2. *Watershed Management*

2 WATERSHED MANAGEMENT

This Chapter includes information on watershed management (sections 2.1 to 2.4), and GIS (remaining sections).

2.1 Soil and Water Conservation Practises

(1) Introduction

Soil erosion is influenced by several interrelated factors that include rainfall, soil erodibility, topography, cultivation practices, conservation practices and others. In utilising upland slopes for crop production, it is necessary to implement appropriate soil and water conservation practices minimise the degree of erosion and maintain the fertility of the soil. Knowledge of the volume of soil loss or severity of erosion may provide a reliable guide in planning suitable conservation practices for specific areas at risk.

Historically, several soil loss equations have been developed to estimate erosion. These equations were attempts to extrapolate limited research data to the wide variety of conditions found in the field. The Universal Soil Loss Equation (USLE) has evolved to become the best available model to predict erosion, and was originally developed for use in the United States; its application has been expanded to cover other regions and countries. The USLE was originally developed to predict long-term, average soil losses from runoff from specific field areas in specific agricultural cropping and management systems.

The existing soil erosion in the Project Area has been evaluated using the Universal Soil Loss Equation (USLE) as described by Wischmeier and Smith (1978), and is described in detail in the GIS section of this report.

The soil loss equation is represented by $A = RKLSCP$, where:

- A is the computed soil loss per unit area, expressed in the units selected for K and for the period selected for R. In practice, these are usually selected so that A is calculated in tons/acre/year, however other unit may be selected.
- R is the rainfall and runoff factor, expressed as the number of rainfall erosion index units, plus a factor for runoff from snowmelt or irrigation water where such runoff is significant.
- K is the soil erodibility factor, expressed as the soil loss rate per erosion index unit for a specified soil as measured on a unit plot. (A Unit Plot is defined as a 72.6 foot-length of uniform 9% slope in clean-tilled fallow).
- L is the slope-length factor, expressed as the ratio of soil loss from the field slope length compared to that from a 72.6 foot-length under ideal conditions.
- S is the steepness of slope factor expressed as the ratio of soil loss from the field slope gradient compared with that from a 9% slope under identical conditions.
- C is the vegetation cover and management factor, expressed as the ratio of soil loss from an area with specified vegetation cover and management to that from an identical area in tilled continuous fallow.

- P is the conservation practice factor, expressed as the ratio of soil loss from an area with land management practices such as contour ploughing, to that with straight row furrowing with the gradient of slope.

(2) Soil and Water Conservation Principles

In recent years, a new approach to soil and water conservation has been emerging, based on experience gained through farming systems research. This approach, sometimes called land husbandry, shifts the emphasis from looking only at what is happening to the soil (e.g.) symptoms of erosion to examining why erosion is taking place (e.g., the underlying causes of erosion). Examining the why component involves understanding the biophysical and socio-economic factors that contribute to land degradation.

Farmers need to understand the balance of interactions between the biophysical environment in developing sustainable land use systems. Due to the biophysical characteristics of many upland areas of Southeast Asia, the loss of soil and water resources remains a critical problem.

The following soil and water conservation and soil fertility management practices may make up an integrated approach to upland farm management. Some of the practices focus more on agronomic principles, others more on engineering strategies. However, all of the practices attempt to balance the conservation and production objectives of the farm household. There is a tremendous variability within each of practices presented and very few species-specific recommendations are given. Instead, a description and analysis of each of the practices are presented focusing on the advantages, limitations and the biophysical and socio-economic factors that might affect adoption or rejection of the practice.

(a) Some Key Principles for Soil and Water Conservation

1. Loss of soil productivity is much more important than the loss of the soil itself. Therefore, soil conservation must be an integral part of a general agricultural development strategy that focuses on improved production practices. Generally, conservation measures designed to control soil loss precede soil improvement practices. However, the two are interrelated and must be considered in combination, even if one practice would actually follow the other in sequence.

2. Erosion is a consequence of how the land is used and is not in itself the cause of soil degradation. Land degradation should be prevented before it occurs, rather than attempt to develop a cure afterwards.

