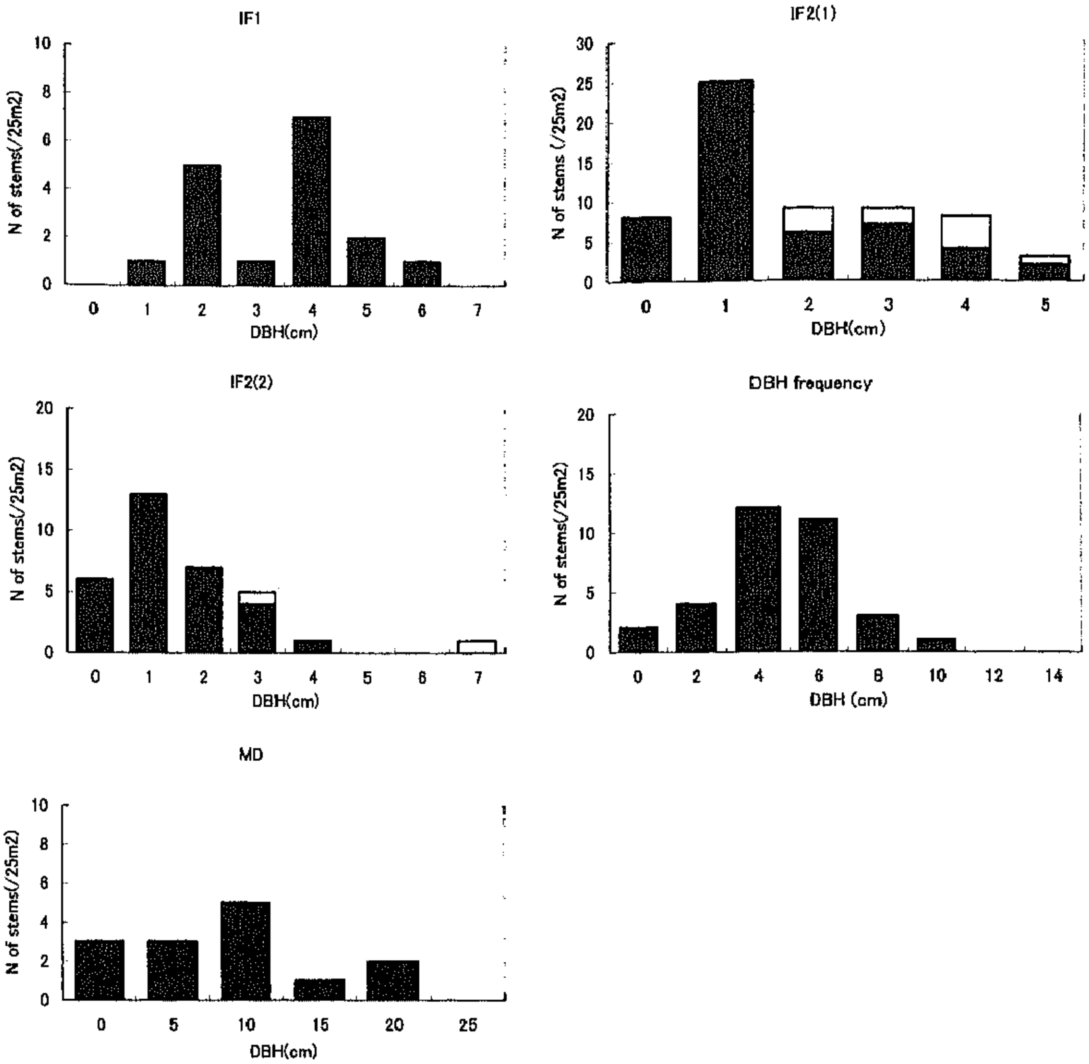


Fig. 18 DBH frequency of each plot
Closed bar and open bar indicate living stems and dead stems respectively

The species composition of each plot suggests that forests on the fringe of croplands are secondary forests. The density of trees is higher (622-25,600/ha) and the mean BA is much lower (5.5-129.7cm$^2$) in these secondary stands than in the natural mixed deciduous forest (171/ha, 1,005.8cm$^2$) in this region reported by Marod et al. (1999). Of the five plots investigated, the MD plot had the lowest density and highest mean BA, indicating the MD plot was in a successionally more developed stage than other plots. The MD plot located in the mountain area, and this plot were considered undisturbed by human activity, such as logging. However, other plots located adjacent to the arable fields suffered various human impacts, affecting these plots and setting these plots back to the early successional stage frequently. Those human impacts include logging for fuel woods, construction timbers, and the clear-cutting for shifting cultivation. Some trees in the IF2(1) had fire scars indicating past fire events. It seemed that such a difference in the disturbance history might cause the difference of stand structure between the MD plot and the four other plots.

With the exception of the MD plot, all the plots possessed a prominent unimodal distribution of DBH. The unimodal distribution of DBH or height was reported for the even-aged stand regenerated after the disturbance (Lorimer and Krug 1983, Palik and Pregitzer 1992). Thus, the size structure indicated that these secondary stands were even-aged stands composed from stems regenerated simultaneously after the disturbance, such as logging or fires. Also the mode of DBH frequency was smaller in all stands compared to that of natural stands. We could thus conclude that the secondary stands around the pineapple fields were immature and in the initial stage of stand development because of frequent and intensive disturbance by human activity, such as loggings or fires.

## 4. HUMAN IMPACT ON SOIL EROSION

### 4.1 Forest Conversion to Cultivated Lands

The conversion of secondary forests to cultivated lands has undoubtedly been the most widespread land use change in the Lam Phachi River basin during the past two or three decades (Fig. 19).

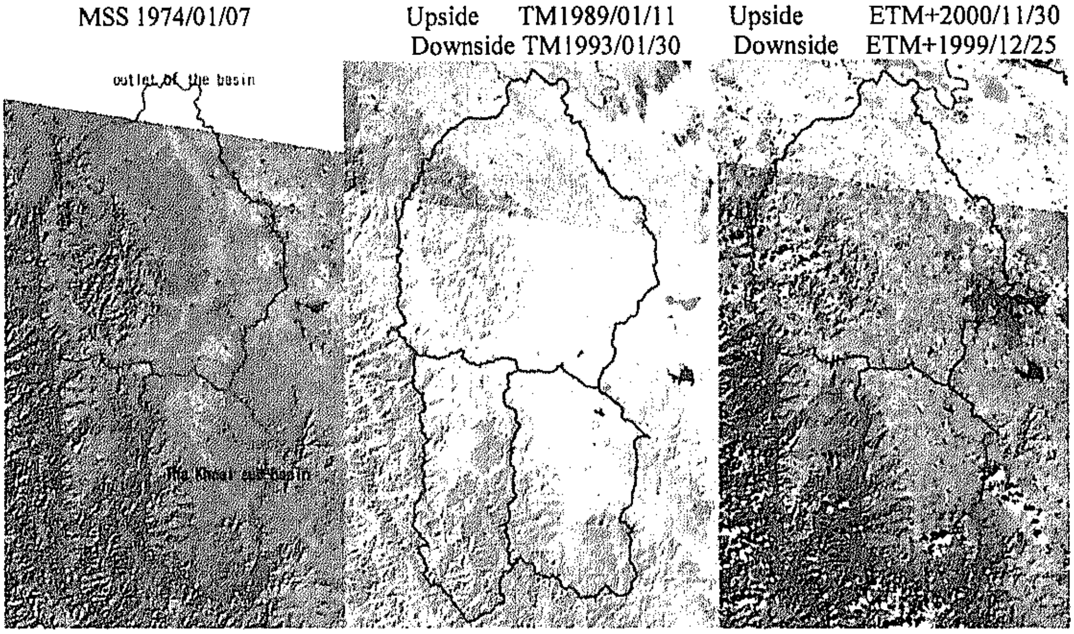


Fig. 19 Land use changes of the Lam Phachi river basin during the past three decade by the satellite images (Landsat TM1973/01/07, TM1989/01/11;1993/01/30, LandsatETM+ 1999/12/25;2000/11/09)

Green color shows forests, and reddish color shows cultivated and bare lands.

Most impacts appear to occur during the land-clearing processes and in the initial few years following cropland establishment, with much rapid storm runoff and sediment produced on disturbed areas within the cultivated land. Cultivated lands modify site hydrology by decreasing the infiltration capacity compared to forestlands. If rainfall intensity at any time during the storm exceeds the infiltration capacity, water will accumulate on the soil surface and will run down slope as a Horton overland flow. The overland flow, or surface runoff, causes sheet, rill and gully erosion. Thus, cultivated lands converted from secondary forests during the past several decades were apparently more susceptible to erosion than forestlands. This can be regarded as the primary stage for the soil erosion in Lam Phachi river basin. The conversion may be caused by the shortage of cultivated lands that resulted from the increase in rural population by settlement, and limited cultivated land resources could have accelerated the conversion during the past several decades.

According to the vegetation survey, most forests, at least the fringe of cultivated lands of the basin, were secondary forests, and also it was very difficult to find natural forests in the research target area. This suggests that before the conversion to cultivated lands the forests had been affected by various human activities such as the logging for fuel woods and for shifting cultivation by native people. However since this disturbance was within acceptable limits for watershed capacity, the productivities of the basin were sustained in those days that might continue during several hundred years.

**4.2 Dynamic Cultivation Changes**

Recently, forest cover in the Lam Phachi River basin has been relatively stable, however dynamic cultivation changes have occurred on the converted land related to a shift to a more cash-crop culture since the 1990s. The main cash crops in the research target area are pineapple, sugarcane and cassava. Pineapples can grow in sloping areas due to its tolerance of drought and other physiological conditions. Due to the recent high price, pineapple fields are expanding to the fringe of the forests, or the sloping area of the mountain foot. This expansion, coupled with exposed fields during tillage and early growth stages caused by the cultivation practice in which

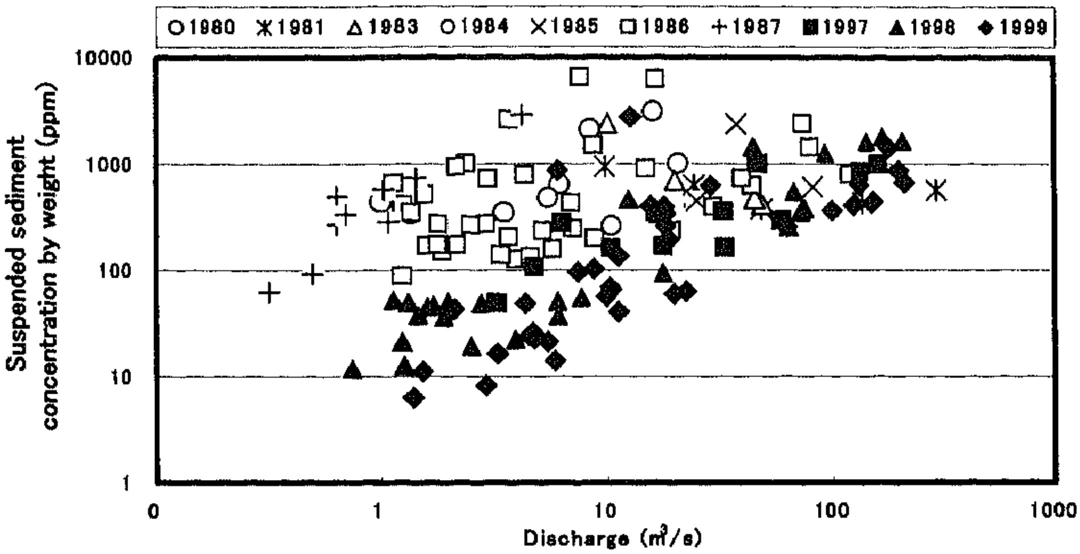


Fig. 20 Comparison of the suspended sediment concentration in the 1980s with the 1990s

that new pineapples are planted after clearing the field every three years, increased the susceptiblity to erosion more than did other crops. In the most severely eroded site, the erosion rate exceeds 100 t/ha/yr as monitored in the EP2 plot. Such severe soil erosion affects pineapple productivity by reducing the availability of water, nutrients and organic matter. This can be regarded as the secondary stage for the soil erosion.

Judging from the suspended sediment concentration data at the K17 monitoring site of Royal Irrigation Department (about 5km downstream from the confluence of the main stream with the tributary (Fig. 2)), the primary stage of soil erosion during the past few decades could supply more sediment in streams than the secondary stage during the last decade (Fig. 20). From a viewpoint of infiltration capacity, the above understanding could be supported. However, the development of irrigation ponds to cultivate land during the last decade might contribute to a lower supply of sediment to streams. Therefore, further research is required to understand the above phenomena because of complicated interrelationship of factors involved.

**4.3 Vicious Cycle of Watershed Degradation**

Most dynamic cultivation changes shifting from subsistence to cash crops inevitably disturb surfaces and accelera erosion. However, most watersheds have the capacity to withstand the impact of use without permanent loss of productivities so long as accelerated erosion is kept within acceptable limits. Accelerated erosion deteriorates a site to an ever greater degree unless the process is reversed (Fig. 21). The more surface runoff occurs, the more soil is removed and the less water and nutrients remain to support the plant growth that would protect it from further deterioration. A vicious cycle is initiated that reduces favorable plant growth conditions to a minimum, while erosion rates reach their maximum. Once the critical point in deterioration is exceeded, the cycle is carried to completion with the removal of the soil mantle unless people intervene to reserve the process (Satterlund and Adams, 1992).

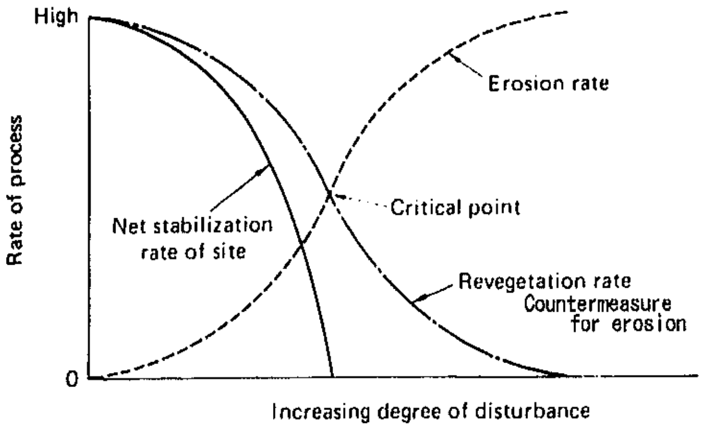


Fig. 21 Relationship of deterioration of a site by erosion to the rate of revegatation and countermeasure for soil erosion

At the critical point in deterioration, accelerated erosion becomes self-sustaining and the site cannot recover by natural processes of revegetation. To the right-hand side of the critical point, deterioration continues to completion. To the left, the site recovers its stability at an increasing rate (adapted from Satterlund and Adams, 1992).

According to the analysis using the remotely sensed data in the research target area (Ogawa, 2002), the pineapple fields area increased by approximately 20 percent during the last decade. However cultivation changes from pineapple to other crops during the this period reached approximately 70 percent, leaving the pineapple field area was only approximately 30 percent. This may suggest one reason why the dynamic change from pineapples to other crops represents the soil deterioration of pineapple fields due to soil erosion. Considering that pineapple fields around the EP1 and EP2 plots can be ranked as the highest level in soil erosion, and that the bank erosion near the IF4 site resulted from inappropriate agricultural practices coupled with the low infiltration capacity due to hardpans, the vicious cycle of watershed degradation has already begun in some cultivated areas, particularly pineapple fields of slopes in the Lam Phachi River basin. Therefore, we need protection measures against accelerated erosion, and appropriate agricultural practices to maintain the sustainable development. Cultivation along the hillslope contour and the use of agricultural hedgerows and buffer strips are useful countermeasures for soil erosion. Agroforestry practices may be a general countermeasure for reducing soil erosion. They offer a combination of both short-term economic returns to farmers (i.e., crop production) together with longer-term investments and soil and water conservation benefits (i.e., trees) (Sidle, 2002). However, research on watershed management in the context of sustainable agricultural production and environmental protection in the basin is needed in the future.

## 5. CONCLUSIONS

As a result of infiltration test, the forestlands have higher final infiltration rate (44-160 mm/hr) than the pineapple and cassava fields (5-39 mm/hr) though they have considerable variation in the rate depending on the soil characteristics.

According to the monitoring data that collected in 10-minute intervals at the upper region of the basin, the rainfall pattern is characterized by strong intensity and short duration. This suggests that croplands, which have the lower value in the final infiltration rate, are susceptible to soil erosion because a Horton overland flow occurs easily due to intense rainfall, but that the eroded sediment load could be not transported great distance due to the short rainfall duration.

The erosion rates of two pineapple fields in sloping area (max. slope, 11 and 18 percent) of the upper region of the basin are estimated to be 69 and 163 t/ha/yr. These values can be ranked as the highest level though they may be obtained from the pineapple fields that exhibit the most severe erosion in the research target area.

As a result of a vegetation survey, we could concluded that forests on the fringe of croplands were secondary forests and that they were immature and in the initial stage of stand development because of frequent and intensive disturbance by human activity, such as loggings and fires.

Two stages for soil erosion problems were recognized in the Lam Phachi River basin. The first stage is that forest conversion to cultivated lands was practiced in the entire basin during the past two or three decades. However, before this conversion, various human activities must have had already impacted on the basin though the productivities of the basin were sustained because the disturbance was within acceptable limits for watershed capacity.

The second stage is that dynamic cultivation changes have occurred on the converted land related to a shift to more cash-crop culture since the 1990s. According to an analysis using remotely sensed data in the target area, the area remained in the pineapple field was only approximately 30 percent. This may suggest one reason why the dynamic change from pineapples to other crops represents the soil deterioration of pineapple fields due to soil erosion. Considering that pineapple fields around the EP1 and EP2 plots can be ranked as the highest level in soil erosion, the vicious cycle of watershed degradation has already begun in some pineapple fields of slopes in the Lam Phachi River basin. Therefore, we now need protection measures against accelerated erosion, and appropriate agricultural practices in the context of sustainable agricultural production and environmental protection to maintain the sound watershed.

## ACKNOWLEDGEMENTS

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# Identifying Significant Tributaries from Human Impacted Sedimentary System, Lam Phachi Catchment, Western Thailand

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***Abstract***

Lam Phachi catchment located in western Thailand is one of the human impacted sedimentary systems. Recent agricultural machinery in Thailand has much influenced on the link between hill-slope erosion and sediment delivery. Especially lots of reservoirs excavated by local peoples may bring huge influence on water resource and sediment of the catchment. To strategically mitigate the erosion-sedimentation linking caused by human impact, catchment scale study on sedimentary system is necessary. This study aims to the sedimentary cascades linking with discontinuity of hydrological processes changed by human impacted landscape management Gentle channel slope of tributary catchments is one of the reason why low water runoff does not increase downstream, because fine sediment and water flow from hill-slope stored in tributary catchments themselves. Reservoirs excavated by local farmers were resulted to intercept the water and suspended discharge from hill-slope into mainstream.

**Keywords: catchment scale, significant tributary, reservoir, sedimentary system**

## 1. INTRODUCTION

To mitigate sediment disaster and achieve sustainable landscape management, estimation of erosion rates of farmland is applied to many agricultural countries in the world. However the add and multiplication for calculating methods such as the United Soil Loss Equation (USLE) is already an old fashion, because not only more scientific insight related with discontinuity, intermittency and catastrophic changes (Fryirs *et al.*, 1998; Marutani *et al.*, 1999; Graf, 1988) but also new indices for time scale (Lu *et al.*, 2000; Pickup, 1988) are brought into the research of earth surface changes.

On the other hand human impact on landscape changes associated with sediment yield raise new interests rather than geomorphologic interest in natural landscape. Recently many earth scientist move their interest into the human impacted geomorphology (Ziegler *et al.*, 2000;

Reid et al., 1981; Reid et al., 1984 ). Road construction, logging and farmland reconstruction are addressed based on geomorphological and hydrological methods. To strategically analyze the erosion linking with sedimentation caused by human impact, catchment scale study on sedimentary system can be efficient (Marutani et al, 2000).

Rice (1998) proposed to identify significant tributaries disrupts downstream fining along the gravel bed rivers. Sediment supplied from lateral tributaries makes an important enrolment to control the discontinuity in main channel processes. Sedimentary systems of earth surface will changes the nature influenced by agricultural development in farmland. Therefore identifying significant lateral sources and associated sedimentary links is important for the human impacted sedimentary systems.

Lam Pachi catchment located in the western Thailand is also one of the human impacted sedimentary systems. Recent agricultural machinery in Thailand much influenced on the linking between erosion and sediment delivery. In this study, the sedimentary cascades linking with discontinuity of hydrological process changed by human impacted landscape management is aimed. Especially lots of reservoirs excavated by local peoples may bring huge influence on water resource and sediment transport along the main channel. In this paper, we identified significant tributaries controlling sedimentary cascades caused by reservoir excavating.

## 2. STUDY AREA

Lam Phachi catchment located in west Thailand has been intensely impacted by development of farmland since 1970's. Lam Phachi River drains a approximately 2620 $km^2$ basin bordered on the west by Myanmar. The main channel is 130km long and slope of riverbed averaged at 0.0042. Main channel of LanPhachi River joins into Mae Klong River at the downstream of Kancha Nabris City.

The Sedimentary rocks of Quaternary period are overlain igneous rocks of Mesozoic era and sedimentary rocks of Paleozoic era. Soil is mainly composed of three groups such as Slope Complex, Paleustults and Haplustalfs (Maita,1998). These geological components are weathered and crashed for long time, and the land surface today shows smooth and gentle slope. Sediment produced from hill-slope has extended in the valley floor by storms and developed huge flood plain.

Although the forest partly cutting by local peoples grew up the flood plain before 1970's, land-use changes from forest-dominated utilization to primitive farmland such as Sugar Cane and Pineapple has quickly extended into the entire flood plain. After 1970's, forest area keep decreasing and at last in 1999 more than 37% of the entire catchment area was cultivated (Maita, 1998, Maita 1999). Multiple use of the entire catchment by immigrants from the outside is out of the control for land-use guideline developed by RID.

Annual rainfall is ranged from 1500mm to 1200mm in the entire Mae Klong river basin, but in Lam Phachi catchment averaged annual rainfall is trend to decrease from 1200mm to 800mm since 1950's in this area (Kwanyuen et al., 1998). The lack in rainfall has caused the agricultural degradation in the entire catchment, and farmers settled in each tributary catchment started to construct reservoirs for personal use. Many reservoirs distributed in tributaries make an enrolment of temporally storage of water and sediment.

Catchment area and tributary divides are shown in Figure 1. Main channel of Lam Phachi sedimentary system incise flood plain with meandering. The lateral side of riverbank keeps recessing by excavation and attain to maximum 4m in height. Each number indicates tributary catchment. Totally 45 tributaries ranged from 573$km^2$ to 1.81$km^2$ in catchment area are identified and analyzed. The No.29 tributary is still covered deeply by tropical rain forest. Small squares along main channel are measuring and sampling points. Riverbed of main channel and tributary month were composed of sandy sediment and cobble-sized particles.

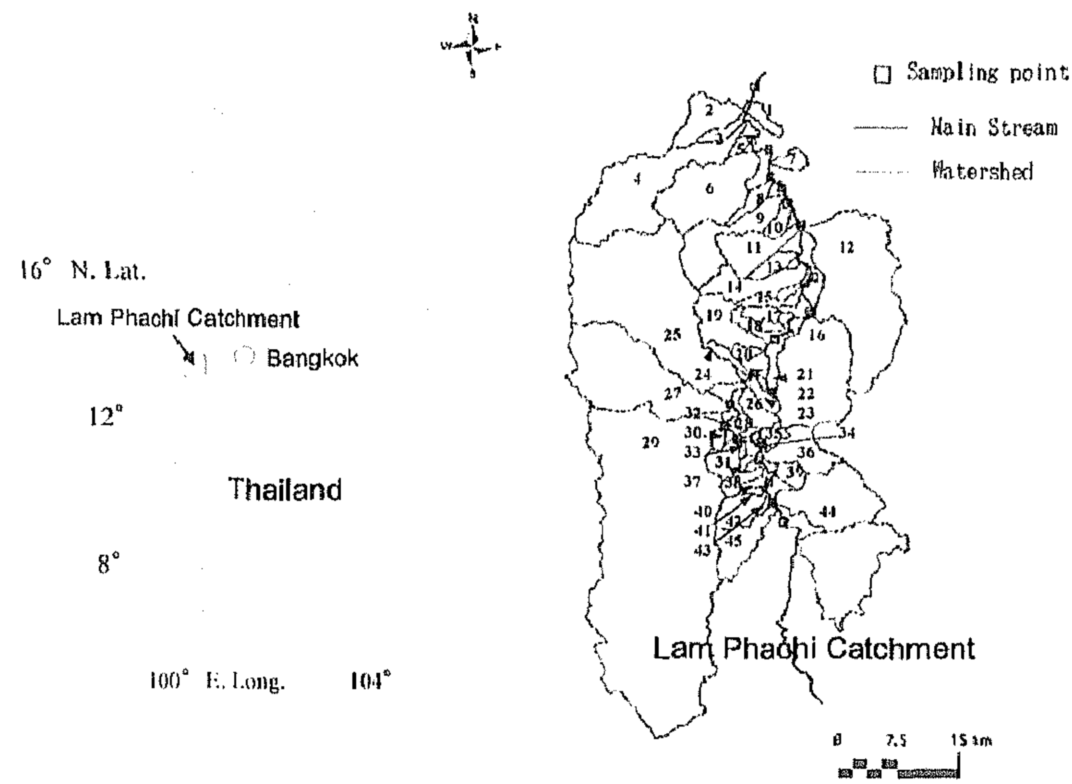


**Figure 1. Location of research site and the entire catchment map of Lam Phachi.**

## 3. METHODS

Totally 45 tributaries are identified from Lam Phachi catchment and geomorphic analyses have done by GIS method as follows. First topographic maps originated from Royal Thai Survey Department have imported to computer by the optical scanner, and after geometric correction using TNT Mips software the catchment topographic map has completed. Catchment area and averaged slope of identifying tributaries were analyzed.

The air photos taken in 1973, 1984, 1994 and 1998 by Royal Thai Survey Department were employed for analyzing reservoirs. Photographs were scanned and imported into computer. After geometric correction using TNT Mips software, the numbers and sizes of reservoirs were measured. As each air photo did not cover all catchment area, the total area of reservoirs per unit catchment area was calculated for each tributary catchment.

Cross section measuring, runoff measuring, suspended load and sedimentary particle samplings are conducted totally at 20 points along Lam Phachi River. Cross section measuring has been conducted in summer time of 2001 at 12 points. The other 8 cross section points were impossible to access because of deep bush cover. Laser distance meter and laser digital compass were used for field survey. The accuracy of laser distance mater is ±5cm per 100m. Cross section lines were set on between both riverbanks. To calculate runoff at low water, flow velocity and flow-cross section were measured using measuring staff and laser distance meter. Water velocity was measured at the thalweg of cross section lines using automatic current meter.

Water samples (4 liter) including suspended load were drawn from 0.5m in water depth at each cross section line, and the samples were percolated using 5 $\mu$ m filter. Particle sizes deposited on the riverbed were sorted out using three sieves such as 1mm, 3mm and 20mm in diameter. Particles larger than 20mm in diameter were measured their size respectively.