3. Land-use has been studied in detail in soil conservation programmes, whereas the land users (the farm households) have been studied too little. A conservation programme that aims to solve a land degradation problem through treatment of causes requires a bottom-up approach based on a detailed knowledge of the farm and the farm household as a holistic land-use system. Top-down programmes, on the other hand, tend to focus primarily on the symptoms of erosion through subsidised terracing, promotion of alley cropping, or other measures, which have had mixed success when introduced by outside agencies.

4. In upland systems, plant yields are reduced more by a shortage of soil moisture than they are by soil loss. Therefore, there should be more emphasis on rain water management, particularly water conservation and less on soil conservation *per se*. Consequently, agronomic processes (tillage, mulching) are potentially more significant than mechanical measures in preventing erosion and runoff.

5. Soil conservation efforts will be more successful when applied through long-term programs rather than through short, fixed term approaches.

6. The farm household and its environment should be the focal point of every soil conservation program.

7. Farmers need to be convinced of the short-term benefits that will result from change. It is important to address farmers' immediate needs through the development and introduction of production strategies that are both effective and which will provide productive returns to the farmers.

(3) Crop Rotation

Crop rotation is arguably the most important crop management practice in Southeast Asia and widely adopted. Various crop species are grown in sequence, one after another, in the same part of the farm or field. These crop patterns may vary from year to year; however they are designed to achieve a common result: better physical and chemical characteristics of the soil. Each crop places a different demand on the soil in which it is grown. Likewise, each crop leaves some amount of beneficial residual or has a benefit on the physical structure of the soil. A good crop rotation takes into account each crop's characteristics so that the net effect is improved soil conditions. In agroforestry systems, the perennial crop component may be changed after several years, while the agricultural crop component may follow shorter rotation periods, usually less than one year. Agroforestny requires a longer-term approach to rotations, involving a wider variety of crops, each with a unique production cycle. A typical crop rotation is rice-mungbean-corn-cowpea. Since leguminous crops increase levels of soil nitrogen, mungbean (*Vigna simensis*) is often planted after rice.

(4) Bench Terraces

Bench terraces are a soil and water conservation measure used on sloping land with relatively deep soil to retain water and control erosion. They are normally constructed by cutting into the slope and filling to produce a series of level steps or benches. This allows water to infiltrate slowly into the soil. Retaining banks of soil or stone on the forward edges reinforce bench terraces. This practice is typical for rice-base cropping systems.

In China, a modification of bench terraces includes an interval slope planted with perennials and grasses between individual terraces. This system is suitable where soil erosion is critical, rainfall is low and labour and farm manure are not typically available. Shrubs and herbs may also be grown on the edge of the terraces.

(a) Advantages

1) Effectively control soil and water runoff and erosion.
2) Traps sediment in the drainage ditches built along the terrace.
3) Reduces slope length. Every 2-3 meters of slope length is levelled to terraces. The velocity of water running down the slope is greatly reduced.
4) Improves soil fertility over longer periods.

(b) Limitations

1) Initially disturbs the soil, reducing productivity in the first 2-3 years.
2) Needs intensive labour and investment for construction and maintenance.
3) Needs skill for proper construction.
4) Terraced fields with an interval slope consume large amounts of land.

(c) Factors Affecting Adoption

Biophysical

1) Not suitable for shallow and unstable upland soils.
2) Not suitable for cultivation of root crops since the terrace tends to become water logged.
3) Terraces with interval slopes may be used in regions with low rainfall.

Socio-economic

1) Labour shortages and low incomes make bench terraces difficult for farmers to adopt in some areas.
2) Lack of land tenure serves as a disincentive to long-term construction measures such as terraces.
3) In areas with poor soil, the terraces have a low return on investment.