**Table 1. Results of geomorphic properties of tributary catchments.**

| X-section number | Number of mesuring point | Distance from the river mouth (L, km) | Averaged slope of tributaries(I) | Catchment area(A, km2) | Channel slope of tributary | Indexes of stream power (AI) |
|---|---|---|---|---|---|---|
| XN | TN 1 | 4.98 | 0.01 | 8.37 | 0.0091 | 0.08 |
| | 2 | 6.78 | 0.01 | 31.62 | 0.0052 | 0.17 |
| | 3 | 8.91 | 0.01 | 7.46 | 0.0053 | 0.04 |
| 3 | 4 | 9.24 | 0.01 | 117.46 | 0.0100 | 1.17 |
| | 5 | 14.44 | 0.00 | 4.19 | 0.0048 | 0.02 |
| 4 | 6 | 16.01 | 0.02 | 84.35 | 0.0186 | 1.57 |
| 5 | 7 | 21.52 | 0.01 | 7.81 | 0.0086 | 0.07 |
| 6 | 8 | 24.39 | 0.01 | 10.35 | 0.0064 | 0.07 |
| 7 | 9 | 28.61 | 0.03 | 54.22 | 0.0263 | 1.43 |
| | 10 | 30.62 | 0.01 | 7.62 | 0.0082 | 0.06 |
| 8 | 11 | 33.45 | 0.01 | 35.46 | 0.0137 | 0.49 |
| | 12 | 34.33 | 0.04 | 183.03 | 0.0407 | 7.45 |
| | 13 | 39.08 | 0.01 | 10.74 | 0.0077 | 0.08 |
| 9 | 14 | 40.36 | 0.04 | 35.18 | 0.0361 | 1.27 |
| 10 | 15 | 45.28 | 0.02 | 9.99 | 0.0206 | 0.21 |
| | 16 | 50.49 | 0.00 | 111.86 | 0.0041 | 0.46 |
| | 17 | 52.64 | 0.02 | 9.76 | 0.0170 | 0.17 |
| 11 | 18 | 54.59 | 0.01 | 10.23 | 0.0098 | 0.10 |
| | 19 | 58.93 | 0.03 | 36.37 | 0.0334 | 1.21 |
| | 20 | 59.72 | 0.02 | 5.79 | 0.0234 | 0.14 |
| | 21 | 62.47 | 0.01 | 4.88 | 0.0083 | 0.04 |
| 12 | 22 | 64.61 | 0.01 | 1.86 | 0.0082 | 0.02 |
| | 23 | 64.89 | 0.00 | 8.39 | 0.0046 | 0.04 |
| | 24 | 65.46 | 0.06 | 6.60 | 0.0604 | 0.40 |
| | 25 | 66.66 | 0.02 | 241.27 | 0.0172 | 4.14 |
| 13 | 26 | 67.52 | 0.01 | 13.81 | 0.0114 | 0.16 |
| | 27 | 70.91 | 0.02 | 141.95 | 0.0182 | 2.59 |
| | 28 | 72.83 | 0.01 | 3.42 | 0.0147 | 0.05 |
| 14 | 29 | 75.35 | 0.01 | 573.68 | 0.0064 | 3.68 |
| | 30 | 75.60 | 0.07 | 4.23 | 0.0736 | 0.31 |
| 15 | 31 | 77.24 | 0.04 | 16.24 | 0.0383 | 0.62 |
| | 32 | 78.19 | 0.01 | 2.24 | 0.0098 | 0.02 |
| | 33 | 78.73 | 0.02 | 1.56 | 0.0204 | 0.03 |
| 16 | 34 | 79.89 | 0.01 | 0.96 | 0.0134 | 0.01 |
| | 35 | 81.71 | 0.02 | 7.13 | 0.0234 | 0.17 |
| | 36 | 83.21 | 0.01 | 32.51 | 0.0090 | 0.29 |
| 17 | 37 | 84.36 | 0.01 | 2.47 | 0.0108 | 0.03 |
| | 38 | 86.25 | 0.06 | 9.21 | 0.0598 | 0.55 |
| | 39 | 88.14 | 0.00 | 8.80 | 0.0046 | 0.04 |
| 18 | 40 | 89.47 | 0.02 | 3.58 | 0.0168 | 0.06 |
| | 41 | 91.21 | 0.07 | 2.07 | 0.0711 | 0.15 |
| | 42 | 91.76 | 0.09 | 21.04 | 0.0856 | 1.80 |
| | 43 | 92.95 | 0.03 | 1.81 | 0.0267 | 0.05 |
| 25 | 44 | 93.71 | 0.01 | 72.06 | 0.0073 | 0.53 |
| | 45 | 94.69 | 0.05 | 32.91 | 0.0488 | 1.60 |

## 4. RESULTS

The result of geomorphic analyses of tributary catchments was shown in Table 1. The first and second files are the number of cross sections and the number of tributary mouths respectively. The third file is the distance from the river mouth of Lam Phachi River to the tributary mouths. The fourth and fifth files indicate average slope and catchment area of tributaries respectively. The sixth file is the result from calculating stream power of each tributary.

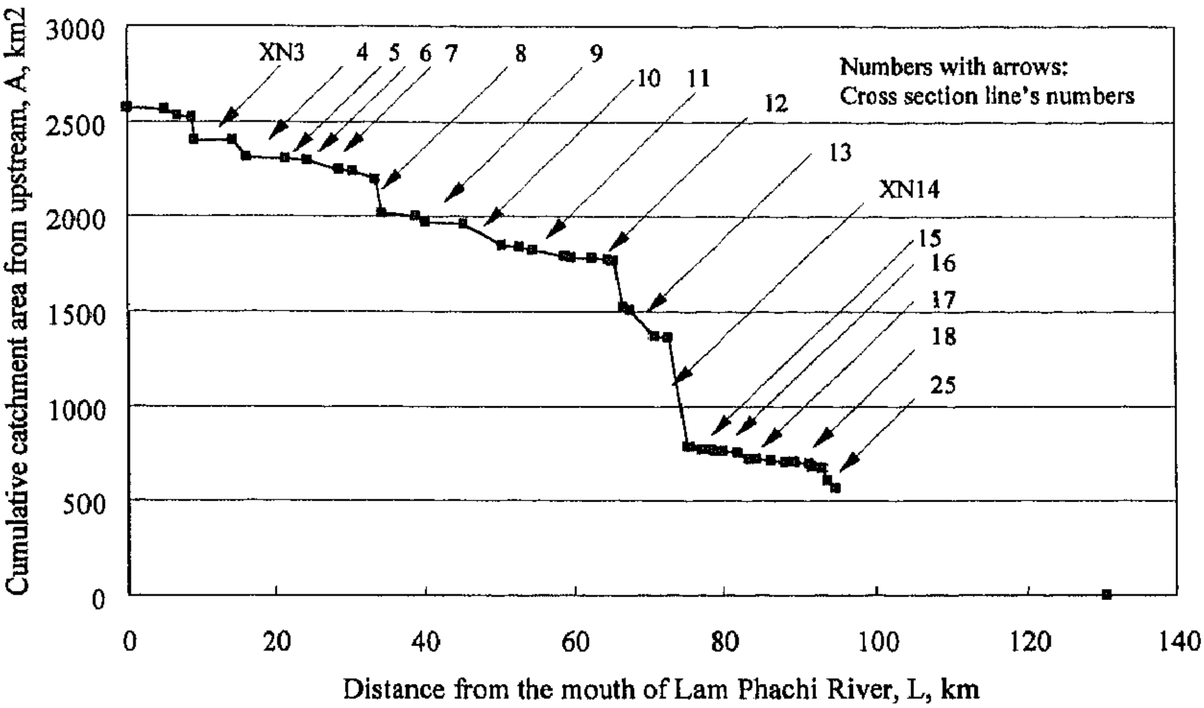


**Figure 2. Longitudinal changes in cumulative catchment area from upatream of Lam Phachi River.**

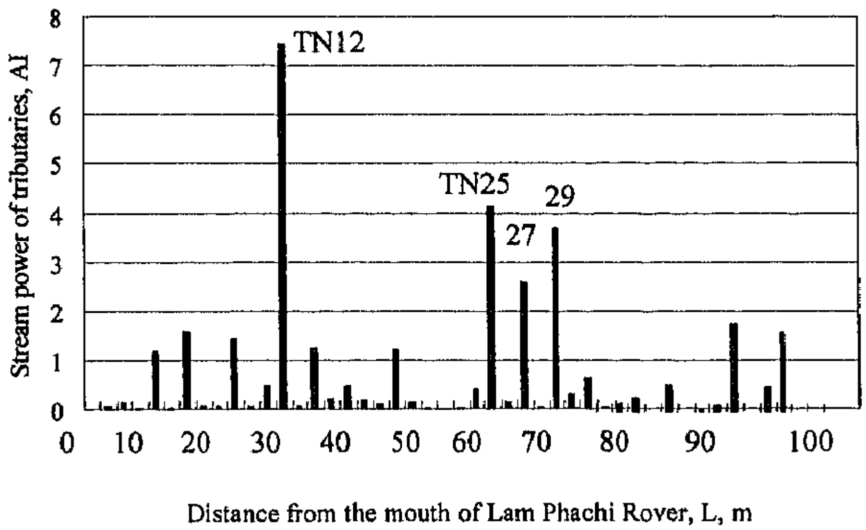


**Figure 3. Calculated stream power of each tributary.**

Figure 2 shows the longitudinal changes in cumulative catchment area from upstream. Tributary channel joined main channel causes not only sediment input but also stream power rising in main channel. Therefore tributary catchment sequences were overviewed from this figure. Numbers with allows are cross section lines. Cascade-like changes with increasing in catchment area are demonstrated at 10km (TN3 or XN3), 35km (TN12 or XN8), 65km (TN25 or XN12) and 70km (TN27 or XN13; TN29 or XN14) points.

Figure 3 shows the calculated stream power of each tributary. Indices of stream power, A·I, indicate large values at the joining points of tributaries, TN12, TN25, TN 27 and TN 29, respectively. Except for TN3, these points are coincident with the joining points with large catchment as shown in Figure 2. Therefore in Lam Phachi River, increasing in stream power yielded from tributaries can result to owe not to slope but to catchment size.

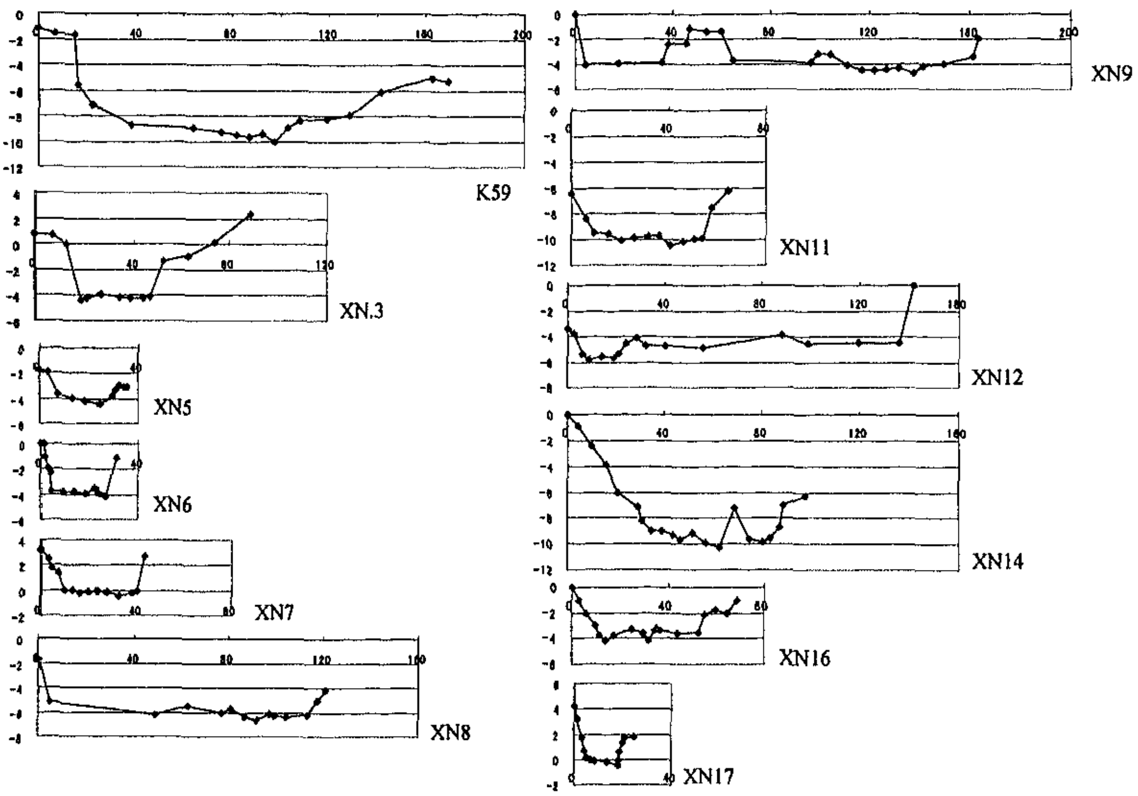


**Figure 4. Cross section along Lam Phachi main channel**

Cross sections measured in the summer of 2001 are shown in Figure 4. K59 point was mostly closed to the river mouth of Lam Phachi and XN17 was the highest points along the main channel. Bankful width of main channel is increasing from XN17 to XN12, and decreasing at the lower reach of XN9, at last increasing again from XN6 to the river mouth. From the observation of riverbed rough, the channel widening at XN9 in flooding time was between 60m point (bank on the mid river) and 160m point (left bank). As a result, the local widening in bankful width is dominated in XN12, No.8 and XN59 respectively. These points located in the downstream of junction with large tributary catchments (Fig. 2). On the other hand he bankful width at XN5, 6 and occasionally XN7 (TN7, 8, 9 and 10; 20-30km from the mouth) are relatively narrower than the upstream.

Runoff measuring at the low water was conducted twice in summer of 2001 and 2002 at the same water cross section. The results are shown in Figure 5. Both changes in runoff along the main channel are similar. After runoff, Q$m^3$/s, quickly increases at the junction, XN14, with large tributary, they keep going constantly or slightly decrease. The runoff begins to increase again at the lower reach from XN5 (TN7; 30km from the mouth). Although cumulative catchment area increase downstream of main channel (Fig. 2), changes in low water runoff are not affected by the geomorphologic nature.

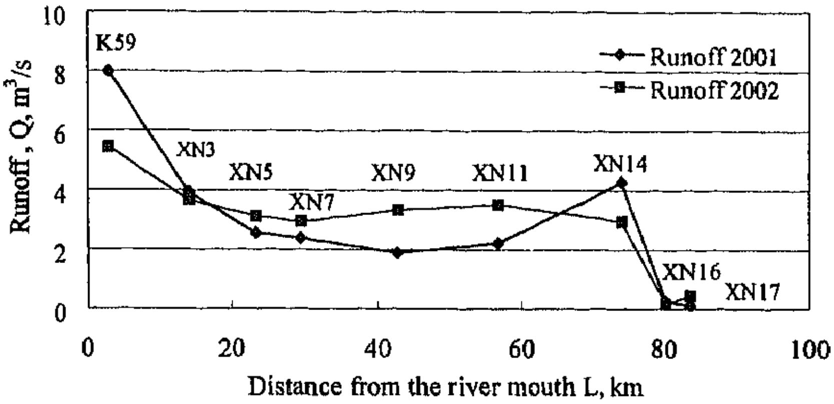


**Figure 5. Low water runoff along the main channel of Lam Phachi River.**
Water cross-section and flow velocity available for calculating runoff were collected at the cross section points of riverbed. Both measuring lines in 2001and 2002 were precisely identified at the field site.

Because changes in runoff along the main channel can reflect to changes in stream power downstream, sediment discharge at each point along the main channel can be affected by runoff changes. Riverbed slope is almost constant ranging within 0.005±0.002 except for 0.019 at XN12 (TN22), and the bed slope may not a control factor of stream power. Although conductivity of suspended load in proportion to runoff squared is expected to increase downstream, changes in particle size distribution of bed load along main channel may be related with sediment input from tributaries. Therefore suspended load discharge and particle size of bed load should be compared with runoff respectively. Figure 6 shows longitudinal changes in suspended load conductivity and low water runoff, and Figure 7 shows longitudinal changes in mean diameter of particle size distribution of bed load and low water runoff respectively. Although suspended load conductivity is harmonized with low water runoff, mean diameter of particle size distribution of bed load is not coincident with the changes in low water runoff but contrast to suspended load conductivity.

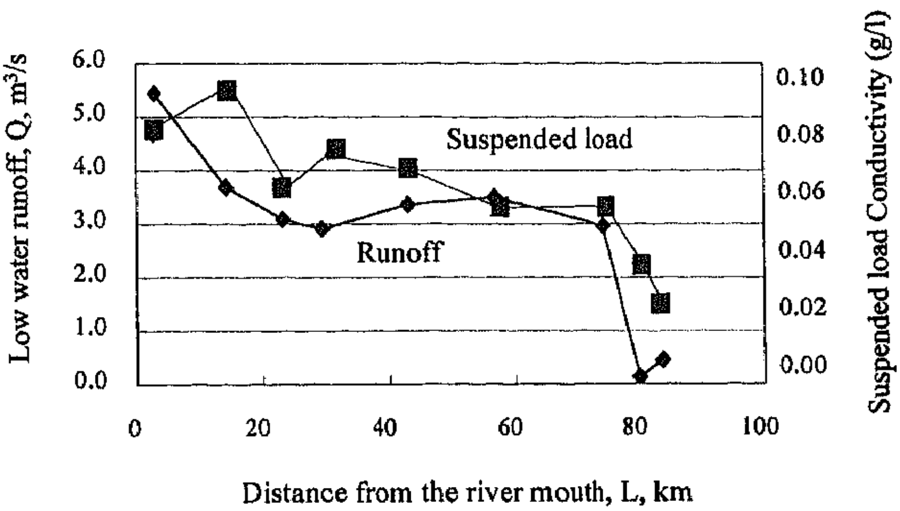


**Figure 6. Comparing suspended load conductivity with low water runoff along Lam Phachi River.**

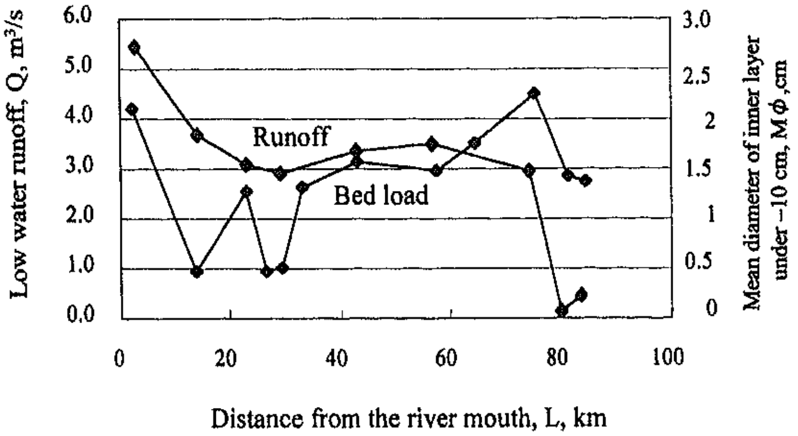


**Figure 7. Comparing mean diameter of bed load particle distribution with low water runoff along Lam Phachi River.**

Mean diameter of particle size was coarser at 75km and finer at 15km and 30km points from the mouth. Comparing with Fig.6, suspended load also slightly increase at the 15km and 30km points from the mouth. These result suggest that fine sediment may produced from the tributary channels joining at those points. From the result of Fig.2, those points show the cascades of catchment area increase, which are due to join with large tributaries.

One of the biggest impacts of human processes on sedimentary system of Lam Phachi catchment is expected to be temporally storage of water and sediment in reservoirs. Recent agricultural development substituted with forest dominated land use has disturbed the landscape management in the entire catchment. Among of many kinds of human-related earth surface changes, the reservoirs excavating at farmlands, which are available for personal use here, can affect to sedimentary system.

Figure 8 shows longitudinal changes in total area of reservoirs per unit catchment area of tributaries. Because the air photos does not always cover an entire tributary catchment and reservoir measuring was done in a part of catchment, the result surveyed should be calculated as totalized reservoir area per unit catchment area. Comparing air photos taken in 1994 with them in 1998, the area of reservoirs increased at any tributary catchments. In the upper reach of the 40km point from river mouth, area of reservoirs much more increased.

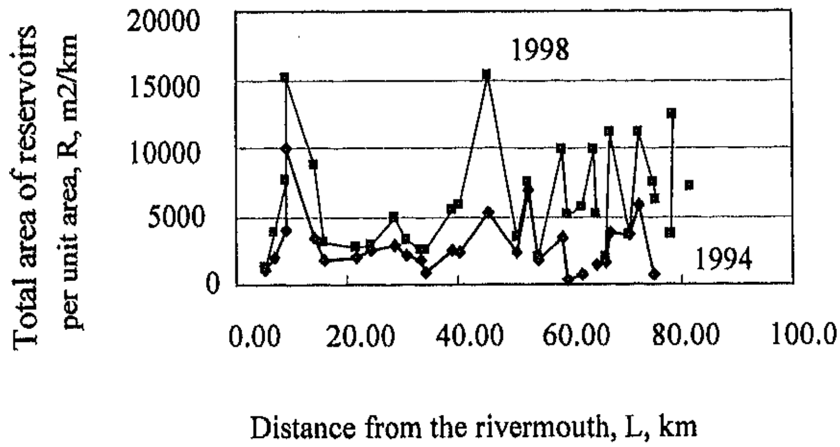


**Figure 8. Longitudinal changes in total area of reservoirs per unit catchment area, with comparing between 1998 and 1994 air photos.**

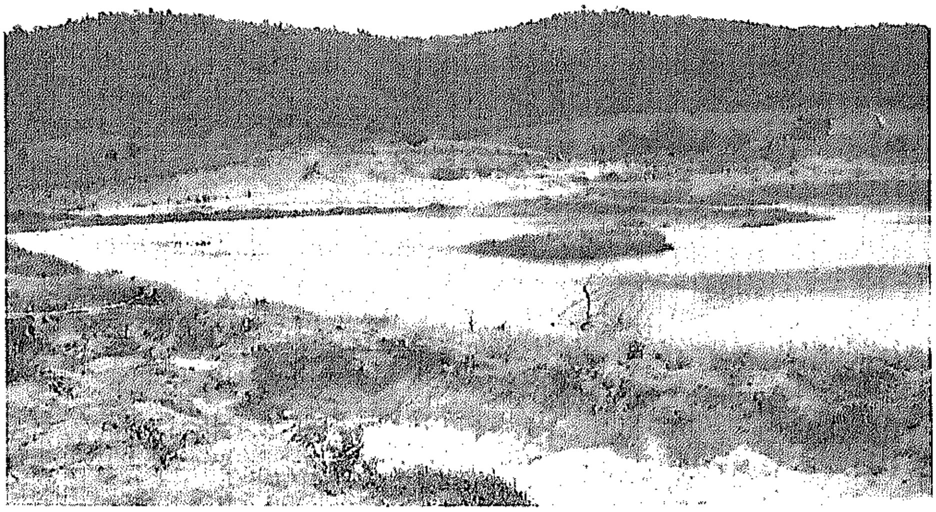

**Photo 1. Reservoir excavated in a tributary catchment by local farmers.**
Sediment and water from hill-slope were temporally stored in this reservoir and local farmers are used to sometimes deal illegally fine sediment excavated from the reservoir with local construction contractors.

At last, to characterize the significant tributaries, the relationship between magnitude and frequency analysis of reservoir distributions in tributary catchments is shown in Figure 9. Magnitude is defined as averaged area of reservoirs in each tributary catchment, and frequency is done by numbers of reservoirs per unit catchment area. The graph shows the hyperbolic relation between magnitude and frequency of reservoirs. That is, many reservoirs distribute with small size, and large-sized reservoirs distribute with isolating. The tendency of magnitude-frequency relation of reservoirs can be provided from the agricultural demand of water resource balance managed by local peoples.

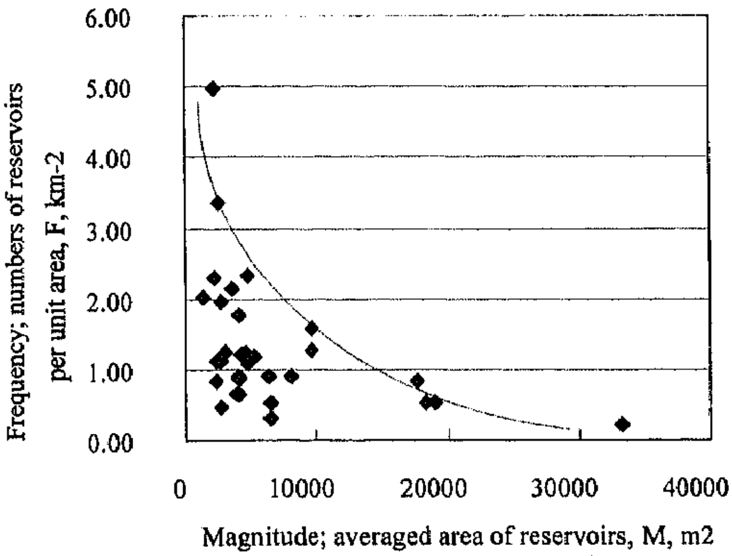


**Figure 9. Frequency-magnitude analysis of reservoirs**

Reservoirs may make an enrolment to temporally deposit of the water and fine sediment produced from hill-slope to tributary channels. As shown in table 1, channel slope of tributary channels ranged from 0.07 to 0.004 against 0.005±0.002 in main channel slope. Especially slopes of tributaries joining at the points of 15km and 30km from the mouth are 0.0048 and 0.0082 respectively. Branch channel in the mountainous area show steeper slope than the main channel, but in Lam Phachi catchment slope of tributary channels are rather gentler than main channel. In such flat catchments, the influence of reservoirs excavated by local farmer on water and sediment storage is much bigger than the mountainous catchment.

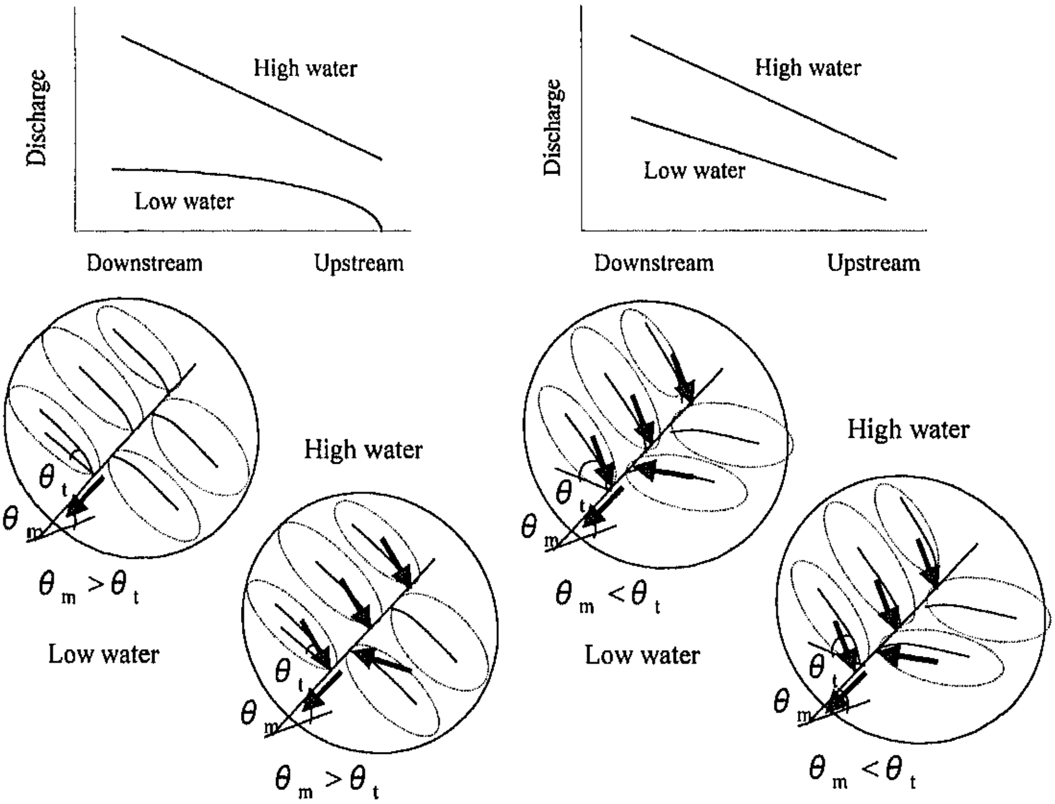


**Figure 10. Idealized model of sediment and water discharge from tributary cathments under geomorphic control.**

## 5. DISCUSSION

Figure 10 shows the idealized model of sediment and water discharge from tributary cathments under geomorphic control. From the result that low water runoff could not increase downstream accompanied with increasing in cumulative catchment area, water supply may be expected to be disturbed by geological and/or geomorphologic control. From the experiences of Waipaoa catchment, New Zealand, geomorphologic control, such as changes in stream order, gives much influence on sediment delivery ratio. However in the case study of the Lam Phachi catchment, because the slopes are more gentle in tributary catchment than in main stream, the model suggest that tributary storage of water and sediment during low flow and overflow from tributary catchment during flooding (left figure). Hydrological system of catchment, in common, develops the geo-system composed of steep-slope channel spaced in branch and gentle-sloped channel spaced in main channel (right figure).