(5) Composting

Compost is a type of organic fertiliser derived from the decomposition of plant and animal wastes. It is an excellent source of plant nutrients. Composting is common in domestic gardens. There are many ways to prepare compost (in a pit, above ground, in a field, near a livestock pen, etc.), depending on various socio-economic and biophysical factors. Composting involves the decomposition of plant and animal wastes. The decomposition process involves bacteria, invertebrates and soil. Moisture content, an adequate supply of air, and temperature control are important parameters for the production of high quality compost. In practice, large mounds of soil are built up and weeds and grasses are collected and placed in the centre of the mound. These are left for periods of up to 10 weeks for the decomposition process to start. The mounds and biomass are subsequently covered with soil. Compost mounds are common on slopes of up to 10 degrees.

(a) Advantages

1) Decaying compost generates nutrients for crops.
2) Decaying compost generates heat, which maintains temperatures at optimum levels for root growth, despite low night-time temperatures at high attitudes.
3) Composting cannot be practised on steep slopes .
4) Labour-intensive.

(b) Factors Affecting Adoption

Biophysical

1) Compost may not be required on soils with high organic content.
2) Composting requires an adequate supply of biomass.
3) Biomass requirements may be difficult to meet in drier climates.

Socio-economic

1) Labour is needed to harvest, haul and distribute the organic matter.
2) In some societies, it is not acceptable to handle animal dung.

(6) Contour Tillage /Planting

Contour tillage or planting is practised on slopes to reduce soil erosion and surface runoff. A contour is an imaginary line connecting points of equal elevation on the ground surface, perpendicular to the direction of slope. Structures and plants are established along the contour lines following the morphology of the ground. Contour planting may involve construction of soil traps, bench terraces or bunds, or the establishment of hedgerows. Contour tillage is being promoted in the Southeast Asian region for sustainable upland farming. Different combination of crops may be planted following different patterns.

(a) Advantages

1) Reduces runoff and soil erosion.
2) Reduces nutrient loss.
3) Cultivation is faster if using draught animals or machinery since the equipment is able to move along the same elevation.

(b) Limitations

1) Improperly laid- out contour lines may increase the risk of soil erosion.
2) Labour-intensive maintenance.
3) Requires special skills to determine contour lines.

(c) Factors Affecting Adoption

Biophysical

1) Increased productivity and soil condition are attractive.
2) Water retention in the furrows increases infiltration and production.

Socio-economic

1) In some marginal lands, the construction of engineering structures is inappropriate; so contour planting is a suitable alternative.
2) In some areas, people using hand tools find it is easier to cultivate the soil up and down the slope.

(7) Cover Crops

Cover crops are grown to protect the soil from erosion and to improve it through the use of green manure (the ploughing-under of a green crop or other fresh organic material). Cover crops are usually short-term crops (less than two years), planted in fields or under trees during fallow periods. cover crops are also inter-planted or relay-planted with grain crops such as maize, or planted once in a cropping cycle. Cover cropping is practised in many countries in Southeast Asia to suppress weeds under rubber and coconut plantations and to provide forage for animals. Cover crops may also be used in fallow systems to improve soil fertility quickly and shorten the fallow period. Most of the plants used as cover and green manure belong to the legume family. Examples are: *Desmanthus virgatus*, *Phaseolus*, *Clitoria ternatea* (butterfly pea), *Sesbania rostrata*, *Vigna radiata* (mungbean) *Pueraria phaseoloides* (kudzu), *Desmodium heterophylla*, and *Tephrosia candida*.

(a) Advantages

1) Improves soil fertility and physical and chemical properties.
2) Reduces soil erosion and water loss.
3) Suppresses weeds.
4) Reduces requirements for fertilisers and herbicides.
5) Provides human food and animal forage.
6) Increases soil organic content.
7) Helps retain moisture in the soil and prevents the soil from drying.

8) Some cover crops provide good cash income.

(b) Limitations

1) Cover crops may compete for soil moisture and nutrients with the perennial crops.
2) Involves additional farm labour and inputs.
3) May result in weed problems.
4) May provide alternate host species for pests.
5) Some cover crop species may contain chemicals that inhibit subsequent crop growth.
6) May provide habitat for large animal pest species.