In the case that reservoirs distribute in an entire tributary cathment, water supply during low water runoff will keep decreasing. This tendency is evidenced from the river located in dry area of the continent, such as Australia. On the contrary to low water runoff, high water will yield surplus water in tributary catchments according to their catchment area. Therefore reservoir may make a large enrolment to control water supply and sediment delivery, especially suspended sediment, through the dry season. Controlling magnitude and frequency of reservoirs in tributary cathments is ke issue for the human impacted sedimentary systems.

This study is subject to describe the longitudinal changes in geomorphic and hydrological features along Lam Phachi River. Rice (1998) implies identifying significant tributaries along main channel is important for analyzing downstream fining. Furthermore in this study, influence of catchment area and slope of tributaries on suspended load and runoff, especially for low water, is examined. Land use data such as reservoirs distributions in tributary catchments suggest that magnitude and frequency of reservoirs should be controlled in terms of degrading and reconstructing significant tributary cathments.

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**Workshop on Watershed Degradation and Restoration of the Lam Phachi River Basin, Thailand**
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# Deformation of River-bed and Its Causes in the Recent Quarter Century in the Lam Phachi River Basin

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***Abstract***
Comparing the aerial photographs taken in the years 1974 and 1998 the changes occurring in channel morphology since the beginning of colonization and cultivation in Lam Phachi river basin were analyzed to consider the magnitude and site of deformation and its causes. Morphological features of channel changes during the last quarter of the century can be grouped mainly into the following types; bank erosion, bend cutoff in meander, lateral migration of flow with massive sedimentation and terrace deformation. The spatial distribution of reaches for each type of changes were mapped out with respect to channel slope and the amount of discharge. The largest magnitude of change among them was indicated in the site with lateral migration and massive sedimentation located around the middle reaches in the study area, and sediment load flooding there suggested that it was transported by flood from the upstream where terrace deformation had occurred. Compared with the channel's morphological feature in 1974, the major source area of sediment yield has shifted and expanded from upstream to about 13 km downstream so that it is necessary for channel adjustment and stabilization to prevent reactivation of sediment load existing in these reaches.
**Keywords: bank erosion, bend cutoff, terrace deformation, lateral migration**

## 1. INTRODUCTION

Fluvial morphology is dominated not only by increases or decreases in water discharge, but also by the process of sediment transport and deposition. Particularly, the channel's morphological features strongly depends on the amount of sediment yield in the source area and the frequency of flood events causing bedload movement. Transport process of sediment from the headwaters to the floodplain has been expressed as 'sediment delivery' (Walling, 1983).

The morphological changes in a river's course take place also because development of land significantly affects the type of sediment load to be transported from the source area across the alluvial plain. In the Lam Phachi river basin, located in western Thailand, the colonization had began in earnest about 30 years ago. At present, three quarters of the river basin is under cultivation and being used as settlement.

In this report, we attempted to clarify the morphological changes that have occurred in the channel and its causes since the beginning of colonization and cultivation by analyzing aerial photographs and field surveying. Based on our findings, we tried to explain the processes of sediment transport relative to time and space.

## 2. METHODS AND STUDY AREA

Lam Phachi river basin has a watershed area of 2,657 $km^2$. As the traffic road network along the river has not been well completed, the field surveying on each river site is difficult to carry out. Two kinds of aerial photographs taken in different years were therefore used for comparing and analyzing the changes in the channel morphology, because the differences in pattern and channel shape as identified can be of use in the interpretation of river behavior from aerial photography when no other data are available (Kellerhals et.al., 1976). The photographs used were taken in 1974 and in 1998 both by the Royal Thai Survey Department, Thailand. The scale used for the photographs was 1:15,000 in 1974 and 1:50,000 in 1998. In addition to the photograph analysis, the cross sections and gradient of channel slope were surveyed beside 14 bridges crossing over Lam Phachi to calculate the amount of water discharge.

The study plot covers an area from the river mouth to the junction with the main tributary located 74km upstream, belonging almost to flood plain at an elevation under 100 m, with scattered settlements and widespread over cultivated fields. Therefore, the area is characterized by a higher tendency of disaster occurrence caused by flood and sediment movement. The study area is 1,447 $km^2$ covering about 54% of the whole river basin. The aerial photographs indicate that the settlement developed scarcely along the river in 1974. However in 1998 the well-vegetated riverside were almost cleared to change for cultivated fields and settlement.

## 3. MORPHOLOGICAL FEATURES

New shapes of channel are formed as a result of sediment movement. The extrinsic thresholds of sediment load and stream power determine whether the river will be straight, meandering or braided (Schumm, 1977). Harvey (1992) classified the shape of channel change resulting from floods into several types with reference to sediment input and discharge in a river basin of northwest England. Comparing the aerial photographs in 1974 with those in 1998, channel changes that occurred during the 24-year period can be grouped mainly into the following types:

**Type A: Channel widening by bank erosion**

Where the channel made a curve, the floods run against the out-curved bank and intensively led to lateral degradation (Harvey, 1992). Almost bank erosion occurred in the study area at the bent site without forest cover. Fig. 1 shows the channel around the 3 km point upstream from the river mouth in 1974 and in 1998 respectively. Circles pointed in the photo indicate the places where bank erosion has occurred. The right bank had regressed approximately 30-50 m backward during the 24-year period and could be said to be responsible for the widening of the channel. The scale of eroded sheer cliffs reaches 80-350 m in length with 5-20 m relative height.

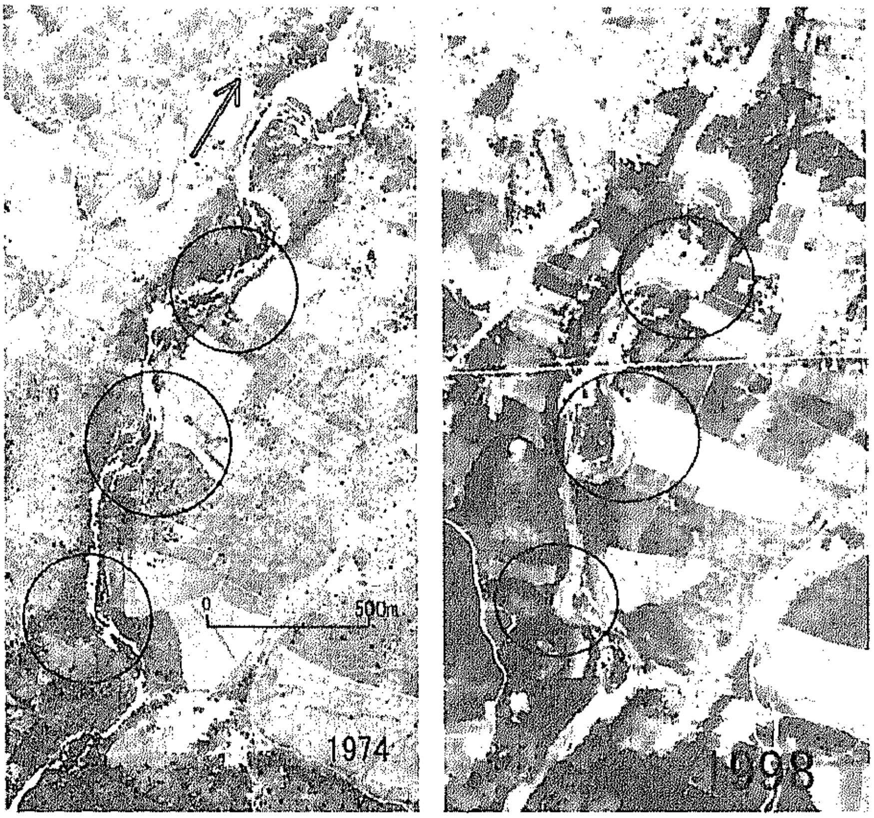


Fig. 1 Aerial photographs showing the bank erosion at the study site in 1974 and 1998

On the cliff the cultivated field of cassava, for example, extends until the edge of the cliff. As rainwater gathers between ridges and falls on the cliff, vertical erosion is accelerated resulting in a particular shape just like the teeth of a comb (Photo 1). Photo 2 shows the eroded steep cliff at the right bank located at a distance of about 1km upstream from the river mouth. The cliff reaches almost 12 m in terms of relative height. The site at which bank erosion occurred is observed where the stream bends, in addition to the cultivated fields extending up to the bank edge.

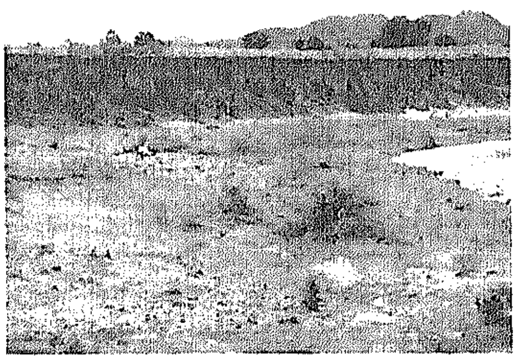

Photo 1 Bank erosion near the 3 km point

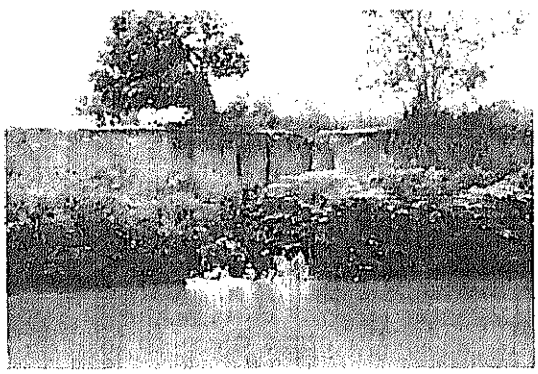

Photo 2 Bank erosion near the 1 km point

**Type B: Bend cutoff in meander channel**

This channel often shows meandering in plain reaches, where the gradient of the river-bed decreased and then the velocity of water flow reduced (Laronne & Duncan, 1992). Although water flows usually along bent course, the intensive floods flushed straightened across the floodplain foreshortening the course by bend cutoff, through which a new straight channel is formed.

Fig. 2 shows the channel around the 22 km point upstream from the river mouth in 1974 compared with the channel in 1998. In spite of the bent shaped channel in the year of 1974, the straight channel is observed at the same position in 1998, and over floodplain between meander a sheet of sediment spread. The old meandering channel depicted on the aerial photograph in 1974 is still visible in the field, nevertheless the modification of meandering initiated the former channel partly abandoned. Compared with bank erosion newly formed straight channels caused by bend cutoff took place where the relative heights of bank are lower.

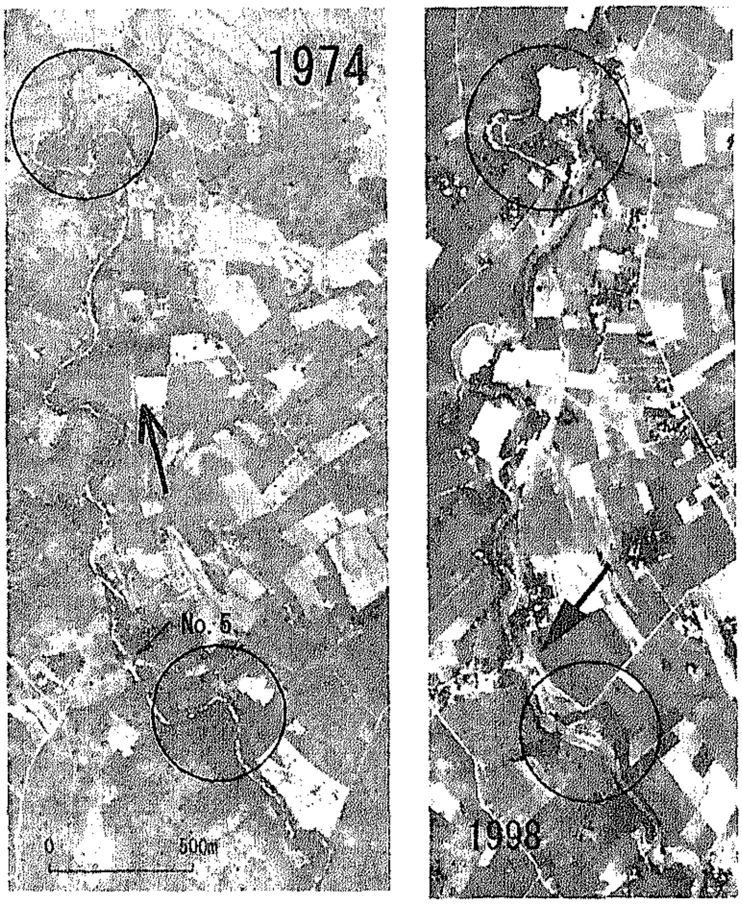


Fig. 2 Aerial photographs showing the bend cutoff at the study site in 1974 and 1998

**Type C: Lateral migration and massive sedimentation**

Massive sediment depositions by floods took place on reaches with widespread river-bed and caused lateral migration of channel forming a braid water course. Less water discharge and excess sediment input often led to a massive sedimentation, and through which a new widened river floor is initiated.

In 1998 a broad river-bed of 200-250 m width could be identified on the reaches between 38 and 40 km upstream from the river mouth, as shown in Fig. 3. Compared with the aerial photograph in 1974 the channel is entirely buried by new sediment, taken on a different

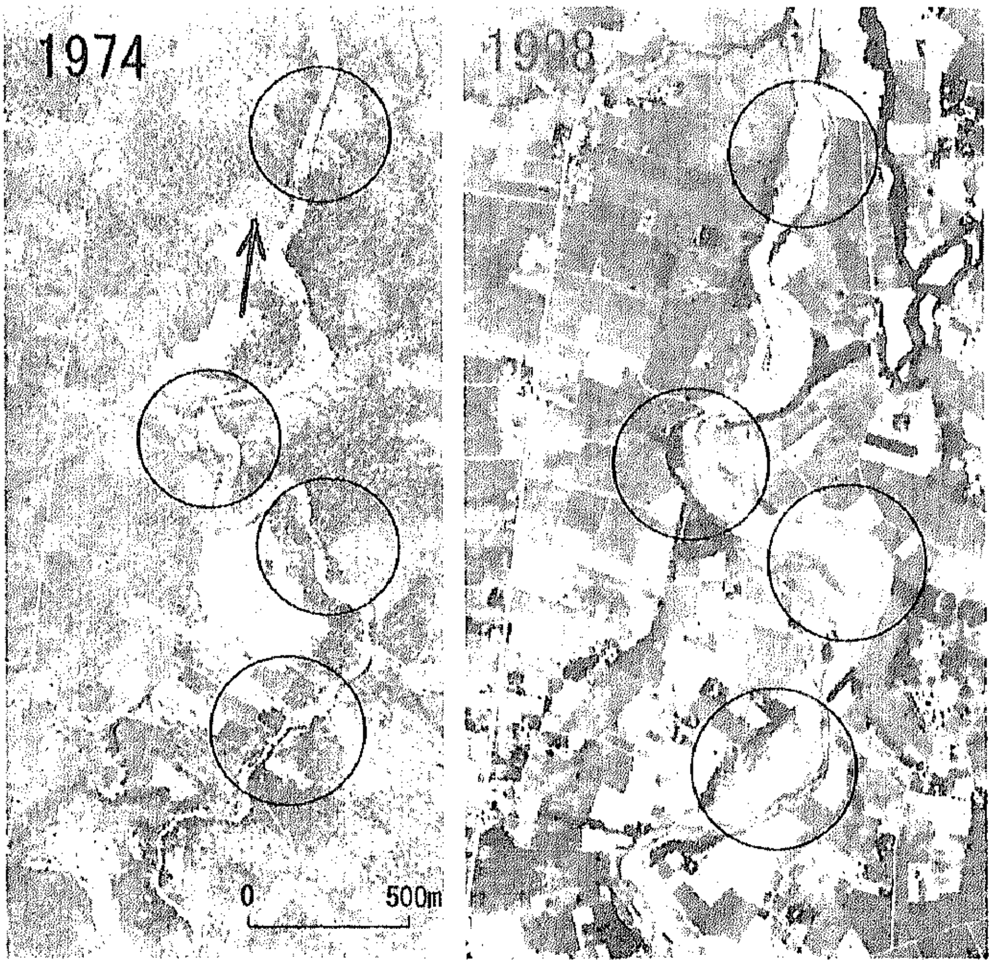


Fig. 3 Aerial photographs showing the lateral migration and massive sedimentation at the study site in 1974 and 1998

appearance and widened approximately 3 times as the previous figure. It is considered that the widening of the channel is caused by sediment floods rather than by scouring. The channel widening and braided flow has led to about a distance of 2.2 km, which indicates that among the study area the most massive deformation of channel has taken place in this site.

**Type D: Terrace deformation**

Different from water discharge, sediment is transported discontinuously and deposited from place to place under geomorphologic condition (Reid and Frostick, 1994). The widening of channel accelerated deposition and made the appearance of widespread sediment floods on river-bed. With scouring by flows thereafter, deposited sediment removed partly downstream which caused a depression of the river-bed and the formation of terraces beside the stream course.

Fig. 4 shows terraces with 20-100 m wide and vegetation covering the middle reaches of the study area on the aerial photograph in 1974. Even though the terraces were covered by vegetation, which suggested stabilization temporarily, the aerial photograph in 1998 indicated the disappearance of this vegetation cover over a long span. The terraces themselves have been deformed and altered to the widened bare channel. Deformation of terraces occurring in response to flood did not go beyond the river width, and scouring remained within the river. As scouring and deformation of terraces by floods extends over a wider area, reaches with this pattern could be a major source of sediment yield for downstream.

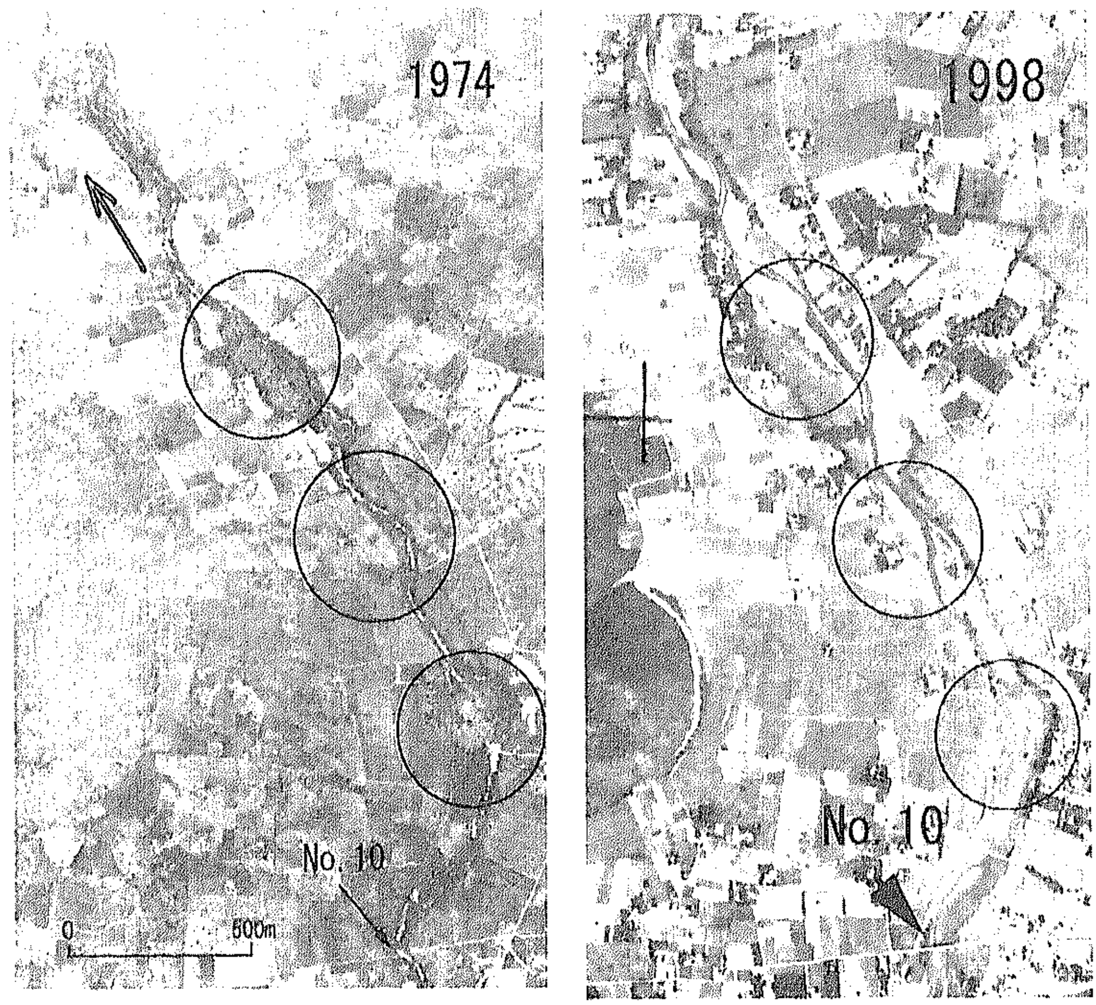


Fig. 4 Aerial photographs showing the terrace deformation at the study site in 1974 and 1998

## 4. CHARACTERISTICS OF DEFORMATION

### 4.1 Magnitude

Table 1 summarizes the site, types, magnitude and riverside of the whole channel deformations. Terrace deformation indicated the largest area among them, and its average value amounted to several tens of hectares per reach. The deformations with almost the same magnitude took place on the reaches with lateral migration and massive sedimentation. Therefore, the sections from 33 to 40 km and from 44 to 49 km could be pointed out as the sites on which massive deformation occurred in the channel during the last quarter of the century. Deformed areas due to bank erosion and bend cutoff in meander channel ranged from 0.2 to 3.2 ha, relatevely smaller in magnitude compared with other types.

Because it was difficult to estimate the depth of deformation from the comparison using aerial photographs, quantitative calculation of the morphological changes occurred in the channel could not be carried out. Considering the fact that floodplains with gentle slope constituted a greater part of the study area, the calculated values of the deformed area could reflect the amount of sediment that was contributed to the sediment load by floods.

Table 1 Types of deformed areas and their characteristics along the river

| Distance from river mouth (km) | Type | Magnitude | | | Bank side |
|---|---|---|---|---|---|
| | | Length (m) | Av. Width (m) | Area (ha) | |
| 2.2 | B | 100 | 30 | 0.3 | R |
| 3.0 | B | 350 | 50 | 1.8 | R |
| 3.7 | M,C | 250 | 80 | 2.0 | R |
| 4.0 | B | 200 | 50 | 1.0 | R |
| 4.8 | B | 100 | 30 | 0.3 | L |
| 5.2 | B | 130 | 60 | 0.8 | L |
| 7.0 | B | 80 | 30 | 0.2 | L |
| 7.5 | C | 400 | 80 | 3.2 | R |
| 12.2 | M,C | 80 | 30 | 0.2 | L |
| 12.5 | D | 100 | 50 | 0.5 | R |
| 13.5 | C | 200 | 70 | 1.4 | L |
| 15.2 | C | 100 | 40 | 0.4 | L |
| 16.5 | C | 150 | 50 | 0.8 | R |
| 16.7 | M,C | 400 | 50 | 2.0 | L |
| 17.5 | C | 600 | 50 | 3.0 | L,R |
| 19.0 | M | 150 | 100 | 1.5 | R |
| 20.5 | C | 500 | 50 | 2.5 | R |
| 22.0 | B | 200 | 30 | 0.6 | L |
| 22.5 | C | 200 | 40 | 0.8 | R |
| 24.0 | C | 150 | 50 | 0.8 | L |
| 25.0 | B | 150 | 50 | 0.8 | R |
| 27.0 | C | 60 | 40 | 0.2 | L |
| 27.2 | B | 150 | 50 | 0.8 | R |
| 29.0 | C | 150 | 40 | 0.6 | L |
| 30.0 | M | 250 | 100 | 2.5 | R |
| 31.0 | M | 600 | 100 | 6.0 | L,R |
| 33.0 | M | 400 | 200 | 8.0 | L |
| 35.5 | M | 450 | 60 | 2.7 | R |
| 36.0 | B,M | 400 | 100 | 4.0 | R |
| 37.2 | M | 600 | 220 | 13.2 | R |
| 38.0 | M | 700 | 180 | 12.6 | R |
| 38.5 | M | 1,500 | 200 | 30.0 | L,R |
| 43.0 | D,M | 500 | 80 | 4.0 | L |
| 43.5 | D | 350 | 120 | 4.2 | L,R |
| 44.0 | D | 5,000 | 100 | 50.0 | L,R |
| 50.0 | B,D | 300 | 100 | 3.0 | L,R |
| 50.5 | D | 400 | 120 | 4.8 | R |
| 51.0 | B | 300 | 100 | 3.0 | R |
| 53.2 | B | 300 | 20 | 0.6 | L |
| 54.0 | D | 1,200 | 120 | 14.4 | L,R |
| 57.0 | D | 1,200 | 100 | 12.0 | L,R |
| 58.5 | D | 900 | 120 | 10.8 | L,R |
| 61.0 | D | 1,000 | 80 | 8.0 | L,R |
| 62.0 | D | 700 | 100 | 7.0 | L |
| 64.5 | D | 1,500 | 100 | 15.0 | L,R |
| 67.0 | D | 250 | 50 | 1.3 | R |
| 68.5 | D | 400 | 100 | 4.0 | L,R |
| 73.0 | D | 400 | 70 | 2.8 | R |
| Total | | 24,550 | | 250.2 | |

Type: B(Bank erosion), C(Bend cutoff), M(Lateral migration), D(Terrace deformation)

**4.2 Site**

Fig. 5 illustrates the location of deformed sites classified into 4 types. There was scarcely any site without deformation in the study area, and the channel is morphologically changed in the section with a total length of 24.6 km being equal to one third length of the study area. Each type of site is not distributed uniformly, but concentrates obviously on the particular section which could be divided spatially.

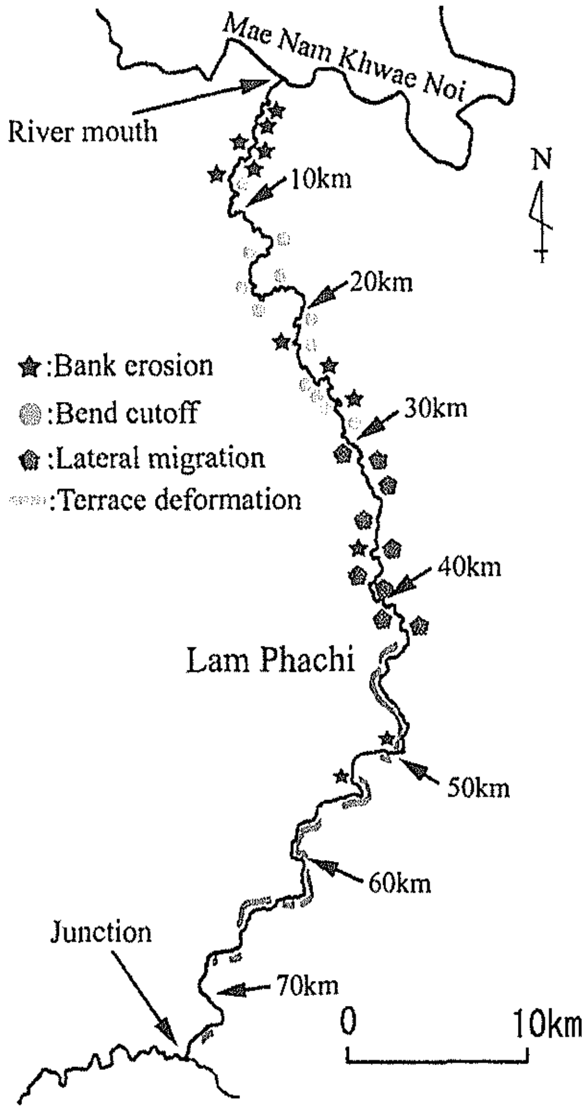


Fig. 5 Location of deformed areas

The bank erosion site was mainly found in the section from the river mouth up to 8 km upstream and from 35 to 38 km. The bend cutoff site was found to be concentrated around the meandering section between 12 and 37 km. The lateral migration site with massive sedimentation were located within reaches from 30 to 43km. Terrace deformation occurred from a point nearer to the 42 km mark up to the 68 km mark, extending several kilometers long per site. Consequently the morphological feature of the deformed channel could be defined spatially from the river mouth upstream as bank erosion, bend cutoff, lateral migration with massive sedimentation and terrace deformation in that order.