(c) Factors Affecting Adoption

Biophysical

1) Not applicable for very steep slopes.
2) Contributes to improved soil fertility.
3) Some cover crops are self-seeding and difficult to control, while other species do not seed well under some climatic conditions.

Socio-economic

1) Reduces the need for herbicides and labour required for weed control.
2) May not appeal to farmers with short-term land tenure.
3) In some circumstances, may require additional labour.
4) Cover crops may contribute to generation of lower short-term income.
5) Cover crops often do not yield products that have obvious tangible benefits (i.e. food, seeds etc.)
6) Many cover crop species are palatable to livestock. They may produce good fodder, however are difficult to establish if livestock are allowed to graze.

(8) Drop Structures

Drop structures are constructed to slow the flow of water in channels. In a steeply sloping channel, erosion be controlled by allowing the water to flow over a series of steps, or drop structures. Though effective, these structures are quite expensive for ordinary farmers to construct. Drop structures are more effective when combined with check dams. They may also be reinforced by vegetation, such as the planting trees or shrubs.

(a) Advantages

1) Controls upstream water velocities to reduce erosion.
2) Reduces water velocities to a lower level.
3) Dissipates the excess energy of water flow.
4) Controls downstream erosion.

(b) Limitations

1) Requires some skill to design and construct.
2) Needs rainfall data for detailed design.

(c) Factors Affecting Adoption

Biophysical

1. Drop structures built of wood may rot over time; it may be necessary to use preservatives.

Socio-economic

1. Expensive to construct when materials other than logs or stone are use.
2. Complex design using concrete requires skill to construct.
3. Unless causes of excessive upstream runoff are also addressed, drop structures will be ineffective in the long-term..

(9) Grass Strips

Planting grasses along contour lines creates barriers to minimise soil erosion and runoff, and induces a process of natural terracing on slopes as soil collects behind the grass barrier, even in the first year.

Grass may be planted along the bottom and sides of ditches to stabilise them and to prevent erosion of the upper slope. Grass may also be planted on the riser of bench terraces to prevent erosion and maintain the stability of the benches.

Grasses are trimmed regularly (every 2-4 months) to prevent them from flowering, shading and spreading to the cropped area between the strips. Grass strips may be appropriate for farmers who cut and carry fodder for their animals. Cut grass may also be used as mulch for crops.

Examples of grass species commonly used are: Setaria grass (*Setaria anceps*) Suzi grass (*Brachiaria ruziiensis*), Napier or Elephant grass (*Pennisetum pupureum*), Guinea grass (*Paniccum maximune*), NB21 (Napier crossed with Pearl Millet), Lemon grass (*Cymbopogon citratus*) and Vetiver grass (*Vetiver zizanoides*).

(a) Advantages

1. Controls soil erosion and runoff.
2. Provides fodder.
3. Grass may be used as mulch.

(b) Limitations

1. Labour requirement for management of grass strips.
2. Ruzi grass can root itself from cuttings.
3. Mulching of grass cuttings may contribute to weed growth.
4. Utilises land that might otherwise be used for crop food production.

(c) Factors Affecting Adoption

Biophysical

1. Not suitable on steep slopes or areas with prolonged rainfall patterns.
2. Not suitable in dry areas where grasses are unable to withstand drought.

Socio-economic

1. Farmers may not have time to manage the system intensively resulting in weed problems.
2. In traditional farming systems where livestock graze freely, farmers may not wish to use cut-and-carry practices.
3. Farmers often perceive grassed areas as a refuge for pests.
4. Planting materials are not available in many upland locations.
5. Farmers who do not own livestock, have little incentive to plant grasses.

(10) Hedgerows

Hedgerows are one of the simplest erosion control practices on sloping land. Nitrogen fixing trees/shrubs, grasses, fruit-trees or other crops such as pineapple or banana, are planted in rows along the contour. Various crop species and trees are established in the hedgerow to enhance farm income and diversity. Hedgerows help reduce velocities of runoff and trap soil to gradually form natural terraces and also improve soil fertility and productivity. Contour hedgerow cultivation is an indigenous practice in Indonesia, the Philippines, Thailand and Vietnam and is now adopted in many other countries.

(a) Advantages

1. Reduces soil erosion.
2. Improves soil fertility and soil moisture content.
3. Provides biomass for green manure.
4. Provides shading for younger plants.
5. Serves as a source of fodder, firewood and light construction materials.
6. Improves soil structure and water infiltration.
7. Provides a source of mulch.
8. May contribute to production of cash crops.

(b) Limitations

1. Loss of land for cultivation due to establishment of contour hedgerow (at least 10% of cultivated land is used).
2. Hedgerows compete with food crops planted between the rows for light, soil nutrients and moisture (in dry season). Root pruning and trimming can limit this competition.
3. Hedgerow plants may be hosts to pests.
4. Effective retention of excess water may result in soil slippage on steeper slopes.

(c) Factors Affecting Adoption

Biophysical

1. Extreme temperatures at altitude may be unsuitable for some hedgerow species.
2. Difficulty establishing contour hedgerows on very steep slopes (> 50 degrees)
3. Most nitrogen species are not adapted to acid soils.

Socio-economic

1. Shortages of seeds and saplings for preferred species.
2. Shortage of funds to purchase seeds or saplings.
3. Lack of time/labour to establish contour hedgerows.
4. Lack of land ownership/tenure.
5. Farmers' perception of hedgerows being non-productive.

6. Farmers' perception of hedgerows competing with food crops and harbouring pests.
7. Inertia against change on behalf of farmers who use more traditional cultivation methods

(11) Minimum Tillage/Zero Tillage

The use of simple farm implements such as hoes and digging sticks to prepare land and plant food crops is common and effective in controlling soil erosion. Examples of minimum tillage include rice cropping systems in Thailand and Vietnam and taro cultivation in the Papua New Guinea lowland.

(a) Advantages

1. Reduces the direct impact of raindrops on bare soil, thus minimising soil erosion.
2. Minimises the degradation of soil structure.
3. Reduces the rate of soil mineralisation.
4. Requires less labour than full tillage.
5. Can be practised on marginal soils that might not otherwise be feasible to cultivate.

(b) Limitations

1. Inadequate seedbed preparation may lead to poor establishment and low yield of crops such as maize and sweet potato.
2. Rooting volume may be restricted in soils with massive structures.

(c) Factors Affecting Adoption

Biophysical

1. Under no-burn swidden conditions, the soil is covered with tree litter and brush, making it difficult to cultivate.

Socio-economic

1. Provides an alternative to more intensive cultivation.
2. Farmers using more traditional swidden systems are familiar with minimum tillage practices.

(12) Mulching

Mulching is a soil and water conservation practice in which a covering of cut grass, crop residues or other organic material is spread over the ground, between rows of crops and around the trunks of trees. This practice helps to retain soil moisture, prevents weed growth and enhances soil structure. It is commonly used in areas subject to drought and weed infestation. The choice of the mulch depends on locally available materials. The optimum density of soil cover ranges between 30% and 70%.

In alley cropping systems, hedgerow biomass is often used as mulch. In orchards, cover crops may also be used as live mulches, especially around young trees that are well-established. Another strategy is to leave crop residues on the ground after harvesting (e.g. pineapple tops, corn stoves, rice straw, etc.). This ensures that some nutrients taken up by the plant are returned to the soil.

(a) Advantages

1. Intercepts the direct impact of raindrops on bare soil and reduces runoff and soil loss.
2. Suppresses weeds and reduces labour costs of weeding.

3. Increases soil organic content.
4. Improves chemical and physical properties of the soil.
5. Increases moisture retention capacity of the soil.
6. Helps to regulate soil temperature.

(b) Limitations

1. Possible habitat for pests and diseases.
2. Unsuitable in waterlogged conditions.
3. Difficult to spread mulch evenly on steep slopes.
4. Lack of available materials suitable for mulching.
5. Some grass species used as mulch can root and become a weed problem.