**4.3 Causes**

The distribution of channel deformation appears to be related to changes in river profile and the amount of water discharge. Fig. 6 indicates the graph of elevation against distance from the river mouth for the Lam Pachi river basin. It can be seen from this graph that the slope is gentle (1/1000) from the river mouth to a point roughly 5 km upstream. The gradient further reduces to 0.7/1000 up to the 33 km mark after which it changes to a value of 1.7/1000 up to the 56 km mark, before becoming gentle again (0.6/1000).

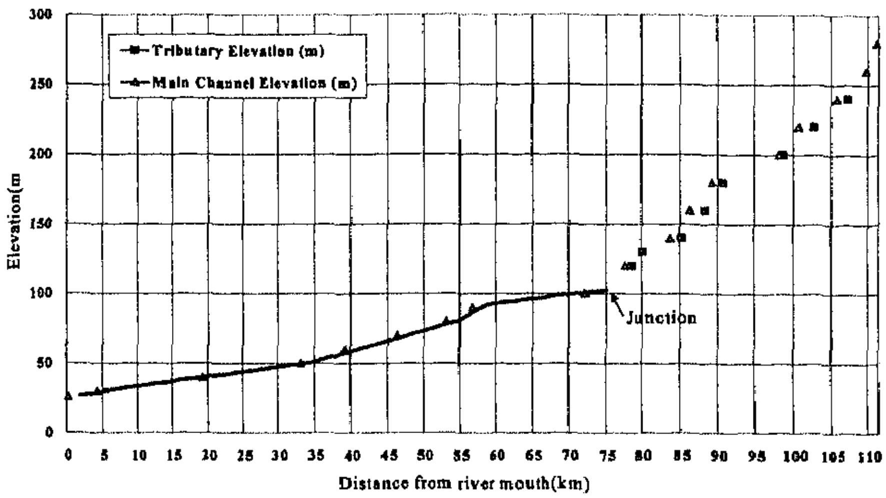


Fig. 6 Longitudinal profile for Lam Phachi River

Fig. 7 represents the water discharge during usual flows in the study area for the past two years calculated from the surveying of cross sections. Although there is a little difference in the tendency for the values to change according to the distance from the river mouth for both years, there was very little variation in the discharge from the junction to around the 30 km point and increased from there rapidly downstream.

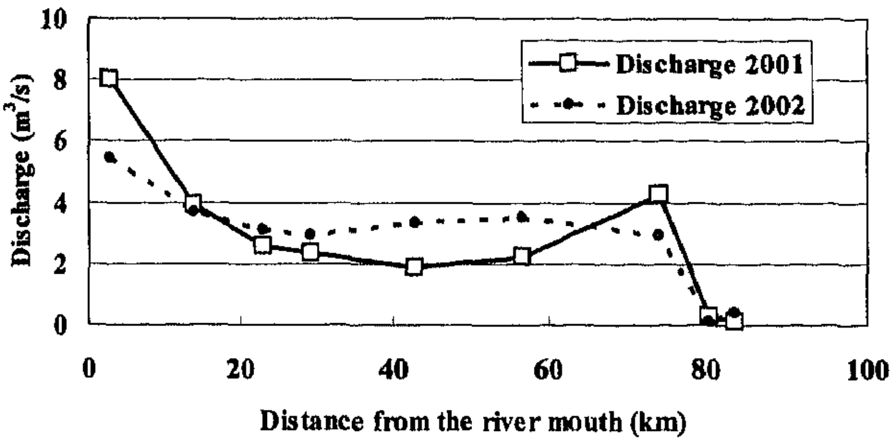


Fig. 7 Discharge during usual flow for two years

Considering both features, a massive sediment transport by floods from upstream might terminate around the point of 33 km due to mitigation of the channel gradient and little fluctuations in the water discharge. Especially, the tendency of the discharge to remain suggests an acceleration in the unloading of sediment. Terrace deformations corresponds remarkably with transitional reaches of channel slope from gentle to steep gradient.

After sediment deposition in large quantities, it is considered that flood flow might result in the straightening of the channel in the meandering section. According to the observation of water level by R.I.D., the highest water level resulting from a flood on 26th October 1999 is recorded approximately as 7 m. This is higher than the usual water level so the increase in the water discharge at the downstream reach could be related to escalation in the magnitude of bank erosion there.

## 5. DISCUSSION AND CONCLUSION

Alluvial channel morphology tends to adjust with the input of water and sediment to the fluvial system, with a high rate of coarse sediment input leading to unstable, often braided channels, and a lower rate to more stable, often meandering channels (Schumm, 1977). The patterns of channel deformation in the Lam Pachi river basin could be classified mainly into 4 types, and the site at which each pattern occurred has been divided spatially according to the channel slope and water discharge.

The largest magnitude of channel deformation occurred where the slope gradient changed from steep to gentle, and rare fluctuation of discharge according to distance is recognized. On this reach, sedimentation by flood is assumed to exceed scouring by lateral migration. Because of that the calculated values of water discharge indicated no remarkable changes with respect to distance, transported sediment should be deposited with a reduction in slope angle and widening of flow.

The reaches with terrace deformation upstream could therefore be pointed out as the main source of sediment yield, located from 44 to 60 km. In 1974 the distribution of existing wide terraces was limited to the upper reaches from 43km, but in 1998 it extended downstream until the 30 km point. After the floods which resulted in the deformation of terraces, vegetation has thriven quickly and recovered on the surface of the terrace within a short time (Photo 3, 4). With vegetation cover, the terraces appear to be stable, but in actual fact they are unstable and likely to move again.

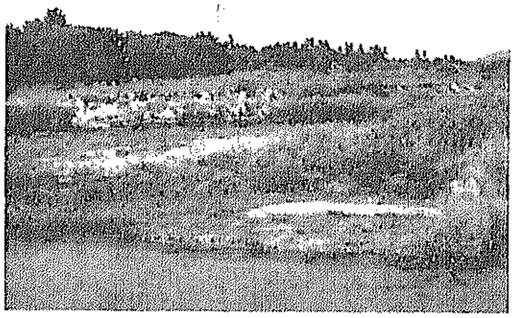

Photo 3 Vegetation cover on terraces

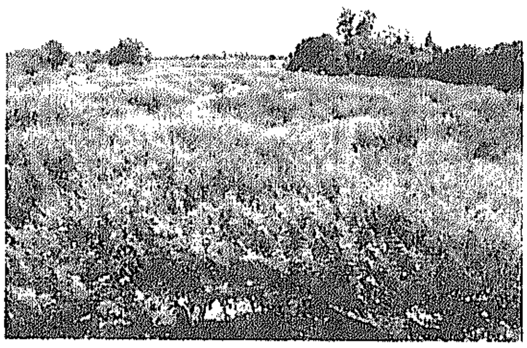

Photo 4 Vegetation cover on river-bed

It is considered that the extension of reaches with terrace formation is due not only to sediment input from the upper reaches, but it is also related to the changes in land use in the river basin. However, the data to discuss the relationship between channel deformation and human impact is insufficient.

The channel in meandering reaches is assumed to be relatively narrow, and no large-scale sediment deposition has been found. As a massive deposition of sediment took place on the upper reaches, only small size materials such as silt, loam and sand are transported as suspended load by usual flow, but in our opinion, the cross section of the river was not able to handle the discharge by the flood. Furthermore, increment of discharge downstream tends to lead to enlargement of bank erosion.

For stabilization of the river in study area, it is necessary to prevent reactivation of scouring as well as to reduce removability of sediment deposits on the river-floor in middle reaches, to adjust channel width artificially at meander sections and to protect both banks against lateral erosion downstream (Fig. 8).

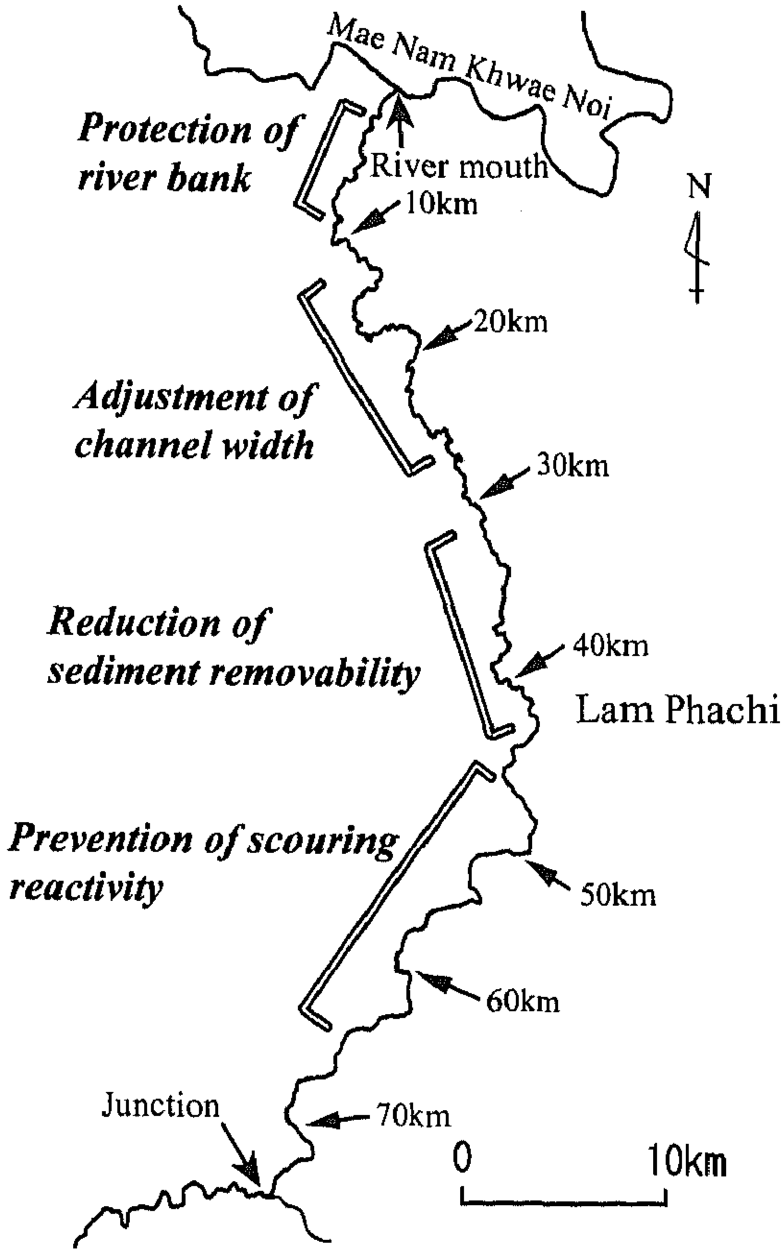


Fig. 8 Proposals to prevent sediment disasters and flooding


## ACKNOWLEGEMENT

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# Invasion of Woody Plants into the Abandoned Pineapple Fields in the Lam Phachi River Basin

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***Abstract***

To clear the possibility of restoration of the pineapple field, we carried out field studies of vegetation revegetated immediately after abandonment on a pineapple field in the upper region of Lam Phachi river basin. The mean density of stems at one year after abandonment was 18.8 trees/25m$^2$. But the mean density of individuals regenerated was 14.0 individuals/25m$^2$. The total number of species recorded in 5 plots was 11 and the mean number of species was 3.8 species/25m$^2$. The mean density of stems at two year after abandonment was 32.8 trees/25m$^2$ . The mean density of individuals regenerated was 15.6/25m$^2$. The total number of species recorded in 9 plots was 8 and the mean number of species was 3.1 species/25m$^2$. *Wrightia arborea* and *Mussaenda angustisepala* dominated on the abandoned pineapple field in both years. While the density of stems increased from 18.8 trees/25m$^2$ to 32.8 trees/25m$^2$ , the density of individuals was similar between two years. Both the density of stems and the density of individuals were significantly higher in the boundary than in the interior, where only several woody plants grew. The boundary had significantly more species than in the interior both in 2001 and in 2002. The density of stem was 94.8stems/25m$^2$ and the number of species recorded was 11 in 5 years old *Eucalyptus* plantation. *M.angustisepala* dominated significantly (71%) and *W.arborea, Capparis micracantha, Callicarpa longifolia* , *Cleistanthus hirsutulus* occurred in comparatively higher density. The number of species was significantly larger in the boundary than in the interior. From these results obtained, it was concluded that the recovery of woody vegetation on the abandoned pineapple filed might be difficult and it might take very long time before recovery of original forest.

**Key words: restoration, woody plants, distance effect, pineapple field**

## 1. INTRODUCTION

In Thailand, the most of forested area have been destroyed to convert into agricultural lands, resulting in smaller forested area ( 22.8%) ( FAO, 1997 ). Immediately after clear-cutting, the yield of crop is greater, but it become lower due to run off of nutrients from the soil. Thus recently larger area of abandoned fields have been remained in the tropical area. On the degraded land, the regeneration of woody plants and the recovery of forest is very difficult because of the soil condition, direct solar radiation, high temperature, competition with herbaceous plants, seedling predation, and smaller input of seeds (Uhl, 1987; Aide and Cavelier, 1994; Aide et al., 1995; Nepstad et al., 1996; Parrotta et al. 1997). It was suggested that graminoid species such as *Imperata* species dominated on cutover sites and inhibit the growth of trees (Otsamo, 1998). But Holl (1999) cleared that the regeneration of woody species on the abandoned pasture had inhibited at the stage of seed input and exotic herb dominated the pasture rather facilitated the emergence of seedling. In those degraded land, it have been pointed out that the plantation had catalyzing effect of the forest recovery (Lamb et al., 1997; Parrotta et al., 1997). Such a method of forest recovering are called the framework species method, and have been applied to the restoration of degraded land in the neotropical forest area (Leopold et al., 2001), the tropical forest in Australia (Lamb et al., 1997), the tropical forest of Southeast Asia ( Otsamo, 1998) and also in northern Thailand ( Hardwick et al., 1997). Carnevale and Montagnini (2002) cleared that the mixture of species might bring more abundant woody seedlings and higher diversity in the understory than the pure species plantations.

In the Lam Phachi river basin located in western part of Thailand, the larger part of forest have been logged and converted into sugarcane fields, cassava fields and pineapple fields ( Maita et al., 1999). Especially the upper region of Lam Phachi river basin, the pineapple field have been created on the gentle slope after logging. Maita et al.(2002) cleared that the physical condition of soil in pineapple fields was quite different from those in surrounding secondary forest. The soil of pineapple field had lower permeability than the secondary forest surrounded the pineapple field (Maita et al., 2002). As a result of lower permeability, the soil erosion had developed in the pineapple field with the time elapsed after planting.

The abundance of cash crop such as pineapples planted might vary year to year depending on the economic condition, especially on the market price. Furthermore, since the continuing cultivation on the same field for more than three or four years decrease the soil fertility, the farmer applies the chemical fertilizer to enrichment the soil or abandon the field to shift another field. In some cases, after abandonment the field are planted *Eucaluptus* species. *Eucalyptus* plantations are considered to be able to manage carelessly and gain the stable income periodically.

To consider the restoration in the upper region of Lam Phachi river basin with vast area covered by pineapple field, it is necessary to study the process of revegetation both in abandoned pineapple fields and in *Eucalyptus* planted pineapple fields. In the abandoned pineapple field it hypothesized that the seed input might be primary important rate-limiting stage and the distance from the surrounding forest might affect the abundance of seeds dispersed. In the case of Eucalyptus plantation, it was predicted that the effect of Eucalyptus species on the seed input and the seedling survival might play an important role in the woody regeneration.

The purpose of this study is

(1) to clear the vegetation structure in the abandoned pineapple field at one year and two year after abandonment.

(2) to examine the distance effect on the abundance and the diversity of woody plants invaded into the pineapple field.

(3) to clear the abundance and the diversity of woody plants under the canopy of Eucalyptus trees planted.

(4) finally to consider the management to restore the pineapple field.

## 2. STUDY AREA AND METHOD

The study was carried out in the upper region of Lam Phachi river basin. At Kanchanaburi station about 50 Km distant from the study area. The annual mean temperature was 27.9°C, monthly mean temperature varying from 24.6°C in December and 31.2°C in April (AIT,1994 ). The annual precipitation was 1130mm (Maita et al., 1999). The climax community of this area was considered to be the mixed deciduous forest with bamboo ( Suksawang, 1995).

The study plots were set up in the abandoned pineapple field and in *Eucaluptus* plantation near Lam Phachi river. In August 2001, when one year had elapsed after abandonment, 5 plots ($25m^2$) were set up in the abandoned pineapple field. At each 5m, 10m, 15m from the forest edge, one plot was set up, and at 20m from the forest edge two plots were set up. In 2002, when two year had elapsed after abandonment, 9 plots ( 25m2) were set up. At each 5m, 20m from the forest edge, one plot was set up, at each 10m, 30m from the forest edge two plots were set up and at 25m from the forest edge 3 plots were set up. In each plots set up in 2001 and in 2002, the species was recorded and height was measured for each woody plants with height over 1m. The pineapple field located on the western gentle slope.

In 2002, we studied the *Eucalyptus* plantation, where *Eucaluptusca maldulensis* trees had been planted at 1997 in a abandoned pineapple field. The *Eucaluptus* plantation located on the southern east slope and the inclination of slope was 30 degree. Two plots ( $25m^2$) were set up both in the boundary ( within 10m from the forest edge ) and in the interior ( over 30m from the forest edge ). In each plots, the species was recorded and height was measured for each woody stems with height over 1m.

In this study, when multiple stems originated from the same root, we counted these stems as one individual. And to examine the effect of distance from the forest/field edge on the vegetation structure, plots set up in the pineapple field were grouped into two habitats ( the boundary vs. the interior). The boundary included plots with the distance from the edge less than or equal to 10m. The interior included plots with the distance fro the edge beyond 10m.

## 3. RESULTS

### 3.1. Vegetation structure at one year after abandonment

The mean density of stems at one year after abandonment was 18.8 trees/$25m^2$ ( Table 1). The highest density was 34 trees/$25m^2$ and the lowest density was 3 trees/$25m^2$. But the mean density of individuals regenerated was 14.0 individuals/$25m^2$, ranging from 3 individuals/$25m^2$ to 28 individuals/$25m^2$ ( Table 2). The total number of species recorded in 5 plots was 11 and the mean number of species was 3.8 species/$25m^2$, ranging from 1 species/$25m^2$ to 7 species/$25m^2$ ( Table 1).

The frequency distribution of stem height was the unimodal distribution with the mode in 1.5-2.5 m ( Fig.1). The mean value and the maximum value of stem height in 2001 was 1.6 m and 3.5m, respectively.

*Wrightia arborea* dominated in the density ( 8.8 trees/$25m^2$, 6.6 individuals/$25m^2$ ), and *Mussaenda angustisepala* was the next dominant ( 5 trees / $25m^2$, 3.4 individuals /$25m^2$ , Table1,2 ). Other than these two species, *Callicarpa longifolia*, *Abelmoschus moschatus*, *Gmelia asiatica*, *Vitex* sp. and *Leucaena leucocephala* occurred in higher density (Table 1, 2).

### 3.2. Vegetation structure at two years after abandonment

The mean density of stems at two year after abandonment was 32.8 trees/$25m^2$ ( Table 3 ). The highest density was 52 trees/$25m^2$ and the lowest density was 21 trees/$25m^2$. The mean density of individuals regenerated was 15.6/$25m^2$, ranging from 5 individuals/$25m^2$ to 31 individuals/$25m^2$ ( Table 4 ). The total number of species recorded in 9 plots was 8 and the mean number of species was 3.1 species/$25m^2$, ranging from 1 species/$25m^2$ to 5 species/$25m^2$ ( Table 3 ).

The frequency distribution of stem height in 2002 was also the unimodal distribution with the prominent peak in 2.0-2.5 m ( Fig.2 ). The mean value and the maximum value of stem height in 2002 was 2.5 m and 7.0m, respectively.

Table 1 Density of stems regenerated in the abandoned pineapple field at 1 year after abandonment

| | Number of stems/25m² | | | | | |
|---|---|---|---|---|---|---|
| Species / Distance from the edge | 5m | 10m | 15m | 20m | 20m | Total |
| *Wrightia arborea* (Dennst.) Mabb. | 15 | 10 | | 19 | | 8.8 |
| *Mussaenda angustisepala* Ridl. | 6 | 18 | 1 | | | 5 |
| *Callicarpa longifolia* | 3 | 1 | | | | 0.8 |
| *Abelmoschus moschatus* Medik. | 4 | | | | | 0.8 |
| *Gmelia asiatica* L. | 3 | 1 | | | | 0.8 |
| *Vitex* sp. | 3 | 1 | | | | 0.8 |
| *Bauhinia* sp. | | 1 | | | | 0.2 |
| *Aerva sanguinolenta* Blume | | 1 | | | | 0.2 |
| *Ficus hispida* L.f. | | | 2 | | | 0.4 |
| *Litsea glutinosa (lour.) C.B. Rob.* | | | 1 | | | 0.2 |
| *Leucaena leucocephala (Lam.) de Wit* | | | 1 | | 3 | 0.8 |
| Total | 34 | 33 | 5 | 19 | 3 | 18.8 |

Table 2 Density of individuals regenerated in the abandoned pineapple field at 1 year after abandonment

| | Number of individuals/25m² | | | | | |
|---|---|---|---|---|---|---|
| Species / Distance from the edge | 5m | 10m | 15m | 20m | 20m | Total |
| *Wrightia arborea* (Dennst.) Mabb. | 15 | 6 | | 12 | | 6.6 |
| *Mussaenda angustisepala* Ridl. | 5 | 11 | 1 | | | 3.4 |
| *Callicarpa longifolia* | 2 | 1 | | | | 0.6 |
| *Abelmoschus moschatus* Medik. | 3 | | | | | 0.6 |
| *Gmelia asiatica* L. | 1 | 1 | | | | 0.4 |
| *Vitex* sp. | 2 | 1 | | | | 0.6 |
| *Bauhinia* sp. | | 1 | | | | 0.2 |
| *Aerva sanguinolenta* Blume | | 1 | | | | 0.2 |
| *Ficus hispida* L.f. | | | 2 | | | 0.4 |
| *Litsea glutinosa (lour.) C.B. Rob.* | | | 1 | | | 0.2 |
| *Leucaena leucocephala (Lam.) de Wit* | | | 1 | | 3 | 0.8 |
| Total | 28 | 22 | 5 | 12 | 3 | 14 |

*M. angustisepala* dominated in the density of stems ( 16.8 trees/25m$^2$ ), and *W. arborea* was the next dominant ( 11.4 trees / 25m$^2$, Table3,4 ). However, for the density of individuals, *W. arborea* had the most abundant individuals ( 7.1 individuals/25m$^2$ ) and *M. angustisepala* had fewer individuals ( 5.9 individuals/25m$^2$ ) than *W.arborea*. Other than these two species, only *G. asiatica*, occurred in higher density.

Table 3 Density of stems regenerated in the abandoned pineapple field at 2 year after abandonment

| Species/ | Number of stems/25m$^2$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Distance from the edge | 5m | 10m | 10m | 20m | 25m | 25m | 25m | 30m | 30m | Total |
| *Callicarpa longifolia* | 2 | | 2 | | | | | | | 0.44 |
| *Gmelia asiatica* | 12 | 10 | 1 | | | | | | | 2.56 |
| *Litsea glutinosa* | 1 | | | | | | | | 1 | 0.22 |
| *Mussaenda angustisepala* | 5 | 11 | 17 | 6 | 18 | 13 | 30 | 21 | 30 | 16.78 |
| *Wrightia arborea* | 21 | 12 | 31 | 8 | 11 | 15 | | | 5 | 11.44 |
| *Diospyros rhodocalyx* | | | | 4 | | | | | | 0.44 |
| *Mimosa pigra* | | | | 2 | 1 | | 4 | | | 0.78 |
| Unidentified | | | 1 | | | | | | | 0.11 |
| Total | 41 | 33 | 52 | 20 | 30 | 28 | 34 | 21 | 36 | 32.78 |

Table 4 Density of individuals regenerated in the abandoned pineapple field at 2 year after abandonment

| Species/ | Number of individuals/25m$^2$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Distance from the edge | 5m | 10m | 10m | 20m | 25m | 25m | 25m | 30m | 30m | Total |
| *Callicarpa longifolia* | 1 | | 1 | | | | | | | 0.22 |
| *Gmelia asiatica* | 5 | 4 | 1 | | | | | | | 1.11 |
| *Litsea glutinosa* | 1 | | | | | | | | 1 | 0.22 |
| *Mussaenda angustisepala* | 2 | 6 | 6 | 2 | 10 | 6 | 5 | 5 | 11 | 5.89 |
| *Wrightia arborea* | 15 | 7 | 22 | 2 | 9 | 8 | | | 1 | 7.11 |
| *Diospyros rhodocalyx* | | | | 2 | | | | | | 0.22 |
| *Mimosa pigra* | | | | 2 | 1 | | 3 | | | 0.67 |
| Unidentified | | | 1 | | | | | | | 0.11 |
| | | | | | | | | | | 0.00 |
| Total | 24 | 17 | 31 | 8 | 20 | 14 | 8 | 5 | 13 | 15.56 |

### 3.3. Change of vegetation during two years

While the density of stems increased from 18.8 trees/25m$^2$ to 32.8 trees/25m$^2$ (Table 1, 3), the density of individuals was similar between two years ( 14.0 individuals/25m$^2$ in 2001, 15.6 individulas/25m$^2$ in 2002, Table 3,4 ).

The dominant species, *W.arborea* and *M.angustisepala*, had higher density than other species in both years ( Table 1,2,3,4). By two censuses 14 species were totally recorded, and five species occurred in both years. Six species and 3 species occurred only in 2001 and 2002, respectively.

For *M.angustisepala*, the density of stems increased drastically from 5 stems/25m$^2$ to 16.8 stems/25m$^2$, and the density of individuals increased from 3.4 individuals/25m$^2$ to 5.9individuals/25m$^2$. But other species showed little increase or decrease both of the density of stems and of the density of individuals (Table 1,2,3,4). *M.sngustisepala* had higher value of the number of stems per individual than other species in 2002 (Table 5).

There was significant difference in the mean height of stems between 2001 and 2002 ( 2001;mean H=1.64m, 2002;mean H=2.14, $F=41.34$, $p<0.001$). Although *W.arborea* had significantly different mean

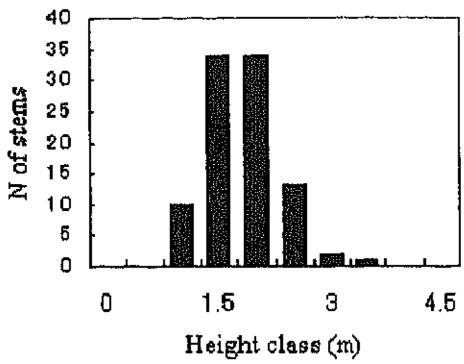


Fig.1. Frequency distribution of height in the abandoned pine apple field at 1 year after abandonment.

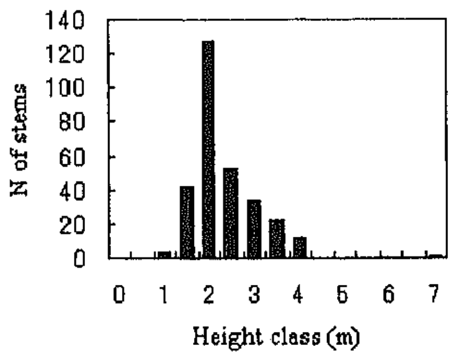


Fig.2. Frequency distribution of height in the abandoned pine apple field at 2 year after abandonment.