(c) Factors Affecting Adoption

Biophysical

1. Suited to areas with limited or irregular rainfall.
2. Insufficient availability of mulch may be a constraint in upland areas.

Socio-economic

1. Farmers are conditioned to burning crop residues instead of returning them to the soil.
2. Labour intensive collection and application of mulch.
3. Mulch is more important in domestic gardens or for valuable horticulture crops than in less intensive farming systems.

(13) Ridge Terraces

A ridge terrace consists of a ridge and furrow, constructed along the contours on slopes (usually less than 15%) to control soil loss and retain water. Grasses and leguminous trees are usually used to stabilise the ridge, but fruit trees, banana and cassava are also commonly used. During the wet season, the furrow fills with sediment and farmers put this back on to their land. Variation on ridges terraces include alley-cropping, and contour tillage.

(a) Advantages

1. Effectively controls runoff and erosion on moderate slopes.
2. The furrow behind the ridge traps sediment and nutrients.
3. Relatively low labour inputs are required compared to bench terracing.
4. Minimum disturbance of the soil - particularly important on shallow upland soils.

(b) Limitations

1. Less effective in controlling erosion than bench terraces.
2. Establishment of a stabilised ridge is time consuming and labour intensive.
3. Requires regular maintenance, since the ridge may be breached, causing channel runoff and resulting in rill formation.

(c) Factors Affecting Adoption

Biophysical

1. Grasses or trees may be grown on ridges to provide fodder for livestock.
2. Intense rain can wash away ridges, especially before they are well established.
3. Ridges on sandy or unstable soils are prone to collapse.

Socio-economic

1. Bench terrace construction on state owned land is prohibited in some countries, so ridge terraces are the next best alternative. This also relates to the tenure problem.
2. Ridge terraces are less labour intensive to construct and maintain than bench terraces.
3. Grass and other fodder species grown on the ridges are sometimes seen as competing with food crops and are removed, thus weakening the ridge.

(14) Soil Barriers

Soil barriers slow down runoff and retain the soil lost by sheet erosion. They may be made of wood or rocks and may develop into live fences of trees and shrubs. In Papua New Guinea and the Philippines, barriers are constructed with logs and branches across the slope. These are placed against wooden stakes driven into the ground. The upper side of the barrier is filled with grass and other materials to act as a sediment trap. The width of the cropland between barriers depends on the slope gradient, but is usually 4 m. to 8 m. Crops such as maize, sweet potato and tobacco are planted in the alley.

(a) Advantages

1. Reduces the velocity of surface runoff.
2. Retains sediment behind the fences.
3. If properly maintained, natural terraces develop over time.
4. Allows cultivation even on steep slopes that may not otherwise be feasible to crop.

(b) Limitations

1. Wooden barriers do not usually last for more than 2-5 years.
2. Barrier construction requires significant labour.

(c) Factors Affecting Adoption

Biophysical

1. More likely to be adopted if land with more moderate slopes is not available for cultivation.

Socio-economic

1. Availability of labour to construct barriers.
2. Allows farmers to grow relatively high-value crops on slopes otherwise impossible to cultivate.

(15) Soil Traps

Soil traps are structures constructed to harvest soil eroded from the upper slopes of the catchment. The most common types of soil traps are check dams and trenches, built in diversion ditches or waterways. A check dam slows down the water flow and allows heavier soil particles to settle. The size of the check dam depends on the size of the drainage channel or gully to be protected. Check dams may be constructed out of stakes, bamboo, loose rocks, logs or other locally available materials.

Trenches are built to trap soil along waterways and compliment the function of check dams. A trench is dug about 1-2 meters above the check dam, at least 0.8 m. deep, 1.0 m. long and 0.5 m. wide.

A variation is to construct the trench above a bund, which traps soil and stores water temporarily to increase infiltration. The accumulated soil in trenches and dam is returned to the field.