Table 5 Number of stems per individual in 2001 and in 2002

| | N of stems/individual | |
|---|---|---|
| Species | 2001 | 2002 |
| *Wrightia arborea* | 1.33 | 1.61 |
| *Mussaenda angustisepala* | 1.47 | 2.85 |
| *Callicarpa longifolia* | 1.33 | 2.00 |
| *Abelmoschus moschatus* | 1.33 | |
| *Gmelia asiatica* | 2.00 | 2.30 |
| *Vitex* sp. | 1.33 | |
| *Bauhinia* sp. | 1.00 | |
| *Aerva sanguinolenta* | 1.00 | |
| *Ficus hispida* | 1.00 | |
| *Litsea glutinosa* | 1.00 | 1.00 |
| *Leucaena leucocephala* | 1.00 | |
| *Diospyros rhodocalyx* | | 2.00 |
| *Mimosa pigra* | | 1.17 |
| Unidentified | | 1.00 |
| All species | 1.34 | 2.11 |

height between 2001 and 2002 ( 2001;mean H=1.60m, 2002;mean H=2.51, F=59.122, p<0.001 ), *M.angustisepala* had the almost the similar mean height between 2001 and 2002 ( 2001;mean H=1.74m, 2002;mean H=1.85, F=1.87, p=0.173).

### 3.4. Effect of distance on the vegetation structure

In 2001, there was a significant difference both in the density of woody stems and in the density of individuals between the boundary of pineapple field and the interior ( density of stems;F=14.17, p=0.033, density of individuals; F=19.31, p=0.022, Table 6). Both the density of stems and the density of individuals was higher in the boundary than in the interior. The same results was obtained in 2002 as in 2001 ( Table 6).

Table 6 Comparison of density of stems, density of individuals and number of species between between the boundaru and the interior. The boundary and the interior of 2001 include plots set up at 0m,10m from the edge and plots set up at 15m,20m from the edge, respectively. The boundary and the interior of 2002 include plots set up at 5m,10m from the edge and plots set up at 20m,25m,30m from the edge, respectively.

| | 2001 | | 2002 | |
|---|---|---|---|---|
| | Boundary | Interior | Boundary | Interior |
| Density of stems (/25m$^2$) | 33.5 | 9 | 42 | 32.8 |
| Density of individuals (/25m$^2$) | 25 | 6.7 | 24 | 11.3 |
| Number of species (/25m$^2$) | 6.5 | 2 | 4.3 | 2.5 |

Table 7 Comparison of mean height between the boundary and the interior.
The boundary and the interior of 2001 include plots set up at 0m,10m from the edge and plots set up at 15m,20m from the edge, respectively.
The boundary and the interior of 2002 include plots set up at 5m,10m from the edge and plots set up at 20m,25m,30m from the edge, respectively. In 2001, because M.angustisepala had only one stem in the interior, no comparison was carried out.

| | Mean height (m) | | | |
|---|---|---|---|---|
| | 2001 | | 2002 | |
| | Boundary | Interior | Boundary | Interior |
| All species | 1.52 | 1.95 | 2.17 | 2.13 |
| *Wrightia arborea* | 1.44 | 1.81 | 2.36 | 2.75 |
| *Mussaenda angustisepala* | 1.71 | 2.5 | 1.95 | 1.83 |

For the number of species, there was a significant difference between the boundary of pineapple field and the interior in 2001 and in 2002 ( 2001; F=11.22, p=0.044, 2002; F=5.76, p=0.047, Table 6). The boundary had more species than in the interior both in 2001 and in 2002. And also the dominance of *W.arborea* and *M.angustisepala* was higher in the interior than in the boundary both in 2001 and in 2002. *Leucaena leucocephala* in 2001 and *Mimosa pigra* in 2002 occurred only in the interior part.

When all species were included, the average height was higher in interior than in the boundary for 2001( boundary; 1.52m, interior; 1.95, F=17.816, p<0.001, Table 7 ), but no significant difference was detected for 2002 ( boundary; 2.17m, interior; 2.13, F=0.2315, p=0.631, Table 7 ). Stems of *W. arborea* were higher in the interior than in the boundary both for 2001 and for 2002 ( 2001; F=18.174, p<0.001, 2002; F=6.845, p=0.01, Table 7). But *M.angustisepala* in 2002 showed no difference of mean height between the boundary and the interior ( F=3.636, p=0.059, Table 7).

**3.5. Vegetation under the Eucalyptus plantation**

The density of stem was 94.8stems/25m$^2$ and the number of species recorded was 11 in 5 years old *Eucalyptus* plantation( Table 8). Without *E. camaldulensis*, the density of stems was 81.8 stems/25m$^2$ and *M.angustisepala* dominated significantly (71%). *W.arborea, Capparis micracantha, Callicarpa longifolia* and *Cleistanthus hirsutulus* occurred in comparatively higher density (>2.0 stems/25m$^2$).

The density of individuals was 33.3 individuals/25m$^2$ and *M.angustisepala* dominated significantly (70%) (Table 9). Also *E. camaldulensis, W.arborea* and *Capparis micracantha* occurred in comparatively higher density (>1.0 individuals/25m$^2$).

The frequency distribution of height was the unimodal distribution with the prominent mode in 2-3 m

Table 8　Density of stems in the Eucalyptus plantationon the the abandoned pineapple field

| | Number of stems (/25m2) | | | | |
|---|---|---|---|---|---|
| | PL-1 | PL-2 | PL-3 | PL-4 | Total |
| *Broussonetia papyrifera* | 1 | | | 1 | 0.5 |
| *Eucalyptus camaldulensis* | 19 | 16 | 5 | 12 | 13 |
| *Mussaenda angustisepala* | 69 | 80 | 23 | 97 | 67.25 |
| *Wrightia arborea* | 6 | 6 | | | 3 |
| *Capparis micracantha* | | 9 | 2 | 2 | 3.25 |
| *Callicarpa longifolia* | | | 8 | | 2 |
| *Cleistanthus hirsutulus* | | | 12 | 1 | 3.25 |
| *Dalbergra volubilis* | | | 4 | | 1 |
| *Quercus sp* | | | 4 | | 1 |
| *Syzygium megacarpam* | | | 1 | | 0.25 |
| *Leucaena leucocephala* | | | | 1 | 0.25 |
| Total | 95 | 111 | 59 | 114 | 94.75 |

Table 9　Density of individuals in the Eucalyptus plantationon the the abandoned pineapple field

| | Number of individuals (/25m2) | | | | |
|---|---|---|---|---|---|
| | PL-1 | PL-2 | PL-3 | PL-4 | Total |
| *Broussonetia papyrifera* | 1 | | | 1 | 0.5 |
| *Eucalyptus camaldulensis* | 5 | 4 | 2 | 5 | 4 |
| *Mussaenda angustisepala* | 25 | 33 | 9 | 26 | 23.25 |
| *Wrightia arborea* | 1 | 6 | | | 1.75 |
| *Capparis micracantha* | | 2 | 1 | 2 | 1.25 |
| *Callicarpa longifolia* | | | 2 | | 0.5 |
| *Cleistanthus hirsutulus* | | | 2 | 1 | 0.75 |
| *Dalbergra volubilis* | | | 2 | | 0.5 |
| *Quercus sp* | | | 1 | | 0.25 |
| *Syzygium megacarpam* | | | 1 | | 0.25 |
| *Leucaena leucocephala* | | | | 1 | 0.25 |
| Total | 32 | 45 | 20 | 36 | 33.25 |

( Fig.3 ). Each plot had the same height structure. In the overstory ( over 5m ) of this plantation *E. camaldulensis* shared dominance with *W.arborea, C. micracantha* and *D. volubilis* .In the understory ( <3m), *M.angustisepala* strongly dominated.

The density of stems was not significantly different between plots in the boundary ( PL-3. PL-4 ) and

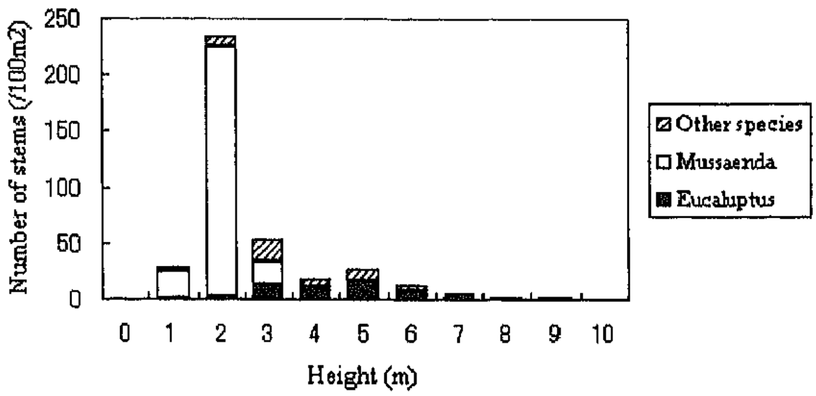


Fig.3. Frequency distribution of height in *Eucaluptus* plantation on the abandoned pineapple field.

plots in the interior ( PL-1,PL-2). But the number of species was larger in the boundary ( 6 species, 8 species ) than in the interior ( 4 species in both plots) ( Table 8). *E. camaldulensis* and *M.angustisepala* occurred in all plots with varying density of stems. While *W.arborea* occurred in the interior plots, *C. longifolia* and *C. hirsutulus* occurred in the boundary plots.

## 4. DISCUSSION

### 4.1. Abandoned pineapple field

The density of woody plants established on abandoned pineapple field seemed to be higher than the density of woody plants established on the abandoned pasture ( Aide et al., 1995 ), on the abandoned crop land ( Chinea, 2002) and on the abandoned orchard ( Milton et al., 1997 ). Aide et al (1995) reported that during first 7 years after abandonment no woody vegetation had developed and the density of woody plants had increased rapidly during 10 –15 years after abandonment. On the abandoned pineapple field, woody plants established even at first year after abandonment. Many authors indicated that the competition with herbaceous plants might inhibit establishment of woody plants on the degraded land in the tropical area (Sun and Dickson, 1996; Parrotta et al., 1997; Holl,1998; Otsamo,1998 ). On this pineapple field, the intensive management such as weeding by hand had been practiced immediately before abandonment. It was considered that the intensive management might inhibit the growth of herbaceous plants and facilitate the establishment of woody plants after abandonment.

Within species occurred in the abandoned pineapple field, *G.asiatica, C.longifolia* and *W.arborea* were observed to grow in the secondary stand surrounding the pineapple field. Thus these woody species established in the plot were considered to be dispersed from the surrounding secondary stand. But in this study, we could not determine dispersal agents of these species. It had been pointed out that the most of species in tropical forest tended to depend their dispersal on animals ( Howe, 1984) and it was very difficult for seeds of woody species to be dispersed into pastures without woody vegetation because animal tended to avoid the open environment (Cardoso da Silva et al., 1996). Because pineapples had the shape similar to the shrub species, these pineapples might function as the attractive center and facilitate the seed dispersal by birds. Residual trees on the abandoned pasture were considered to attract bird species and abundant seeds were deposited under the canopy of these trees with comparing to the open grassland ( Guevara et al., 1992). It is necessary to clear the mechanism of seed input into the abandoned pineapple field.

While the density of stems increased considerably from 2001 to 2002, the density of individuals did not change from 2001 to 2002. *M. angustisepala* contributed mostly to the increase of stem density from 2001 to 2002. *M.angustisepala* had abundant stems per one individual in 2002. Thus it was considered that higher ability of vegetative propagation of *M. angustisepala* brought about the considerable increase of stem number. Because no significant change of individual number could be observed, it was suggested that the recruitment of woody plants might be suppressed at 2 years after abandonment. At 2 years after abandonment, the abandoned pineapple field was covered densely by vigorously growing herbaceous plants in addition to woody plants. It was considered that the recruitment of woody plants had successfully occurred only within 1 year after abandonment and the recruitment had failed at 2 years after abandonment because of densely growing vegetation.

Both the density of woody plants and the number of species were significantly higher in the boundary than in the interior of the abandoned pineapple field. Lamb et al (1997) had already reported that there was a significant negative relation between seedling density and distance from the nearest seed source in plantations. Holl (1999) cleared that the number of seeds, especially animal dispersed seeds, decreased sharply on the pasture side of the forest/pasture edge and few seeds were recorded beyond 5m of the forest/pasture edge. Also Holl and Lulow (1997) indicated that in open areas seeds were subjected to high rate of predation. Thus it was suggested that low density and small number of species of woody plants beyond 10m from the forest/field edge might be caused by few seed input and high seed or seedling predation. And also it was considered that harsh environmental condition such as direct solar radiation, higher temperature and lower soil moisture negatively affected the recruitment of woody plants in the pineapple field.

**4.2. *Eucalyptus* plantation**

The density of woody plants in 5 year old *Eucalyptus* stand planted in the abandoned pineapple field was higher than in the abandoned pineapple field. But without *M.angustisepala* and *E.camaldulensi*, there was no significant difference of the stem density between the plantation and the pineapple field. Although there was no difference of total number of species recorded between the plantation and the pineapple field, the mean number of species per plots was higher in the plantation. *Eucalyptus* species had been reported to deplete the soil fertility and suppress the development of understory vegetation ( Malik and Sharma 1990, Lisanework and Michelsen 1993, 1994). But Michelsen et al (1996) cleared that there was no significant difference of density and diversity of herbaceous plants between *Eucalyptus* plantation and natural forests. Also in this study, no significant difference of the density and the diversity of woody plants could be detected between *Eucalyptus* plantation and the pineapple field. Thus it was concluded that the planting of *Eucalyptus* species did not affect the restoration of plant diversity in the abandoned pineapple field.

In this plantation, the most of woody species other than *M.angustisepala* had grew from midstory to the overstory, but in the understory only *M.angustisepala* dominated. Such height structure might suggest the regeneration failure in the understory of these woody species. It seemed that the dense coverage of *M.angustisepala* might inhibit the emergence and growth of woody species in the understory.

**4.3. Conclusion**

In the upper region of Lam Phachi river basin, woody species had invaded both into the abandoned pineapple field and into the *Eucalyptus* planted pineapple field. But it seemed that the density of woody plants was lower and the establishment was restricted to shorter period ( only 1 years ) immediately after abandonment. Furthermore, in the abandoned pineapple field, the establishment of woody plants mainly occurred in the boundary within 10m from the edge and woody plants were difficult to regenerate successfully in the interior beyond 10m from the edge. From these results obtained, it was concluded that the recovery of woody vegetation on the abandoned pineapple filed might be difficult and it might take very long time before recovery of original forest.

Recently, in tropical area the framework species method have been applied to restore the degraded land where various factors suppress the establishment of woody plants (Hardwick et al., 1997; Lamb et al., 1997; Otsamo, 1998; Leopold et al., 2001). In the framework species method, initially planted trees are of native woody species that may grow rapidly, produce fleshy fruits to attract seed dispersal agents such as birds, bats, and create the physical environment suitable for establishment of indigenous woody species (Elliott at al., 1997). Many authors reported that plantation of framework species catalyze the invasion of woody plants and multiply the abundance and the diversity of the stand (Hardwick et al., 1997; Lamb et al., 1997; Otsamo, 1998; Leopold et al., 2001). Because it became evident that the establishment of woody species was difficult on abandoned pineapple fields, it will be necessary to plant framework tree species when we try to restore the degraded land produced by cultivation and abandonment in Lam Phachi river basin.

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# Development of Agricultural Land in a Hilly Area of the Tha Khoei Basin

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*Abstract*

This paper focuses on the development of agricultural land and its relation to the problem of soil erosion in pineapple fields in a hilly area of the Tha Khoei Basin upstream of the Lam Phachi river basin. We used statistical data, farmer interviews and satellite images to survey the historical development of agricultural land and crop production and discuss the background of agricultural land development and the movement of eroded soil in pineapple fields in hilly areas. This study clarifies that (1) the development of agricultural land has been extended from flat areas to hilly areas during the last 30 years; (2) pineapple cultivation has increased, especially in sloped fields; (3) three factors spurring the rapid development of agricultural land are increases in population, the enlargement of farm size and the innovations in farming technologies; (4) the coverage of the catchment area of irrigation ponds, which have been extensively constructed throughout the area, is as high as 70% of the Tha Khaei Basin, thus having a substantial effect on soil movement in the basin.

**Keywords: development of agricultural land, soil erosion, pineapple cultivation, irrigation pond**

## 1. INTRODUCTION

Almost all the land in the Tha Khoei basin of the Lam Phachi river basin was forested in 1970. Around 1975, immigrants from other areas in Thailand moved there, joining other farmers who had originated from the Ban Kha Sub-district upstream of the Tha Khoei Basin. Immigrants developed forest areas into agricultural land. Development gradually extended from flat areas to hilly areas, thus resulting in more than 60,000 rai (about 10,000 ha) of agricultural land in Ban Kha Sub-district in 2000. Some 70 % of agricultural land is currently used for pineapple cultivation. Hilly areas, which are suited to pineapple cultivation, easily incur soil erosion after heavy rains. This problem has several dimensions: (1) soil is lost from pineapple fields, (2) the fertility of the soil in pineapple fields is degraded, and (3) eroded soil contaminates the Tha Khoei river, a tributary of Lampachi river etc.

In this paper, the authors aim to analyze the historical development of agricultural land and pineapple cultivation, the background of the development of agricultural land and the function of irrigation ponds for holding eroded soil from pineapple fields.

## 2. HISTORICAL DEVELOPMENT OF AGRICULTURAL LAND

### 2.1 Analysis by remote sensing

(1) Used data and methods

In order to observe the pineapple field area in Tha Khoei sub-basin upstream of the Lam Phachi river basin, we analyzed four satellite data sets. The satellite data sets used in the study are Landsat/ETM+(acquired on 9 Nov. 2000), JERS-1/VNIR (acquired on 26 Jan. 1997 and on 30 Jan. 1994) and Landsat/TM (acquired on 30 Jan. 1993). *An outline of our analysis is shown* in Fig.2.1. Four data sets were geo-corrected using 1:50,000 maps. Each satellite data set was classified by unsupervised classification, ISODATA method. Images were identified for classification from ground survey data and a crop calendar (Fig.2.2). Each classified image was overlaid and land use change was extracted. Furthermore, pineapple fields and slope angle images made from 1:50,000 scale topographic maps were overlaid and the relationship between slope steepness and pineapple fields was analyzed.

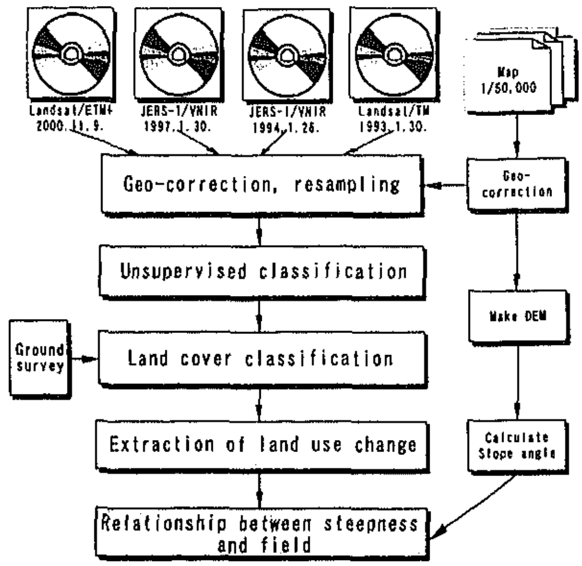


Fig.2.1 Analysis of pineapple field change *using remote sensing data and GIS.*

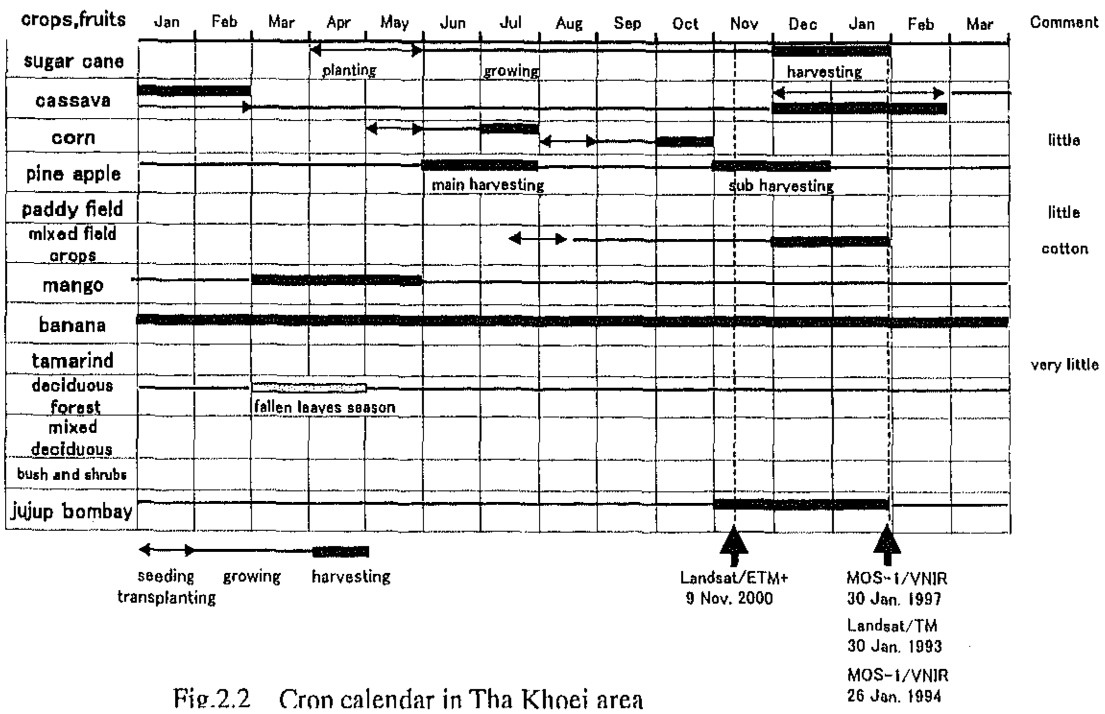


Fig.2.2 Crop calendar in Tha Khoei area

In this area, the main field crops are sugar cane, cassava and pineapple. The most important crop is pineapple. The cropping calendar for these crops and others is shown in Fig.2.2. Satellite data sets employed in the study were acquired in the dry season.

(2) Estimation of pineapple field

As shown in the crop calendar, on November 9, the date of the first satellite images, sugar cane and cassava are in their growth periods, and would not be clearly distinguished from the pineapple fields. By late January, the time frame of the other satellite images, these crops can be distinguished from the pineapple field because they are bare after harvesting. Fields that were cultivated in pineapples during all 4 data collections were estimated by overlaying all these classified results. Classified images analyzed from satellite data sets in 1997 and 2000 were overlaid on a land use change image (Fig.2.3), and classified images in 1994 and 1993 were overlaid an image.

Finally, the four classified images were overlaid and the map of land use change in pineapple fields was created. Fields where pineapples were grown in both 1994 and 2000 are seen in the center of the basin area (Fig.2.4). The areas planted with pineapples in 1993 and in 1994 were approximately the same; pineapple fields increased from 1994 to 1997 and from 1997 to 2000(Fig.2.5). Fields that became pineapple fields between 1994 and 2000 are seen in the circumference part. Fields recently changing over to pineapple cultivation show a tendency of spreading out from the circumference. Fields at 0% slope angle that were pineapple fields in both 1994 and 2000 are more numerous than fields at 0% slope angle recently changing over to pineapple cultivation; this can be seen by overlaying DEM made from the topographical map of 1:50,000 on a map of classified pineapple fields (Fig.2.6).

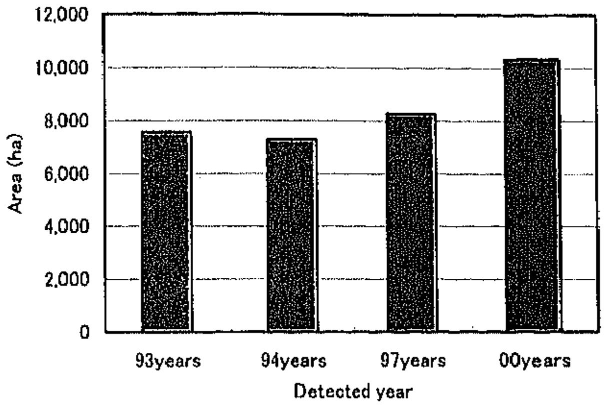

Fig. 2.5 The change of pineapple field area

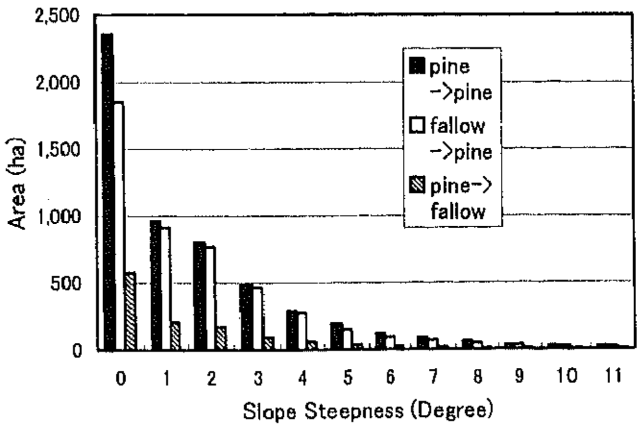

Fig.2.6. Slope Steepness of pineapple fields

## 2.2 Analysis by interview to a farmer

An interview [with] a farmer living near the gauging station K 25A in Ton Ma Ka village, Ban Kha Subdistrict, indicated that he and his several colleagues immigrated there from Nakhon Pathom Province in 1975 and developed forests into agricultural land in the flat part of this area, and that they had been developing fields in the sloped areas since about 1990.

## 2.3 Crop production

Figure 2.7 shows the changes in crop production in Ban Kha Sub-district during the last four years.

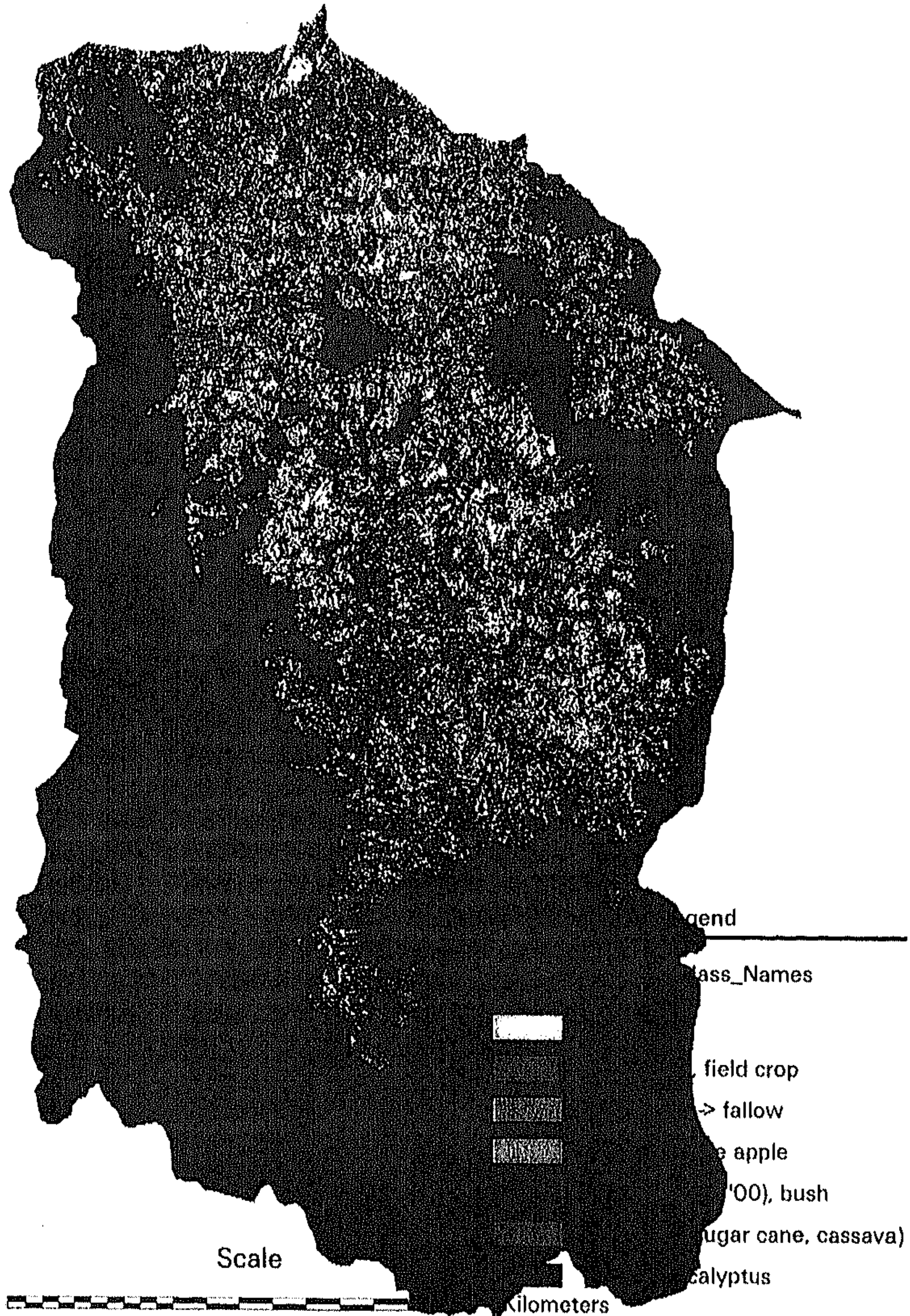


Fig.2.3. Results of land cover classification in 1997 and 2000.