(a) Advantages

1. Prevents widening and deepening of gullies.
2. Promotes the deposition of nutrient rich highly fertile sediments.
3. Reduces the velocity of runoff in gullies.
4. The area where soil accumulates may be used for growing crops.

(b) Limitations

1. Requires continuous desilting to prevent overtopping during heavy rains.
2. Check dams require regular repair and maintenance.

(c) Factors Affecting Adoption

Biophysical

1. Materials for construction of check dams may be unavailable.

Socio-economic

1. Damage to check dams must be repaired and trenches desilting frequently.
2. Soil traps constructed without the necessary support structures may be ineffective.

(16) Water Harvesting

Water availability for upland agriculture can be improved by small-scale impoundments to capture and store rainwater for irrigation. A catchment area of sufficient size is needed to drain water into the reservoir. The amount of runoff generated depends on the catchment characteristics and rainfall. In parts of the Philippines with an annual rainfall of 1200-1500 mm, a catchment area of 0.2 to 0.5 ha of terraced rice land yields 100 cubic meters of water for storage in impoundments. For grassland and residential areas, a catchment area of about 0.6 to 1.0 ha is sufficient area for the same volume. Water harvesting is also possible in areas with low rainfall (300-500 mm per year), but larger catchment areas are required.

Small-farm reservoir sites are suitable in depressed areas (valleys) where irrigation is possible by natural flow. Sites that are communally owned should be managed to ensure sharing among the intended beneficiaries. Sites with springs or streams are good sites for locating small reservoirs and impoundments as they help to ensure a year-round water supply.

(a) Advantages

1. Improves food production (crops, fish, fruit trees etc.).
2. Promotes conservation and ecological balance.
3. Involves low investment cost per hectare.
4. Easy of construction.
5. Provides alternative (often high-return) uses to offset sacrificed land area.
6. Protects against drought.
7. Allows irrigation by gravity (no additional power cost).

(b) Limitations

1. Labour intensive.

2. High seepage and evaporation losses possible (depending on soil type).
3. Floating vegetation may infest reservoir.
4. Uncontrolled runoff in high intensity rainfall areas may over top and damage the embankment.
5. Poor design and management can lead to erosion and flooding.

(c) Factors Affecting Adoption

Biophysical

1. Soils that have high seepage and percolation rates may require lining.

Socio-economic

1. Farmers may be unwilling to sacrifice productive land for a reservoir construction.
2. Land tenure status may influence the investment decision.
3. Availability of labour.
4. Funds for credit services may be unavailable.
5. Engineering knowledge (both for construction of the impoundment and management of the irrigation system) is required.

2.2 Farming Systems Development for Sustainable Agriculture and a Tool to Prevent Encroachment

(1) Introduction

The aim of farming system development (FSD) is to rapidly identify useful local practices, as well as introduce new technology, for the benefit of small farmers. Agricultural extension workers work with families to help choose farm management practices that fit local ecological and socio-economic conditions. This participatory approach to upland rural development considers holistic farming systems. Income generation and food production are important, however sustainability is critical.

The success of FSD depends on the combined efforts of farmers, researchers, extension workers and planners. Scientists, sociologists and economists work with farmers to understand the limits to production and sustainability at the farm level. Plans are developed using a "bottom up" approach. FSD bridges the gap between research and on-farm utilisation, while taking into consideration other influences such as markets, availability of labour, access to credit, level of surrounding infrastructure, extension support and government policies. The approach is long term.

The existing agricultural and natural resource base must be managed properly to maintain its carrying capacity and prevent further environmental degradation. This is a complex and problem, pitting declining productivity and environmental degradation on one side and increasing population on the other.

(2) Methodology

Farming system development is carried out in a series of steps, each step being a discrete stage and affecting subsequent steps.

(a) Area selection

Farming system development should be started within a few trial areas selected by delineating agro-ecological zones. Representative sites should be chosen in each zone. Farm families should be tentatively classified into homogenous groups (families practising more or less similar cropping systems, facing the same resource and other constraints and perhaps requiring similar solutions).