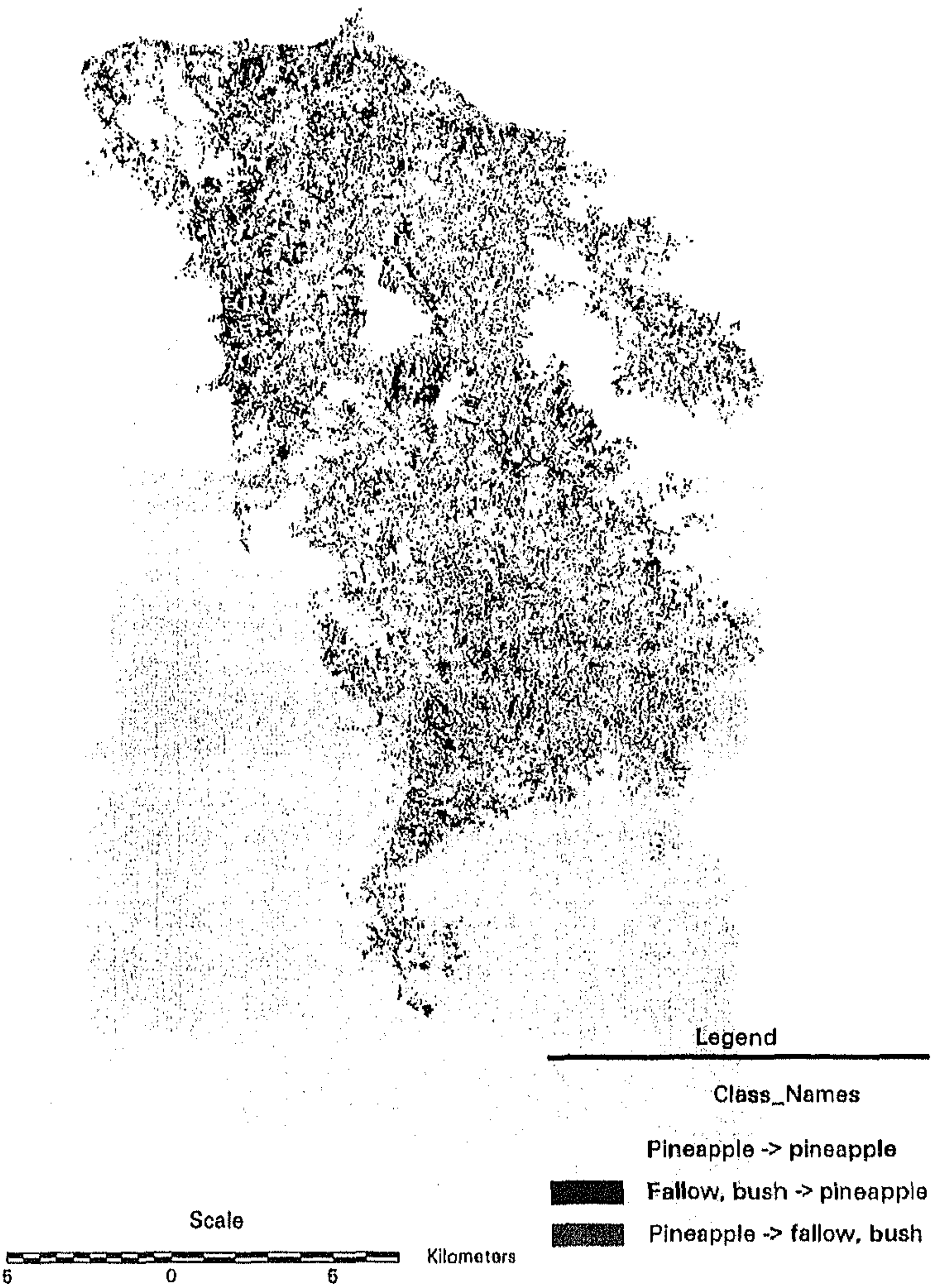


Fig.2.4. Distribution of pineapple field in 1994 and 2000

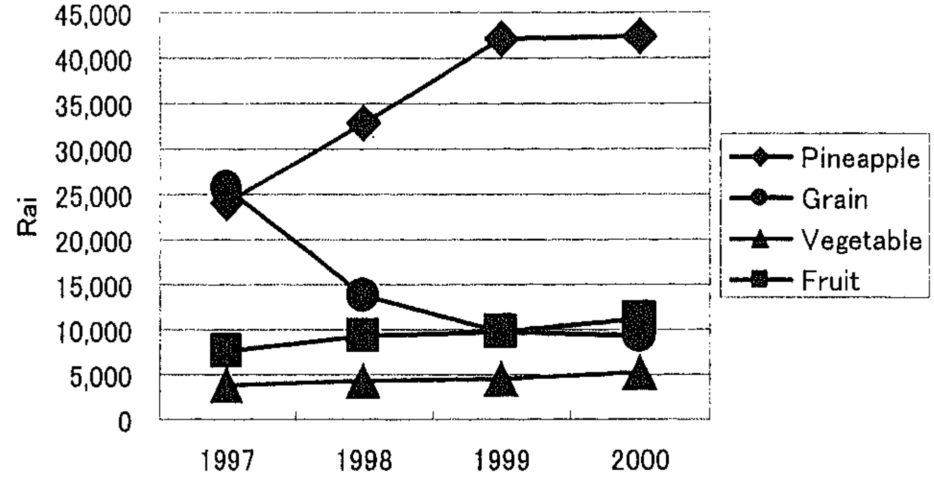


Fig. 2.8 Change of crop production in Ban Kha Sub-district

The areas in pineapple fields almost doubled between 1997 and 2000 and have rapidly become by far the most dominant crop. Because pineapple cultivation is suited to sloped fields, for reasons to be mentioned later, this rapid increase suggests that pineapples are cultivated in a lot of the newly reclaimed, previously forested hilly areas.

## 3. CHARACTERISTICS OF PINEAPPLE CULTIVATION

### 3.1 Good conditions of land for pineapple cultivation

Fields with permeable soil and low levels of ground water are good for pineapple cultivation. Sloped fields certainly have the latter condition. Our survey shows that pineapples are cultivated in fields with gradients of 3°, 4°, 6°, 8° and 10°.

### 3.2 Farming work operation of pineapple cultivation

Farming work in pineapple cultivation has a cycle of three years. Plowing, planting, fertilizing, spraying pesticide or herbicide are performed in the first year, along with one harvest, and fertilizing, spraying pesticide and herbicide, and two harvests occur in both the second and third years. Plowing and planting are performed after the second harvest in the third year or in the beginning of the first year of the next cycle, because pineapple production often decreases after three years. In other words plowing and planting are only performed once every three years. In some cases, however, pineapple cultivation is continued beyond the three-year point without plowing while in others, pineapple fields are allowed to lie fallow after a three-year cycle.

## 4. BACKGROUND OF AGRICULTURAL LAND EXPANSION

As for the background of the rapid development of agricultural land, three important factors emerge. They are the increase in population, the enlargement of farm size and progress in reclamation technology.

(1) The increase in population

Figure 3.1 and Fig. 3.2 show the increase of population and agricultural population in Ban Kha Sub-district in the last four years, respectively.

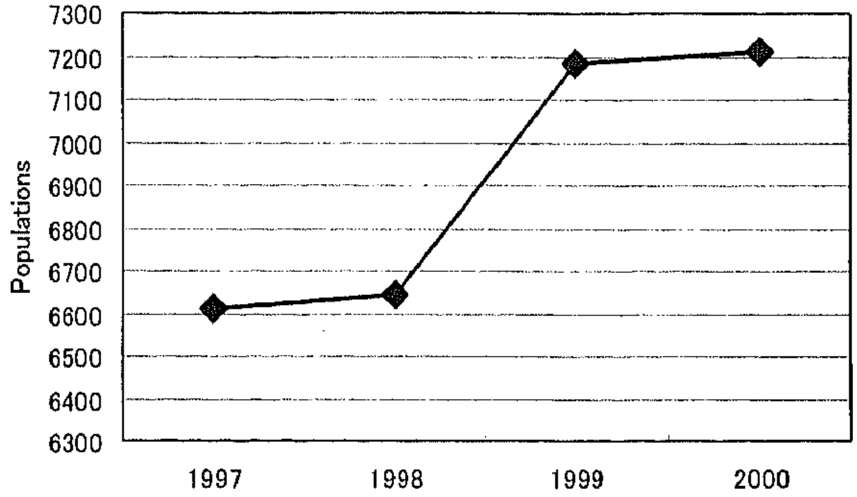


Fig 3.1 Populations in Ban Kha Sub-district

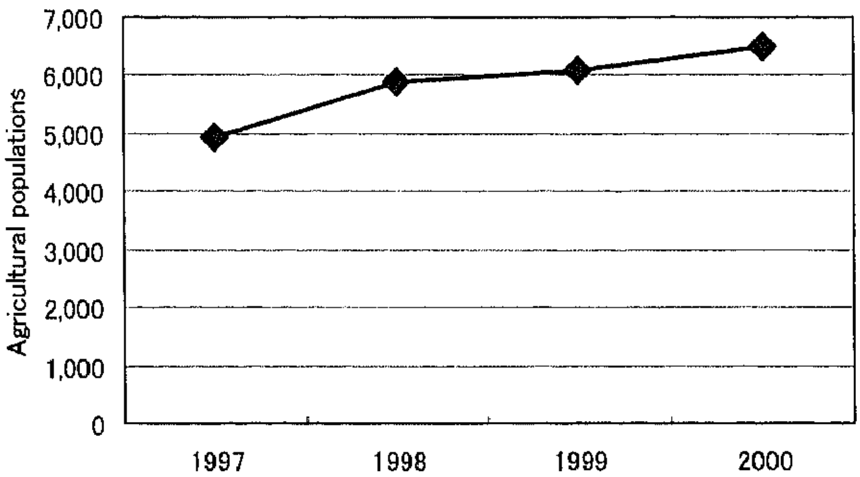


Fig. 3.2 Agricultural populations in Ban Kha Sub-district

Our interview with the farmer indicated that the 10 families including his who lived there in 1975 had increased to 17 families in 2000. An interview with the sub-head of the village indicated that some farmers moved out and some farmers moved in this area, resulting in the increase 3 families during 10 years.

Statistical data and the interviews suggest that increasing population led to expanded development of agricultural land.

(2) The enlargement of farm size

According to the farmer, he had 24 rai under cultivation in 1975 and had extended his fields to 39 rai in 1997 and 54 rai in 1999.

The enlargement of farm size may be one of the factors in agricultural land expansion.

(3) The innovation of farming technologies

In 1975 the farmer his colleagues] reclaimed forest into agricultural land using saws; in 1990, they did it with chainsaws and tractors. Innovations in reclamation technology may also be listed as one of the factors in the development of agricultural land.

The farmer now cultivates pineapples using such materials as herbicide and fertilizer and by hiring a contractor with a large tractor to plow, whereas he used fewer inputs and a smaller tractor in 1975. The innovation of farming work technologies seem to have supported the enlargement of his farm size.

## 5. RETENTION EFFECT OF POND ON ERODED SOIL

### 5.1 Effect of pond on eroded soil retention

Soils are eroded in some pineapple fields around the gauging station K 25A. Fig. 5.1 and Fig. 5.2 show soil erosion in two pineapple fields. The eroded soil from the pineapple field in Fig. 5.2 flows into the pond shown in Fig. 5.3 and accumulates at its bottom. Figure 5.4 shows that eroded soil flowed from the road of the foreground side to the weed-grown side where eroded soil flowed into the pond.

The pond thus has the effect of retaining eroded soil.

### 5.2 Estimation of Catchment area coverage

Ponds for irrigation were read from the topographical map of 1:50,000 and the Landsat/ETM+ data observed on November 9, 2000. Catchment areas of ponds were read from the topographical map and were calculated by GIS (Fig. 5.5).

It was discovered that 69.2 % (43,995 ha) of the whole basin area (63,544ha) was covered by ponds. When the soil from pineapple fields flows into these ponds, sandy soil accumulates at the bottom of the pond; because sandy soil accumulates at a high rate, it can be expected that the pond's effect in preventing outflow of soil is high.

## 6. CONCLUSIONS

1. The development of agricultural land has been climbing up from flat areas to hilly areas during last 30 years.
2. Pineapple cultivation is dominant in the sloped fields, which are easily eroded by heavy rain.
3. Three factors in the rapid development of agricultural land are the increases in population, the enlargement of farm size and the innovations in farming technologies.
4. Ponds distributed throughout the catchment area, most of which are for the purpose of irrigation, cover almost 70 % of the total catchment area of the Tha Khoei basin. Because of the ponds' secondary function of retaining eroded soil, the construction of ponds is thought to have a substantial effect on soil movement in the basin.

## ACKNOWLEDGEMENT

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Fig. 5.1 Soil erosion in a pineapple field with a gradient of 4°

Fig. 5.2 Soil erosion in a pineapple field with a gradient of 6°

Fig. 5.3 The pond near the pineapple field in the Fig.5.2

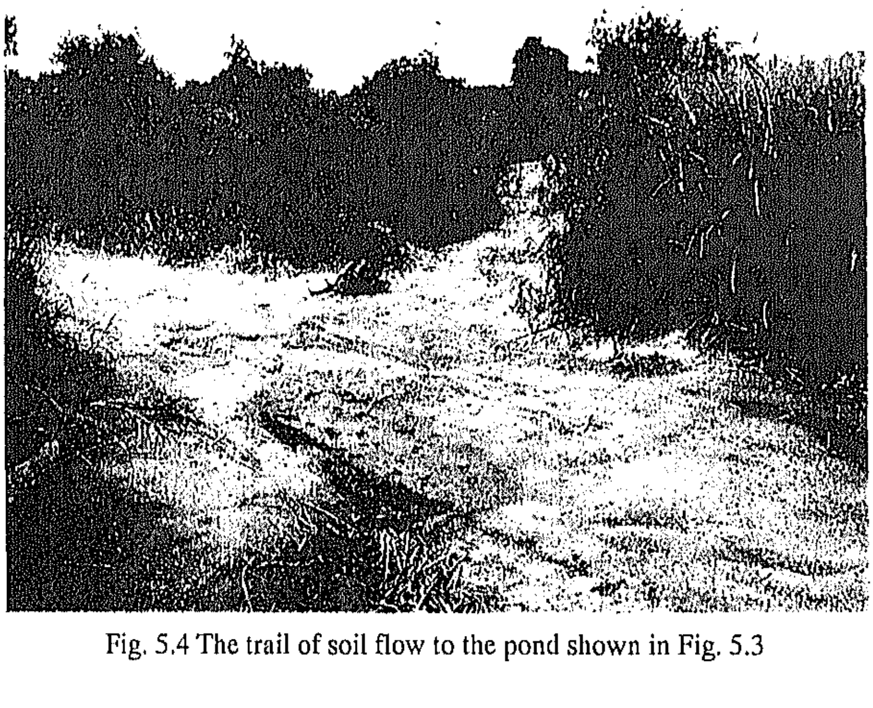

Fig. 5.4 The trail of soil flow to the pond shown in Fig. 5.3

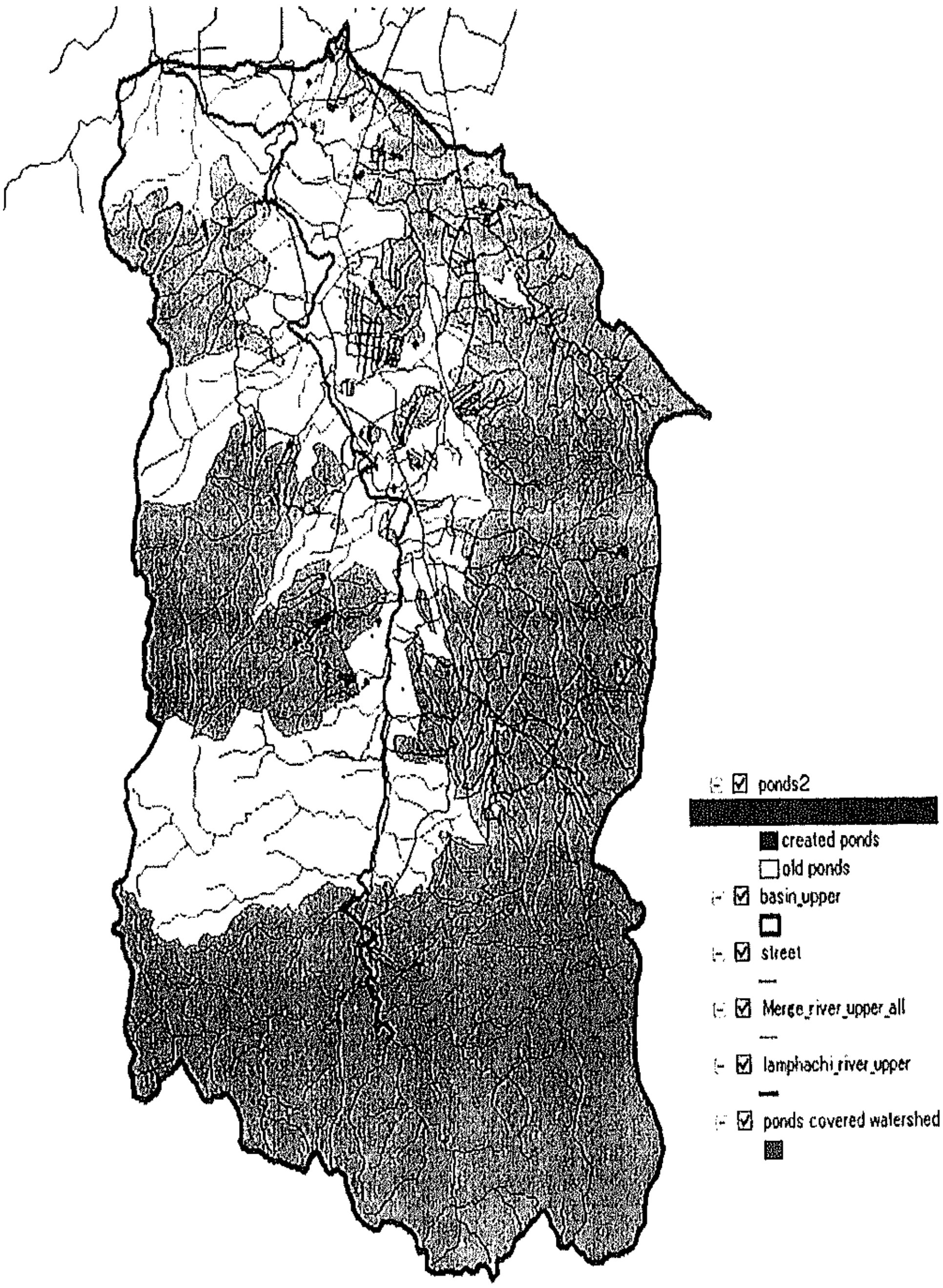


Fig.5.5 Catchment area of ponds

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# Soil Erosion in the Pineapple Fields of the Ban Kha Subdistrict

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*Abstract*

This paper focuses on the gully erosion and physical properties of the soil in the pineapple fields of the Ban Kha Sub-district of the Tha Khoei basin, upstream of the Lam Phachi river basin in Thailand. We surveyed the gully development for 2 years and studied the physical properties of soil in pineapple fields in the Ban KhaSub-district. Our research clarified that (1) soil loss rates in this region are high; (2) the soil in this area is highlyerodable; (3) the lack of vegetative cover and a surface layer with a small hydraulic conductivity contribute tosoil erosion problems in pineapple fields; (4) the fertility of pineapple fields is degraded by soil erosion, especially by the erosion of fine particles.

Keywords: **pineapple field, gully erosion, soil loss, soil physical properties**

## 1. INTRODUCTION

Pineapples are cultivated on much of the agricultural land in the Ban Kha Sub-district of the ThaKhoei basin, upstream of the Lam Phachi river basin in Thailand. Soil erosion has especially occurred in those pineapple fields that are sloped. In this paper, the authors estimated soil loss by measuring gully development and analyzed the physical properties of soil in pineapple fields. The survey sites are located near the gauging station K 25A in Ton Ma Ka village, Ban Kha Sub-district.

## 2. GULLY EROSION IN A SAMPLE PINEAPPLE FIELD

### 2.1 Gully erosion in a pineapple field

We measured the gully development in a pineapple field located 2 km southwest from the gauging station K 25A in order to estimate soil loss rates. Measurements were taken on 30 November in 2000 and 27 November in 2001. The gradient is 7° at the steepest slope of this field. In 2000, pineapple cultivation in this field was in the first year of a three-year cycle. This means that the field in its first year (2000) had experienced one rainy season (2000); in its second year (2001), it had experienced two rainy seasons (2000 and 2001).

The results of gully measurements are shown in Fig. 1.

Red-colored numbers and black-colored numbers are the points where the width and depth of gully were measured in 2000 and 2001, respectively. The orange lines and black lines, which were drawn by connecting neighboring points, are the gully lines for 2000 and 2001, respectively. Contour lines aregiven in red at intervals of 0.5 m. Each elevation of contour lines is the height based on the assumption that the elevation datum point is zero.

Some information Fig. 1 indicates is as follows:

1. Most gully lines and contour lines cross at right angles,
2. Some gully lines in 2000 stretched in 2001; some gully lines in 2001 were new,
3. Some gully lines in 2000 disappeared in 2001. It can be inferred that the reason for this disappearance was that soil from more highly elevated fields and neighboring ridges flowed into and filled the gullies.

### 2.2 Soil loss

The distances of the lines connecting two points are shown on Fig. 1. The soil loss of each line is estimated from the width and depth of gully at two points and the distance between them. Table 1 shows the calculation of soil loss for each line and the total loss in 2001. The average width and depth were 76 cm and 25 cm, respectively, and the range of width and depth were 30 – 130 cm and 3 – 25 cm, respectively. The soil loss for each line was calculated as the average width × the average depth × 1/2, on the assumption that the cross section of each line is V-shaped.

The results of our calculations indicate that the total soil loss in the field was 49.4 $m^3$/ha in 2000, which was given in the first paper in session 2, and 81.2$m^3$/ha in 2001; therefore, the increase in soil loss in 2001 was 31.8$m^3$/ha, which is about 2/3 of that in 2000. If, taking in advance the results of next section, the dry bulk density in a pineapple field is assumed to be 1.4 t/$m^3$, the soil erosion rate can be estimated to be 69.2t/ha/yr in 2000, caused by the rainfall in the first year of the pineapple cultivation cycle, and 44.5 t/ha/yr in 2001, caused by the rainfall in the second year.

Gully measurement was conducted in another pineapple field located 800 m northeast from the gauging station K 25A. The date of this measurement was 28 November in 2001, and the field was in the first year of its cultivation cycle. The steepest slope is a gradient of 8 °. The result of calculation of soil loss was 147.7 t/ha/yr.

According to Sidle (2002), for vegetable crops grown on moderate-to-steep hillsides, the highest levels of soil loss (38-140 t /ha/yr) occurred when cultivation was oriented up and down the hillslope, a typical practice in Southeast Asia. Compared to other soil loss rates in Southeast Asia, the values estimated above can be ranked as the highest level.

## 3. CHARACTERISTICS OF SOIL

### 3.1 Purpose of Investigation

Our study showed that soil erosion definitely occurred in the pineapple fields. On the other hand, soil erosion has not occurred in the neighboring forest. This section clarifies the cause of the soil erosion in the pineapple field by examining and comparing the soils in a pineapple field and an

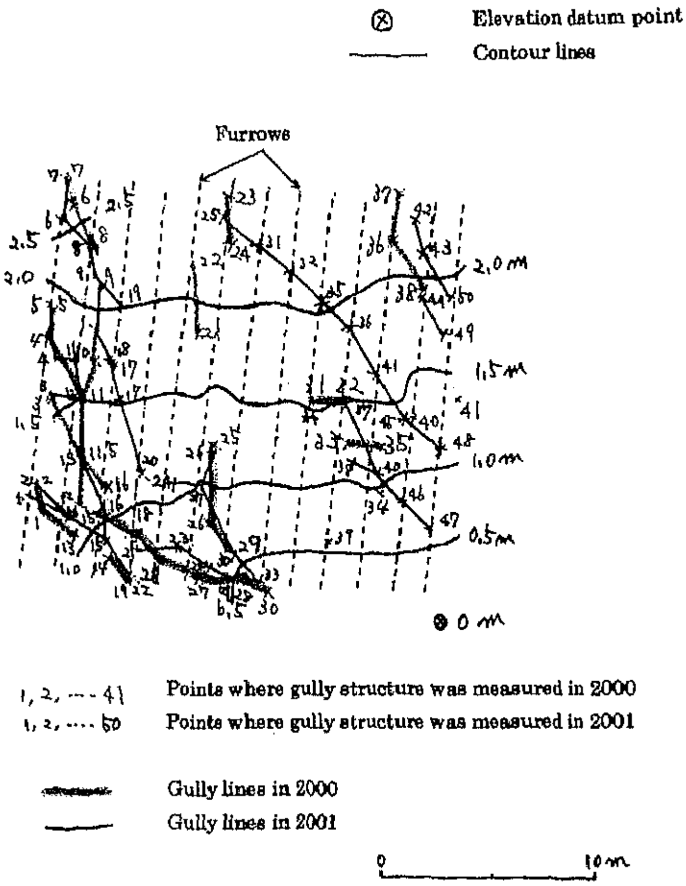


Fig. 1 Gully lines in a pineapple field

Table 1 Calculation of soil loss

| Gully line | Distance of gully line m | Upper point | | Lower point | | Avarege width of two points cm | Avarege depth of two points cm | Averege area of cross section cm² | Soil loss of each line m³ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Width cm | Depth cm | Width cm | Depth cm | | | | | |
| 1-14 | 2.18 | 85 | 10 | 70 | 10 | 77.5 | 10.0 | 387.5 | 0.08 | |
| 2-14 | 2.08 | 30 | 7 | 70 | 10 | 50.0 | 8.5 | 212.5 | 0.04 | |
| 3-12 | 1.80 | 60 | 5 | 80 | 25 | 70.0 | 15.0 | 525.0 | 0.09 | |
| 5-4 | 2.55 | 60 | 15 | 70 | 10 | 65.0 | 12.5 | 406.3 | 0.10 | |
| 4-11 | 0.95 | 70 | 10 | 50 | 20 | 60.0 | 15.0 | 450.0 | 0.04 | |
| 7-6 | 2.13 | 100 | 5 | 80 | 6 | 90.0 | 5.5 | 247.5 | 0.05 | |
| 6-8 | 1.65 | 80 | 6 | 90 | 7 | 85.0 | 6.5 | 276.3 | 0.05 | |
| 8-9 | 1.58 | 90 | 7 | 60 | 10 | 75.0 | 8.5 | 318.8 | 0.05 | |
| 11-12 | 1.85 | 50 | 20 | 80 | 25 | 65.0 | 22.5 | 731.3 | 0.14 | |
| 12-13 | 2.93 | 80 | 25 | 70 | 10 | 75.0 | 17.5 | 656.3 | 0.19 | |
| 14-15 | 2.05 | 70 | 10 | 80 | 8 | 75.0 | 9.0 | 337.5 | 0.07 | |
| 13-16 | 2.55 | 70 | 10 | 50 | 25 | 60.0 | 17.5 | 525.0 | 0.13 | |
| 10-18 | 1.75 | 70 | 5 | 40 | 10 | 55.0 | 7.5 | 206.3 | 0.04 | |
| 9-19 | 2.05 | 60 | 10 | 90 | 5 | 75.0 | 7.5 | 281.3 | 0.06 | |
| 18-17 | 2.08 | 40 | 10 | 80 | 10 | 60.0 | 10.0 | 300.0 | 0.06 | |
| 16-15 | 1.40 | 50 | 25 | 80 | 8 | 65.0 | 16.5 | 536.3 | 0.08 | |
| 15-22 | 2.28 | 80 | 8 | 40 | 12 | 60.0 | 10.0 | 300.0 | 0.07 | |
| 17-20 | 3.70 | 80 | 10 | 100 | 3 | 90.0 | 6.5 | 292.5 | 0.11 | |
| 21-23 | 1.75 | 100 | 5 | 120 | 3 | 110.0 | 4.0 | 220.0 | 0.04 | |
| 20-24 | 1.58 | 100 | 3 | 130 | 10 | 115.0 | 6.5 | 373.8 | 0.06 | |
| 23-28 | 1.98 | 120 | 3 | 80 | 6 | 100.0 | 4.5 | 225.0 | 0.04 | |
| 24-27 | 1.25 | 130 | 10 | 90 | 12 | 110.0 | 11.0 | 605.0 | 0.08 | |
| 26-27 | 1.75 | 70 | 13 | 90 | 12 | 80.0 | 12.5 | 500.0 | 0.09 | |
| 27-30 | 3.83 | 90 | 12 | 90 | 15 | 90.0 | 13.5 | 607.5 | 0.23 | |
| 28-29 | 1.18 | 80 | 6 | 60 | 8 | 70.0 | 7.0 | 245.0 | 0.03 | |
| 25-31 | 2.20 | 80 | 5 | 100 | 5 | 90.0 | 5.0 | 225.0 | 0.05 | |
| 31-32 | 2.00 | 100 | 5 | 70 | 6 | 85.0 | 5.5 | 233.8 | 0.05 | |
| 30-33 | 1.73 | 90 | 15 | 40 | 20 | 65.0 | 17.5 | 568.8 | 0.10 | |
| 29-33 | 1.35 | 60 | 8 | 40 | 20 | 50.0 | 14.0 | 350.0 | 0.05 | |
| 32-35 | 2.10 | 70 | 6 | 100 | 3 | 85.0 | 4.5 | 191.3 | 0.04 | |
| 35-36 | 1.70 | 100 | 3 | 80 | 3 | 90.0 | 3.0 | 135.0 | 0.02 | |
| 34-37 | 1.63 | 100 | 12 | 70 | 10 | 85.0 | 11.0 | 467.5 | 0.08 | |
| 37-40 | 3.78 | 70 | 10 | 90 | 15 | 80.0 | 12.5 | 500.0 | 0.19 | |
| 38-40 | 1.38 | 80 | 7 | 90 | 15 | 85.0 | 11.0 | 467.5 | 0.06 | |
| 36-41 | 2.60 | 80 | 3 | 90 | 7 | 85.0 | 5.0 | 212.5 | 0.06 | |
| 40-46 | 1.65 | 90 | 15 | 60 | 10 | 75.0 | 12.5 | 468.8 | 0.08 | |
| 41-45 | 2.50 | 90 | 7 | 60 | 8 | 75.0 | 7.5 | 281.3 | 0.07 | |
| 42-43 | 1.75 | 60 | 7 | 70 | 8 | 65.0 | 7.5 | 243.8 | 0.04 | |
| 43-50 | 2.38 | 70 | 8 | 90 | 10 | 80.0 | 9.0 | 360.0 | 0.09 | Area of a field ha |
| 45-48 | 2.20 | 60 | 8 | 80 | 5 | 70.0 | 6.5 | 227.5 | 0.05 | 0.038 |
| 46-47 | 2.00 | 40 | 10 | 90 | 5 | 65.0 | 7.5 | 243.8 | 0.05 | Soil loss per ha |
| | | | | | | | | Total | 3.09 | 81.2 |

adjoining forest.

The survey site was a pineapple field located 800 m northeast from the gauging station K 25A.

**3.2 Soil Profile Characterization**

Soil profiles in the forest and pineapple field were conducted to a depth of 50 cm. In the forest, a 5 cm thick surface layer of humus was found, followed by brown colored soil up to 20 cm in depth, due to the influence of the organic matter. On the other hand, there was no humus layer found in the pineapple field. Since both soil profiles were the same from 5 cm to 50 cm in depth, it is surmised that both soils shared the same origination. Also, both the pineapple field and the forest contained gravel, measuring from several cm to 10 cm in diameter, and apart from the forest's humus layer, the soil structure was of single grain structure.

**3.3 Soil Texture and Structure**

The particle diameter composition (ratios among sand, silt, and clay) obtained from particle size analyses of the pineapple field and the forest soils are shown in Fig. 2 and Fig. 3, respectively. As can be seen, the texture of the pineapple field and forest soils were the same to a depth of 50 cm; both can be classified as Sandy Clay Loam (SCL).

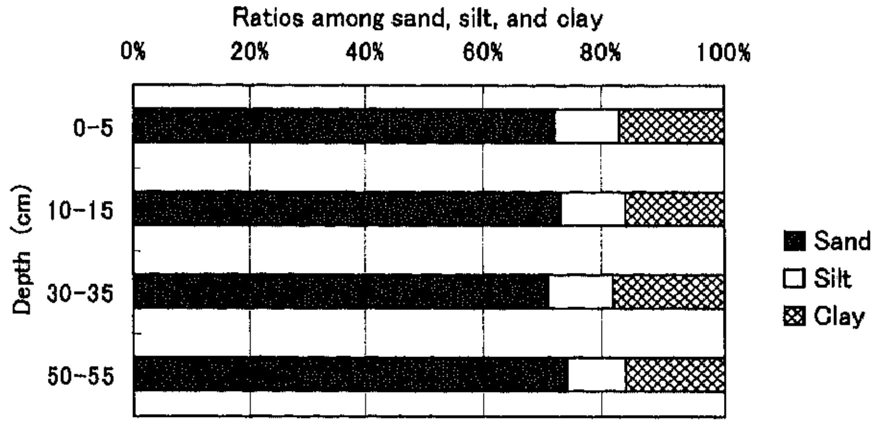


Fig.2 Particle size composition in the pineapple field

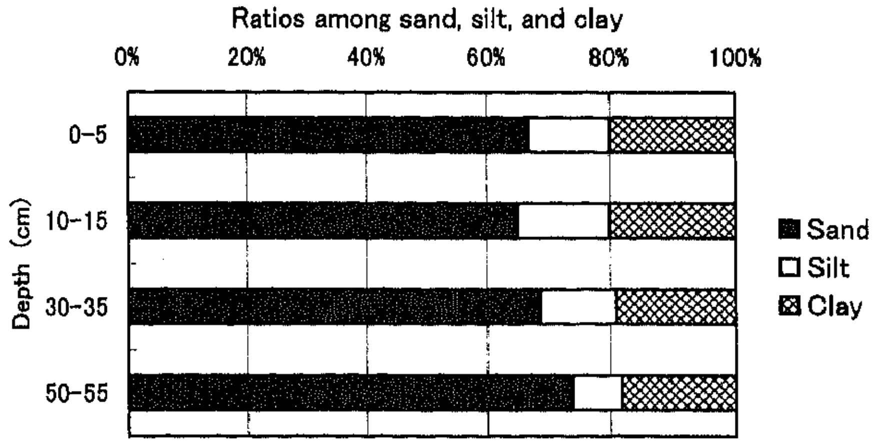


Fig.3 Particle size composition in the forest

Therefore, it is possible to conclude that the soils in the pineapple field and the forest had the same origin. The soil contains a large component of sand and has a single grain structure, giving it a high probability of eroding.

### 3.4 Soil Physical Property

One of the factors leading to soil erosion is a soil's low water permeability. That is, if water permeability of a soil is low, since rain could not infiltrate easily into the soil, surface runoff increased in number, and soil became easily erosional. The hydraulic conductivity of surface soil influenced greatly. We measured the saturated hydraulic conductivity of soils in both the field and the forest at depths from zero to 5 cm, 10 to 15 cm, 30 to 35 cm, and 50 to 55 cm. The results are shown in Fig. 4. From zero to 5 cm, the saturated hydraulic conductivity of the pineapple field is 1/10$^{th}$ of that of the forest. This is considered to be one of the factors generating gully erosion in the pineapple field.

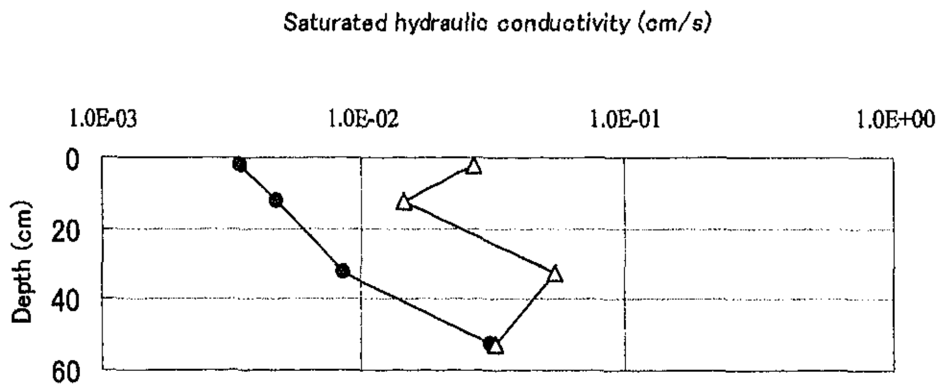


Fig. 4 Saturated hydraulic connductivity at each depth

—●— Pineapple field —△— Forest

Compaction, measured by dry bulk density, is often the source of lowered permeability. The dry bulk densities of the pineapple field and the forest soils at every depth are shown in Fig. 5. In the zero to 5 cm depth, and from 10 to 15 cm, the dry bulk density of the pineapple field soil is larger than that of the forest. However, from 30 to 35 cm, and from 50-55 cm, no remarkable difference in the dry bulk density can be seen between the two.

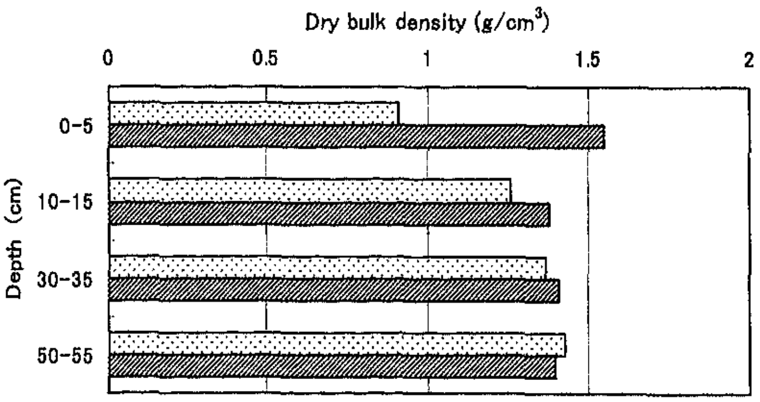


Fig. 5 Dry bulk density at each depth

□ Forest ▨ Pineapple filed

It is likely that the surface of a pineapple field has been compacted by various causes, and since the dry bulk density increased, the water permeability decreased as a result. It is possible that surface soil was compacted by the ground contact pressure of a machine or a farmer at the time of reclamation or cultivation. Or since there was a large component of sand in the soil, it is also possible that the surface soil was compacted by rains after reclamation of the field.

## 4. DEGRADATION OF FIELD

Surface soil usually contains more nutrients than subsoil because of humus and fertilizer application. The surface soil in sloped pineapple fields becomes less capable of maintaining these nutrients because fine particles at the surface layer flow out by soil erosion. Though new fine particles are provided from the subsoil by plowing every three years, their presence still declines; hence, the overall fertility of the pineapple fields becomes degraded.

## 5. CONCLUSIONS

1. The soil loss rate in pineapple field we examined was high in comparison to rates in Southeast Asia.
2. From the results of the soil profile investigation and particle size analysis to a depth of 50 cm, it was discovered that the forest soil and the pineapple field soil are essentially the same. It was concluded that the soil is erosive soil since it contains a large component of sand and has a single grain structure.
3. In the forest, where the soil is covered with a vegetation, rain does not hit on the soil surface directly, so soil erosion does not occur readily. On the other hand, a great portion of the soil surface in the pineapple field is uncovered, so raindrops hit the soil surface directly. This was thought to be the main cause of soil erosion.
4. Since a permeable, largely humus layer existed in the zero to 5 cm surface of the forest, rain tended to permeate into soil. This also contributed to its lack of soil erosion. On the other hand, the surface of the pineapple field has a small hydraulic conductivity. This, combined with the exposure discussed in conclusion 2, makes soil erosion a problem in the pineapple fields.
5. It can be assumed that the fertility of pineapple fields is easily degraded by soil erosion, especially by the erosion of fine particles in the soil.


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the Lam Phachi River Basin, Thailand
Bangkok, November 29, 2002

# Perspective of the Contract Hire Systems in View of the Effective Machine Use Mode —In the Case of *Mooban* Ton Maka, Rachaburi—

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***Abstract***
A distinctive feature of the contract hire systems has been the attempt to understand the process of technology acceptance under accelerated change of mobility at a frontier in western part of Thailand. But it has to be noted that the people's mentality varies from one place to another. And this mentality-related components keep strong bonds with the mode of technology acceptance. Based on such recognition, this paper argues that how do local dwellers manage the farming practices utilizing the uniquely-operated contracting systems. In the study site, *Mooban* Ton Maka, *King-Amphur* Bankha, *Chanwat* Rachaburi, migration took place steadily about 30 years ago. As a destiny of the frontier, this mobility evidently reflected the Government's development policy. And obviously, each migrant has poor level of agricultural technology, and hence they tried to absorb indispensable knowledge from the dwellers already settled a long time ago or his/her relatives' network. Local dwellers felt that the contracting service is one of reliable partners to implement site-specific farming practices with reasonable expenses. Dynamic activities for both sides, *i.e.* farmers and contractors, were investigated and proposed the ways and means for further development. Faced with the difficulty of securing abundant cheaper workforce and enough operating capital, the local contractors can operate more flexible than the big-scale contractors, whose fixed cost are so high.

**Keywords: contract hire systems, Thailand, settlement community, rain-fed**

## 1. INTRODUCTION

The Lam Phachi watershed, which flows into the Greater Mae Klong river basin, has so far been developed enjoying the auspices of the government's financial support for the period of 90 years or more. However, its progressional speed associated with physical and social development was envisaged slower and unaccountable progress due to detrimental traits caused partly by specific topographical conditions, and hence this area deemed as a frontier. It must be noted that this area has long been practiced the rain-fed farming in growing rice, pineapple, cassava, corn and others. But in accordance with the presence of modern technology, local people has likely started to adopt machines in order to secure higher productivity. This area is also categorized as a settlement community where migrants from a certain limited neighboring areas have settled with some hopes roughly 25 years ago.

When it comes to the machine furnishing for individual farmer, the contract hire systems might obviously gain a comparatively-superior substituting status for farming management. For such a behavioral characteristics, social consciousness involved in the technology acceptance may play considerably essential role to describe the causes and countermeasures for the sake of establishment of desirable machine management mode in future.

This paper argues that the framework in relation to technology acceptance affects to the agricultural mechanization modes including contract hire systems. The case material is from local dwellers, who are migrant farmers undertaking their living activities in and around their home. They are a good example of an agrarian society that does not need machine's ownership for the advancement of livelihood. The question is how do they do their farming operation on schedule? What, if any, are the ways and means of the existing contracting systems. Selected findings will be highlighted for this preliminary study which might lead to further detailed field survey in the not-too-distant future.

## 2. DESCRIPTION OF THE STUDY SITE AND METHODOLOGY

### 2.1 Study site

The resilience and persistence of the settlement community in view of agricultural mechanization has not, until recently, been an orthodox topic of discussion. Under the influence of globalization approach, as a whole, the general trend in scholarship was to look at how efficient and economic mechanization would identify the conditions of exploitation and exacerbate impoverishment, dependence, and ethnic degradation. This field study attempts to describe the current situations which happened at the remote place where local dwellers are mainly engaged to the farming practices totally depending on the contract hire systems.

The upper-stream area of the Lam Phachi river in Rachaburi, western part of Thailand, is embracing several tributaries. One of tributaries composes of watershed of the Huai Tha Khoei river, and the study site located at the community of *Mooban* Ton Maka, *King-amphur* Bankha, *Changwat* Rachaburi. Figure 1 indicates its geographical information. In other viewpoint, its location can be described referring as a nearby K25A observatory point designated officially by the Royal Irrigation Department.

Major crops cultivated at the gentle slope field include sugarcane and cassava, whereas pineapple at the steep slope field and vegetable at the flat field are predominantly grown. Several years ago, the conversion from forest to farm land has drastically been progressed. Accordingly, the pineapple field which has newly developed faced severe damages in the form of soil erosion. What is more, paddy fields were scarcely existing even at the space of low-lying depression with gentle gradient from the elevated periphery to the bottom. In particular, it is of interest to note that no farmers have been recognized in engaging rice-growing cultivation practices in this study site.

### 2.2 Methodology

This field survey has been made twice in July, 2001 and March, 2002 respectively. The questionnaire sheet has been prepared to gather basic information through interview mode approaches, or direct access to local respondents.

Items asked at the time of interview include the personal history of both farmer and his/her ancestor, biodata of family members, cropping plants and cultivating acreage, any agricultural machinery owned and their operating hour in the field, history of cropping patterns for the past 20 years, status which depends on the contract hire service, available infrastructure levels, currently-functioning group farming systems and so on. The overall population, the number of farm households, total area of this community were amounted as 270, 53 and 3500 rai, or approximately 560 ha, respectively. The number of respondents was approximately 30 or so, and hence a certain level of reliability can obviously be secured in performing further analysis.

## 3. MECHANIZED TECHNOLOGY AND AGRICULTURAL MANAGEMENT

The mechanization in agriculture is believed to contribute saliently for the economic advancement of rural community. But some difficulties are inevitably accompanied in telling the worthy components and unworthy ones to farmers in the process of the dissemination of mechanization-related technology. In some cases, farmers tends to furnish fully-mechanized systems, but others may satisfy with humble level of mechanization. Various mechanization levels perhaps seem reflect the necessity to analyze the inherent components regarding human mentality which remains unsolved in academic circles. How can we succeed to explain such an important human behaviors logically? One realistic approach is to pay some efforts in

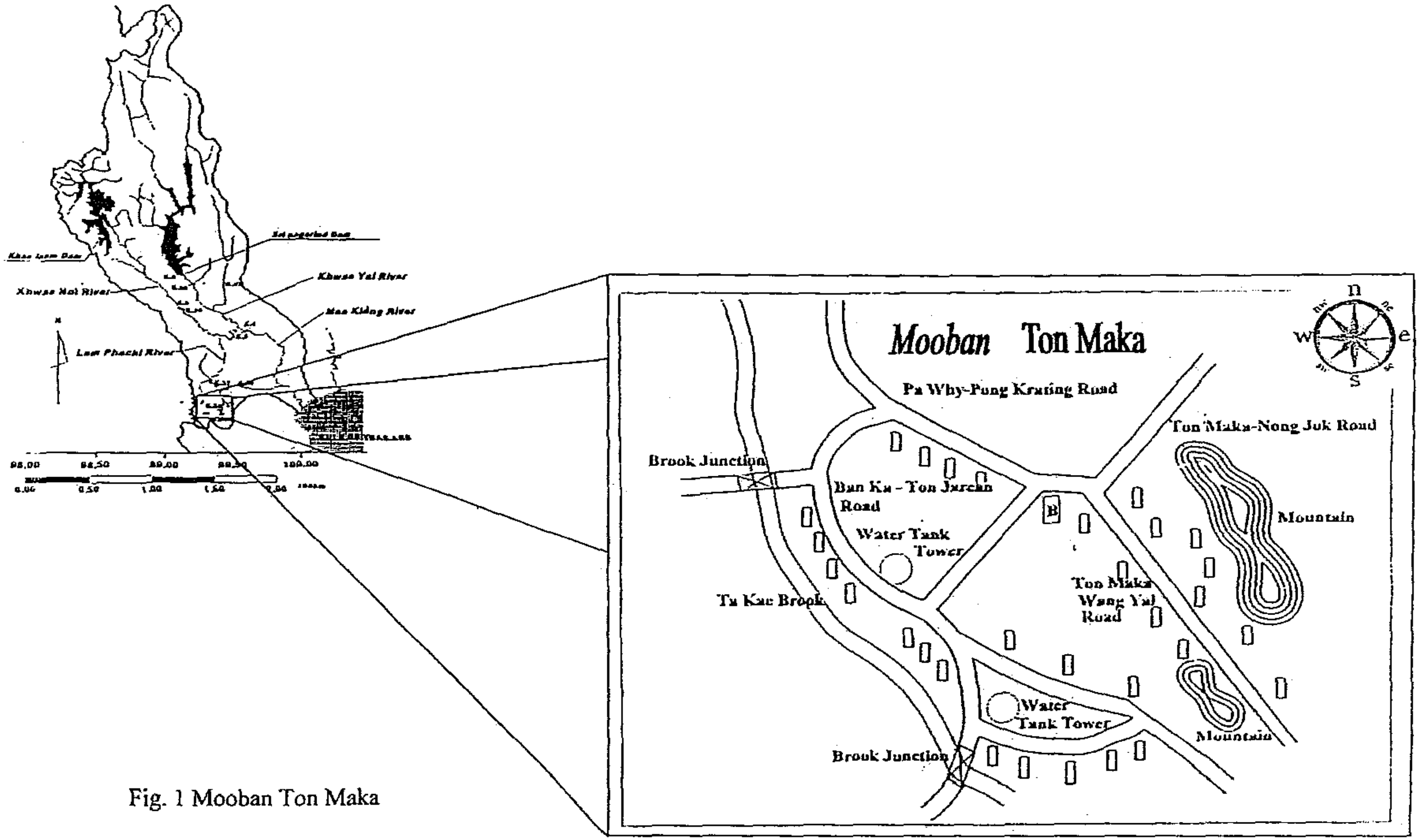


Fig. 1 Mooban Ton Maka

gathering specific data and extracts any significant tendency from them, and then propose some models which are beneficial to the self-sustaining household economy.

Before substantial discussion, current economic situations in Thailand are reviewed as shown in Tables 1, 2 and 3. Table 1 suggests that the rain-fed farming is still practiced in all regions with comparatively higher percentage. As for farm land utilization, all regions fall within the range of higher percentage. This implies that farmers are forced to cultivate lands for the sake of more income.

The unemployment is seemingly taken into account as indispensable indicator to assess the mobility (Table 2). After economic recession in 1997, an unemployment ratio increased once as high as 5.1% in 1998, then decreased suggesting robust recovery. This social factor might keep neutral connection with mobility which affects to the requirements of mechanized power in place of man- or animal-power.

The debt status for individual household is another concerns which are in relation with personal motivation for selecting mechanized power. Generally speaking, farmers tend to adopt mechanized power willingly when they are able to anticipate any profit. On the contrary, Table 3 suggests that most of the farmers keep surprisingly small amount of surplus in producing any profit. Although they are engaging, more or less, the agrarian business, their business scale is so small that they manage to their livelihood by from-hand-to-mouth basis relying heavily on the debt.

About 20 to 30 years ago, one rural community in the vicinity of Nakhon Pathom once embraced many young farmers who possess firm intention in engaging farming practices. Some farmers tried to shift their growing plants from rice to fruit or vegetables due to unattractive income level. Also, in the early morning, a number of day-laborers were

Table 1 Farm land ownership

| Acreage (rai/household) | Region (%) | | | |
|---|---|---|---|---|
| | Northeast | North | Central | South |
| Less than 10 | 20.9 | 34.5 | 28.0 | 31.9 |
| 10~20 | 31.4 | 26.5 | 21.9 | 29.2 |
| 20~30 | 21.0 | 14.0 | 17.1 | 17.6 |
| 30~40 | 10.4 | 9.1 | 11.2 | 9.4 |
| 40~50 | 6.8 | 5.3 | 7.5 | 5.8 |
| Greater than 50 | 9.4 | 10.5 | 15.2 | 8.5 |
| Mean | 25.7 | 22.4 | 31.8 | 23.5 |
| Ratio of rain-fed land | 0.84 | 0.74 | 0.67 | 0.92 |
| Ratio of land utilization | 0.92 | 1.20 | 1.19 | 1.03 |

Source: Office of Agricultural Economics, 1999

Table 2 Unemployment status after economic crisis

| | 1997 | | 1998 | | 1999 | |
|---|---|---|---|---|---|---|
| | A* | B* | A* | B* | A* | B* |
| Bangkok | 123,200 | 3.0 | 219,500 | 5.1 | 151,300 | 3.6 |
| Central | 226,900 | 3.1 | 236,200 | 3.1 | 157,200 | 2.0 |
| North | 233,500 | 3.9 | 252,500 | 4.0 | 243,700 | 3.9 |
| Northeast | 80,900 | 2.0 | 99,800 | 2.3 | 94,700 | 2.3 |
| South | 814,500 | 7.8 | 916,400 | 8.7 | 770,800 | 7.2 |
| Total or mean | 1,479,000 | | 1,715,400 | 5.2 | 1,417,700 | 4.3 |

Source: National Statistics Office, 2001

Note: A* and B* indicate the number of overall unemployment and the unemployment ratio (%) respectively.

Table 3 Debt status of farm household economy

Unit: Bart/household

| Item | Region | | | |
|---|---|---|---|---|
| | Northeast | North | Central | South |
| Debt: D | 28,794 | 29,773 | 77,464 | 49,344 |
| Repayment per year: R | 14,872 | 20,531 | 40,218 | 16,476 |
| Living expenditure: C | 46,503 | 46,454 | 90,349 | 87,597 |
| Overall cash income: T | 71,859 | 68,202 | 135,926 | 111,094 |
| Repayment ratio | 0.21 | 0.30 | 0.30 | 0.15 |
| Living expenditure ratio | 0.65 | 0.68 | 0.67 | 0.79 |
| (R+C)/T | 0.85 | 0.98 | 0.96 | 0.94 |

Source: Office of Agricultural Economics, 2001

recognized waiting factory's coach at the stopping place. One of their destinations was the sugarcane fields at Kamphaengsaen to do harvesting jobs hired by sugarcane factory.
Later on, most of the young workers moved lately from their home to the suburbs of Bangkok, and those who remained at the rural community including women and middle- or aged-persons have engaged in miscellaneous small-scale businesses. Currently, rice-growing promoters are seemingly played by the large-scale farmers, or more than about 26rai holders.

In such a manner, the conventional concept of "rice-growing society " *per se* is apparently forced to transform its contents in adapting to the real social changes. This changes took place not only in Thailand, but also in the rest of Southeast Asian countries.

## 4. RESULTS AND DISCUSSION

### 4.1General aspects in particular reference to the contract hire systems

The study site was the area where tropical forests have densely thrived until about 30 years ago. However, after formulation of the settlement policy implemented by the Thai Government, the agricultural development as well as consolidation scheme has progressed accompanying the shift of growing plants in drastic pace.

The original inhabitants were believed to be the Karen tribe. They have traditionally been engaged in slash-and-burn method to produce upland-rice, corn, chili, sorghum and vegetables. With the advancement of settlement policy, they may be started to engage upland cropping system. To perform such an agricultural works, the manual- or animal-power was selectively used in assimilating the technology being popular in the Central Plain. Also, the period of the Karen's settlement coincided all in all with the one of local dwellers of study site. Only few simple farming tools are still used including a sickle for harvesting and a beating flail for threshing operations. The Karen obviously manages their livelihood undertaking free trade with outsiders. The existence of the Karen seems to provide preferable influences to the periphery of community because the Karen believes in their own faith piously.

Selected results of interviews shall be reported in the following section for more detailed discussion.

Almost all of our interviews with farmers brought about similar accounts. We gradually came to pay attention to their specific comments about their current farming practices. Very often they unconsciously expressed a feeling of the contract hire systems. Our feeling is that farmers do not mind the contract hire systems as a technology, but a package of processing unit available upon request. Because of less knowledge of machines, what farmers can do is to place the request directly to a contractor and prepare for the payment. Only business-like relations can be seen among this practices. Therefore, interrelationships between farmers and this particular systems are extremely remote. In due course, during farming operation, there exists less chance in getting familiar with machines and getting down to contrivance.

### 4.2 Selected findings through interviews

Case-1

Husband 44-year-old, Wife 37-year-old, 3 children

Father ----- Chinese, Mother ----- Thai
Migrated here 20 years ago from Nakhon Pathom
Planting area
100rai (Rented) ----- rental fee: 500 baht/year, Timber culture
5rai ---------------- vegetable growing (Lettuce, cucumber and Chinese radish)
Cropping history
20 years ago ----- pine tree and corn
5 years ago ------ pineapple
Contract hire systems
Primary tillage ----- 250 baht/rai
Secondary tillage -- 250 baht/rai
Furrowing ---------- 300 baht/rai

Prior to migration, they used to grow coconut and chili. They bartered them with local dwellers for rice. Their motiv of migration was due to available information delivered from their relatives who have already migrated here. A special emphasis is likely placed to their kinship from the viewpoint of their consequences of behaviors. After settlement, they learnt necessary knowledge regarding farming systems from the neighboring people.

According to farmers, the quality of tillage operation is so-so, just as they expected. They aware of the soil erosion triggered by the tillage and succeeding soil-engaging operations.

To our surprise, this family began new business which possibly led to the village industry. Since they live at the subsistence level, they need to secure a rice supply as well as cash income. And hence, they determined the division of labor in the household: the husband farms vegetables and the wife makes red-rattan handicrafts. Their primary goal in making rattan handicraft is to meet the basic needs of the household and provide education for their children. Although they did not show any sign in establishing development project, it has been able to sustain such a small business with appropriate improvement.

Case-2

Husband ----- 67-year-old, Wife ----- Deceased, 3 children
Father ----- Chinese, Mother ----- Chinese
Migrated here 32 years ago from Nakhon Pathom
Planting area
23rai ----- Chinese radish, eggplant
50rai ----- pineapple
Cropping history
32 years ago ----- rice, watermelon and pineapple
Contract hire systems
Primary tillage ------------ 250 to 300 baht/rai
Secondary tillage --------- 250 to 300 baht/rai
Clearing and renovating-- 300 baht/rai

A farmer was at 32-year-old when he migrated here from Nakhon Pathom. His parents has grown rice and vegetables, and bartered them with local dwellers for rice and pork. He thought this place probably provided more fertile soils.

For field works, first tillage is done for the processing of previous crop's residues and second one corresponds to the conventional primary tillage, and then third one is for ridging operation. Chemical spraying operation is also another one to ask contracting service. This farmer uses sprinklers to meet the marketing competition. His farms locate in flat area, and hence less problems exist in terms of soil erosion.

Case-3

Husband ----- 70 year-old, Wife ----- 59-year-old, 4 children
Parent ----- Nationalities are not identified.
Migrated here solely 10 years ago from Nakhon Pathom
Planting area

68rai ----- pineapple
20rai ----- pineapple (Owned by his wife)
20rai ----- pineapple (Owned by his daughter)
13rai ----- pineapple (Owned by first son)
13rai ----- pineapple (Owned by second son)
13rai ----- pineapple (Owned by third son)

Cropping history

10 years ago ----- cassava and corn

Contract hire systems

For tillage ----- 200 baht/rai
Planting for pineapple ----- 1200 baht/10000 pieces
Harvesting for pineapple ----- 2000 baht/10000 pieces

This farmer behaved so carefully that he decided his migration after confirming the soil fertility beforehand. When he initiated his farming practices, he encountered severe decline of pineapple price. Accordingly, he returned to his home town for a certain period, and came back here once again after confirmation of the price recovery. Furthermore, he owned only few hoes for harvesting. Therefore, most jobs in the field were done by hand.

Case-4 Contractor

Husband ----- 43-year-old, Wife ----- 35-year-old, 2 children
Father ----- Thai, Mother ----- Thai
Migrated here 26 years ago from Nakhon Pathom

Planting area

180rai ----- corn, pineapple
80rai ----- mango

Cropping history

26 years ago ----- corn
23 years ago ----- banana, corn
3 years ago ----- pineapple

Contract hire systems

Machinery in service ----- Ford 5500 tractor (Engine horsepower 100PS, Price 100,000 baht), a 3-way disk plow, a 7-way disk plow

A four-wheel tractor was employed to undertake heavy-duty tillage works. Actually, the contracting hire service didn't result in higher profit as anticipated. Eight workers, who came from Udon Thani by his persuation, were fully engaging farming practices at his farm, but were ready to help for other households if any extra time exists. He always minds to keep good conditions of a tractor through regular check-up of engine at a repair shop.
He purchased farm lands at the rate of 3000 baht/rai with the external help from bank's loan. Nowadays, this land value raised as high as 70000 baht/rai.
Salient fluctuations of the market price is often dismayed by pineapple growers. For example, its buying price of factory was 5.4 baht/kg in 2001, but 3.0 baht/kg in 2000. What is worse, the middleman seduced to buy them at the rate of 4.6 baht/kg only. In response to this circumstances, this farmer never asked middleman any business matters.

Case-5 Contractor

Husband ----- 47-year-old, Wife, 3 children
Migrated here 10 years ago from Prachuap Khiri Khan

Planting area

1000rai

Contract hire systems

Machinery in service ----- Ford 6600 tractor (Price 500,000 baht), a 3-way disk plow, a 7-way disk plow

This farmer operated comparatively bigger scale of contracting business in the presence of entrepreneur spirits. He repeatedly said this wasn't profitable because of excessive amount of expenses. Its service charge amounts 250 baht/rai for tillage operation. And the annual

coverage area in service was as much as 400 to 500rai. The service charge was usually paid in kind at the period of harvesting. The motive of this enterprise was coming from the fact that his relatives and colleagues urged him to begin this futuristic business.
Altogether 13 workers, who joined voluntarily from Ubon Ratchathani, were engaging at his workplace, and more 10 or more workers were recruited from nearby community in case business load became tight.
Since he also acts as a middleman of pineapple, his bargaining amount excluding domestic production attained as much as 2000 to 3000t annually.

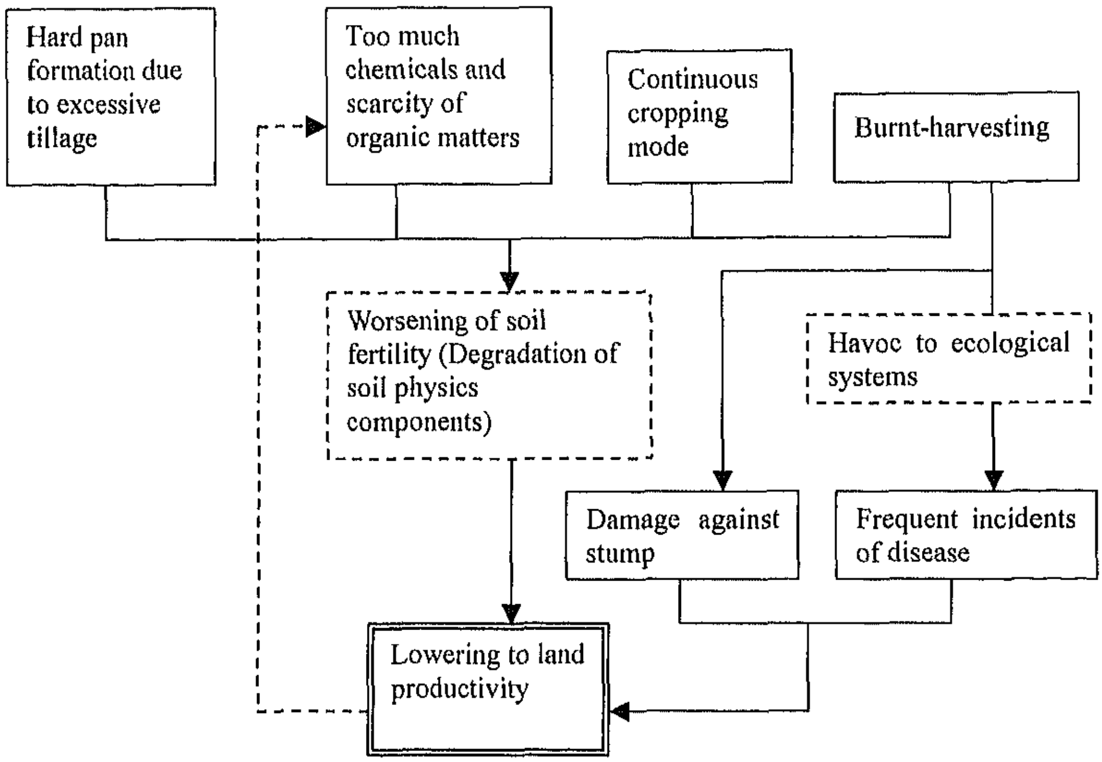


Fig. 2 Interactive factors related to the lowering of farm land productivity

Fig.2 implied the physical problems encountered in the fields. It is of importance to prepare proper countermeasures to implement alleviation of land degradation for which machines occupy significant position in the sense of practical contribution.

## 5. CONCLUSIONS

As our impression is that current farming systems in *Mooban* Ton Maka are diversified, factors involved in this community have to be identified to achieve further improvement. In particular, as this is a story of migrant community, people's backgrounds are naturally diversified. This suggests that there are some possibilities to establish the cropping diversification which meets to the demand derived from markets. Several essential discussions are to be itemized to streamline focusing points as described below.

1) When this migrant community initiated substantially 25 years ago, only 20 units of households or about 100 persons were found. Among of them, 6 households believed in Christian. Provided the land price is reasonable, some of them might seek new place something different like the frontier because they felt the wear and tear on urban life. In fact, land price was found to be so cheap that the cost of virgin land was 30 to 40 baht/rai. Some community members were educated even at the university and experienced to work at the leading enterprises. Such a rich variety of dwellers' backgrounds, or congregation of heterogeneous members, constituted one of pronounced characteristics of this community.

2) One hypothesis goes that such a community tends to have loose dependence to the technology which used to be unfamiliar in daily life. To furnish nil unit of farming tools at each household seems to be one evidence in explaining this hypothesis. At the same time, they provide a capability to evaluate the field works done by contractors. These farmers also did not follow conventional customs when placing request to contractors. On this occasion, they exclude the commitment of a broker, and place request directly to contractors. This request manner is different compared to other community in Thailand which have conducted field survey last few years. In the process of this decision-making, the concept of rationality putting emphasis to economics can likely be recognized.

3) At the inception of migration, most of the local dwellers were at lower level in terms of individual property. However, after 25 years or so from migration, salient discrimination between the have and the have-not could be identified like a bipolarity phenomenon.

4) The agricultural sector is expected to play more productive role, given its stability to generate outputs as a source of income for the country and to absorb unemployed workers from the industries sector, and in these ways help reduce the adverse impact on society. The rationale for this is derived from the possibility in increasing productivity through development of appropriate technology, and the potential for increasing export products and import substitutes. It is of help to undertake mixed farming as one method of addressing rural poverty and minimizing migration to urban areas.

5) Greater emphasis should be placed to use organic fertilizer in order to improve soil quality, increase productivity and conserve the environment.

## ACKNOWLEDGEMENT

Appreciation is extended to the three-year KU-UT joint research project entitled "Watershed degradation and restoration of the Lam Phachi river basin, Thailand" which is granted by JSPS Grant-in-Aid for Scientific Research (No. 12575020).

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# 付録

## 1）調査活動の概要

2000年6月11日：2000年度全体会議（全体研究計画、2000年度の現地調査計画）、場所（筑波大学農林工学系）、参加者（眞板、杉山、木村、丸谷、佐藤、小池、瀧川、佐久間、小川、長谷川）

2000年7月30日-8月11日：現地調査（カセサート大学、チュラロンコン大学、ＦＡＯアジア・太平洋オフィス、王室潅漑局などの訪問による資料・情報の収集；カセサート大学および王室灌漑局の海外共同研究者との研究計画の打ち合わせ；参加者全員によるランパチ川流域現地調査）、調査者（眞板、杉山、小池、佐久間、長谷川、木村、肥後、丸谷（7月30日～8月10日）、小川（8月6日～11日）、佐藤（8月6日～15日）、現地共同研究者）

2000年11月25日～12月4日：流域・森林グループ現地調査（パイナップル畑のリル、ガリ侵食の計測、植生調査）、調査者（眞板、木村、肥後、海外共同研究者）

2000年11月27日～12月7日：水文資料収集、水文環境調査、調査者（杉山、現地共同研究者）

2000年12月10日～17日：土地利用グループ現地調査（地形と土壌侵食の関係調査、農地開発の背景状況調査、リモセンのグランドツルース調査）、調査者（佐久間、小川、佐藤（12月13日～19日）、現地共同研究者）

2001年2月22日～3月8日：農業機械グループ現地調査（コントラクタ農業に係る聞き取り調査、データのとりまとめおよび研究の方向性についての現地共同研究者との検討）、調査者（小池、瀧川、現地共同研究者）

2001年6月2日～3日：2001年度第１回全体会議（2000年度の研究成果、2001年度の現地調査計画など）、場所（岐阜大学農学部）、参加者（眞板、杉山、木村、肥後、丸谷、佐藤、小池、瀧川、佐久間、小川）

2001年7月15日～8月4日：流域・森林グループ現地調査（上流から下流に至る河床横断形の測定、またこれらの地点での流量、堆積層序、洪水痕跡、河床堆積土砂粒径の測定、航空写真を使った河道変遷調査を行うための現状河道の地形把握調査、森林地とパイナップル畑の土壌浸透能の測定、各調査地点の土壌断面を記載、土壌の粒度

分析、森林構造を把握するため植生調査)、調査者(木村、丸谷：7月15日～30日、眞板、肥後：7月21日～8月4日、現地共同研究者)

2001年11月22日～12月1日：土地利用グループ現地調査(パイナップル畑の土壌侵食量の測定、土壌物理性の測定、農業開発の進行に関する聞き取り調査、リモセンのグランドツルース調査)、調査者(佐藤(11月20～12月1日)、佐久間、小川、豊満、木村(11月25日～12月1日))

2001年11月26日～12月6日：水文資料収集、水文環境調査、調査者(杉山、現地共同研究者)

2001年12月3日～14日：王室潅漑局Songpol Kumlungkeng氏の来日(水文データ処理技術に関する研修)

2001年12月9日～18日：農業機械グループ現地調査(改良したコントラクタ農業の構造に係る聞き取り調査)、調査者(小池、瀧川、現地共同研究者)

2002年3月2日：2001年度第2回全体会議(2001年度の研究成果、2002年度の現地調査計画、タイでのワークショップの開催など)、場所(筑波大学農林工学系)、参加者(眞板、杉山、丸谷、佐藤、小池、瀧川、佐久間、小川、長谷川、豊満)

2002年5月31日～6月1日：2002年度全体会議(2002年度の現地調査計画、研究のとりまとめの方向、現地共同研究者の招聘、バンコクでのワークショップの開催、ワークショップ・プロシーディングおよび科研報告書の作成など)、場所(筑波大学農林工学系)、参加者(眞板、杉山、木村、丸谷、佐藤、小池、瀧川、佐久間、小川、長谷川)

2002年7月25日～8月3日：農業機械グループ現地調査(コントラクタ農業の構造に係る詳細な基礎データの収集、調査とりまとめ)、調査者(小池、瀧川、長谷川、現地共同研究者)

2002年7月28日～8月9日：流域・森林グループ現地調査(上流から下流に至る河床横断形の測定、またこれらの地点での流量、堆積層序、洪水痕跡、河床堆積土砂粒径の測定、航空写真を使った河道変遷調査を行うための現状河道の地形把握調査、森林地とパイナップル畑の土壌浸透能の測定、各調査地点の土壌断面を記載、土壌の粒度分析、パイナップルの被覆度調査、放棄畑の植生侵入調査)、調査者(眞板、木村、丸谷、肥後、現地共同研究者)

2002年9月23日～10月2日：水文資料収集、水文環境調査、調査者(杉山、現地共同研究者)

2002年10月11日～21日：王室潅漑局Kosit Lorsirirat氏の来日(研究とりまとめ、ワークショップ打ち合わせ)

2002年10月21日～26日：カセサート大学Banshaw Bahalayodhin氏、Nipon Tangtham氏、Varawoot Vudhivanich氏、Bancha Kwanyuen氏の来日(研究とりまとめ、ワークショップ打ち合わせ)

2002年11月19日～27日：土地利用グループ現地調査(パイナップル畑の土壌侵食量の測定、土壌物理性の測定、リモセンのグランドツルース調査)、調査者(佐藤(11月19～26日)、佐久間、小川、豊満、木村(11月25日～27日))

2002年11月27日～12月1日：バンコクにおけるワークショップ（ワークショップ開催準備、ワークショップにおける発表・討議（11月29日開催、参加者：約70名）、プロシーディング作成に関する現地共同研究者との打ち合わせ）、参加者(眞板、杉山(11月25日～12月2日)、木村、肥後、丸谷、佐藤、小池、瀧川、佐久間、小川、長谷川、豊満、現地共同研究者)

### 2）「アジアと農林工学」フォーラム

第１回　＜演題＞　国際プロジェクトの社会文化的側面　－フィリピン小規模灌漑システムの事例から－

＜講師＞　角田宇子　氏（亜細亜大学、国際関係学部）専門：開発人類学

＜日時＞　2000年7月10日

＜場所＞　筑波大学生物農林学系棟

第２回　＜演題＞　参加型農村開発：日本、インドネシア、タンザニアでのPLA(Participatory Learning and Action)

＜講師＞　平山　恵　氏（筑波大学、社会医学系）専門：国際保健学

＜日時＞　2000年10月4日

＜場所＞　筑波大学生物農林学系棟

第３回　＜演題＞　Agricultural Mechanization Strategy in Thailand towards Next Century

＜講師＞　Prof. Banshaw Bahalayodhin

Department of Agricultural Engineering, Faculty of Engineering,
Kasetsart University, Thailand

＜日時＞　2000年10月11日

＜場所＞　筑波大学生物農林学系棟

第４回　＜演題＞　森林環境評価ネットワークシステムの研究開発

＜講師＞　中島敦司　氏（和歌山大学、システム工学部）専門：保全生態工学

＜日時＞　2001年2月1日

＜場所＞　筑波大学生物農林学系棟

第５回　＜演題＞　水源山地河川流域における渇水特性の抽出と診断

＜講師＞　杉山博信　氏（新潟大学、大学院自然科学研究科）

専門：水文・水資源学

＜日時＞　2002年3月1日

＜場所＞　筑波大学生物農林学系棟

3）ワークショッププログラム

**Workshop on**
**Watershed Degradation and Restoration of the Lam Phachi River Basin, Thailand.**
Held at The Maruay Garden Hotel, Thailand, on November 29,2002.
Organized and sponsored by Faculty of Engineering . Kasetsart University, Thailand and the Institute of Agricultural and Forest Engineering, University of Tsukuba, Japan.

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**Schedule**

8.30-8.50 Registration

8.50-9.30 Opening ceremony

**8:50-9:00** Report on KU-Tsukuba research collaboration by the Dean of Faculty of Engineering (Dean Nontawat Junjareon)

**9:00-9:10** Opening Speech by the President of Kasetsart University(Associate Professor Dr.Viroch Impituks) )

**9:10-9:20** Overview of the workshop by the research team leader (Associate Professor Dr. Hedeji Maita)

**9:20-9:30** Souvenier presentation to the President of Kasetsart University by the Dean of Faculty of Engineering and Group photo with the President of Kasetsart University and the research team

9.30-10.00 **Keynote speech I**

Watershed degradation and hydro-ecological role of western forest complex of Thailand
Nipon TANGTHAM (KU)

10.00-10.30 **Keynote speech II**

Current status and future prospects of farm mechanization in Thailand
Suraweth KRISHNASRENI
(President of the Thai Society of Agricultural Engineering)

10.30-10.50 Coffee break

10.50-11.30 **Session I --Land and Hydrologic Characteristics--**

Rapporteurs: Hironobu SUGIYAMA (NU) and Shigeo OGAWA (NIRE)
Members : Kosit LORSIRIRAT (RID), Varawoot VUDHIVANICH (KU),Andrew C. WHITAKER (NU)
Papers :

1. Factors affecting hydrologic characteristics in the Lam Phachi river basin
2. Evaluation of land condition using satellite data

11.30-12.10 **Session II --Erosion–sedimentation Linkage--**

Rapporteurs: Hideji MAITA (UT) and Tomomi MARUTANI (SU)
Members: Mutsuki HIGO (GU), Masanobu KIMURA (GU), Songpol KUMLUNGKENG (RID), Kosit LORSIRIRAT (RID), Boonsong RUANGWATTHAGEE (RID), Nipon TANGTHAM (KU)
Additional Comments : Mutsuki HIGO , Masanobu KIMURA and Kosit LORSIRIRAT.
Papers:

1. Human impact on soil erosion in the Lam Phachi river basin: From a viewpoint of infiltration capacity.
2. Identifying significant tributaries from human impacted sedimentary system.
3. Deformation of riverbed and its causes in the recent quarter century in the Lam Phachi river basin.
4. Invasion of woody plants into pineapple fields in the Lam Phachi river basin.

12.10-13.30 Lunch

13.30-14.10 **Session III --Agricultural Land Use--**

Rapporteur: Tai-ichi SAKUMA(UT)

Members: Songpol KUMLUNGKENG(RID), Bancha KWANYUEN(KU),Shigeo OGAWA (NIRE), Masayoshi SATOH (UT), Yukio TOYOMITSU MU),Prathuang USABORISUT(KU), Varawoot VUDHIVANICH(KU),

Additional Comments: Shigeo OGAWA and Yukio TOYOMITSU

Papers:

1. Development of agricultural land in a hilly area of the Tha Khoei River Basin.
2. Soil erosion in the pineapple fields of Bankha District.

14.10-14.50 **Session IV --Effective Machine Use Mode--**

Rapporteur: Masayuki KOIKE(UT)

Members: Banshaw BAHALAYODHIN(KU), Hideo HASAGAWA(UT), Tomohiro TAKIGAWA(UT), Prathuang USABORISUT(KU)

Additional Comments : Banshaw BAHALAYODHIN, Tomohiro TAKIGAWA

Paper:

1. Perspective of the contract hire systems in view of the effective machine use mode --In the case of Mooban Ton Maka, Rachaburi--

14.50-15.10 Coffee break

15.10-15.40 General discussion by Hideji MAITA , Masayuki KOIKE , Banshaw BAHALAYODHIN and Varawoot VUDHIVANICH

15.40-15.50 Closing ceremony

Closing speech by the Dean of Faculty of Engineering (Dean Nontawat Junjareon)

16.00-17.30 Party

RID: Royal Irrigation Department, Thailand NU: Niigata University, Japan SU: Shinshu University, Japan GU:Gifu University, Japan MU:Miyazaki University, Japan NIRE:National Institute for Rural Engineering, Japan

4）写真

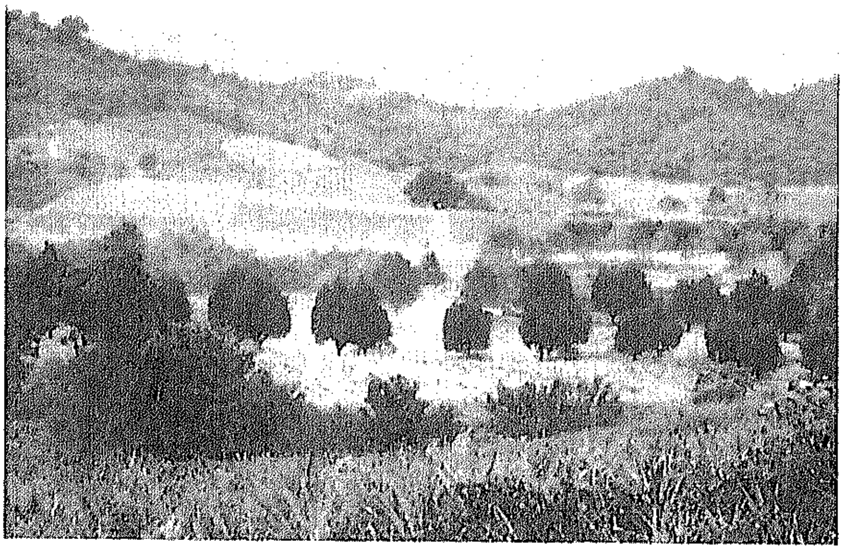

写真１　ランパチ川上流のラッブリ県バンカ準地区の丘陵斜面に拡大していく
パイナップル畑（2002年8月6日撮影、眞板）

手前の裸地はパイナップル畑が整地されているところである。苗を植えてから３年すると大型のトラクターを使い整地がおこなわれ、整地後がまたパイナップルの苗が植え付けられる。傾斜地のパイナップル畑には土壌侵食がみられることが多い。特に、畑地のガリ侵食が作業道路表面の侵食と連結すると深刻な侵食状況を呈する。丘陵上の森林はいずれも二次林であり、当地域ではこれまでも森林に対する人間の働きかけが強かったことを示している。

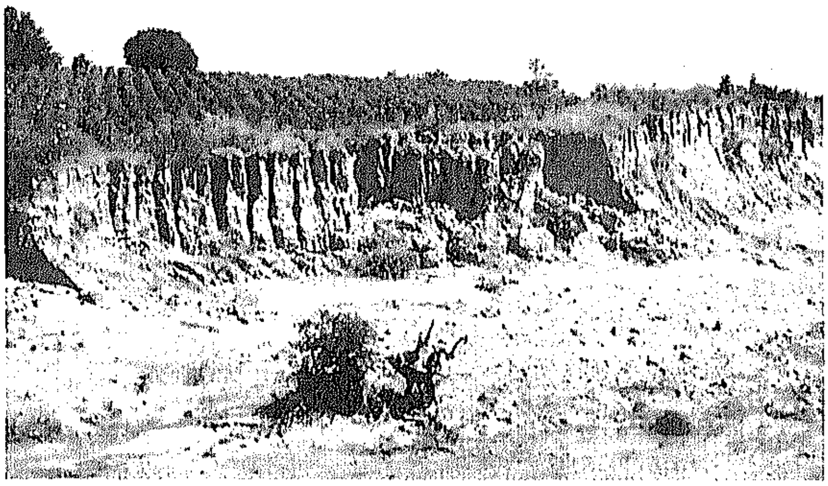

写真２　クワイ・ノイ川との合流点近くのランパチ川下流の河岸侵食状況
（2000年11月28日撮影、眞板）

氾濫原上の作物はキャッサバ、河岸の縦ガリ侵食がキャッサバの植列と対応していることに注意。この畑の最終浸透能は5mm/hrと極めて小さく降雨は地中にほとんど浸透出来ず、ホートン型地表流として流下する。降雨時に植列間の凹地に集中・流下した雨水が河岸の縦ガリ侵食を引き起こしている。洪水時の河川上下流の浮遊土砂濃度から考えると、河岸侵食がランパチ川への土砂供給に果たしている役割を無視できない。