(b) Getting started

Informal exploratory surveys and structured surveys are conducted and secondary data collected in order to help identify constraints and opportunities associated with the existing system, both in qualitative and quantitative terms.

(c) Establishing a multidisciplinary team

A multidisciplinary team of specialists must be assembled to support the programme. The composition of the team will depend on the potential of the area for crop production, forestry, fisheries and livestock but will always take into account the farm families for whom the project is being initiated. A farm management specialist, sociologist, economist and resource management specialist should be included on the team. It should be noted that multidisciplinary work is often problematic, especially when it involves specialists from different agencies.

(d) Evaluation of physical and biological factors

The productive potential of the project area is limited by physical and biological factors. The extent of resource degradation as well as its causes and effects should be assessed to determine the constraints and identify the improvements required. Conservation and management practices required in order to maintain and improve the productivity of land and other natural resources should be identified. Analysis should be undertaken by the team, with the participation of groups of farmers.

(e) Identification of resources and constraints

The resources of the farm family determine the combination of on-farm enterprises. A household survey should be conducted to determine available resources, income and existing farm management practices. An understanding of the goals and attitudes of farmers is important in order to prioritise development strategies.

(f) Formulation of improved systems and strategies

Information on improved farm and natural resource management practices, as well as the experiences of successful farmers and technicians working in the field, should be collated. These experiences should be compared with farmers' existing practices. Those found superior in terms of technical merit, financial and economic viability and sustainability should be used for developing improved farming systems and natural resource management plans.

(g) Implementation, monitoring and evaluation

New systems are tested on farmers' field to determine their value. Did they increase production and income? Did they arrest degradation? Are they acceptable to the farm family? In the process of testing, off-farm factors that may constrain adoption of the new systems are analysed. Means of overcoming these potential constraints are sought. The test farms must be monitored and a revised plan prepared based on the findings.

(h) Expanding the programme

Systems that prove successful may be introduced to new areas with similar conditions. The farmers' perceived value in the new systems will be affected by various socio-economic and institutional factors such as land tenure, availability of credit, the existence of co-operatives and marketing and extension support. Adjustments will be needed to ensure the system fits the new areas.

Optimising use of natural and socio-economic resources.

- Plants and animals selected should be well adapted to the physical environment of the proposed system.
- Establish balanced proportions of crop, forest, livestock, fish and sideline production, according to the natural resource base, family nutritional needs, market demand and need for cash income.

Balance Production and Conservation

- Protect marginal lands and other sites prone to damage from agriculture.
- Appropriate tillage, cultivation and conservation measures must be adopted for conservation soil and water

(3) Important Considerations

(a) Improved data collection system and analysis

The farming systems development approach requires improved methodologies for collation and analysis of information. Understanding of the interrelationships and interactions of the various system components is crucial.

(b) Better research and extension linkages

A strong link between research and extension is critical to farming system development. Farmers' needs, priorities and resources must be considered. Likewise, extension workers rely on researchers for improved technology.

(c) Orientation of agricultural extension workers

Many extension personnel are still commodity-oriented and socio-economic considerations are often neglected. Therefore, training of agricultural extension workers is needed to institutionalise the farming system development approach.

(d) Improved support services

Since farming system development evolved from farming systems research, its natural strength lies in technology generation. However, FSD's success will depend on how factors such as marketing, extension input supply, credit availability and policy support are addressed.

(e) Integrated Farming Systems

Integration of components of a farming system to form a functional whole may promote productivity and sustainability. For example, plant species of different heights grown in the same field can provide good vegetative cover to protect soil and conserve water, while making optimum use of space, labour, rainfall, sunlight and nutrient resources.

In China, livestock, fish and speciality food crops are produced together to make good use of feed crops and crop by-products (such as straw used as a medium for growing mushrooms). The livestock manure improves the soil's physical and chemical properties, which increases water infiltration and reduces erosion. The addition of a biogas digester to the system enables organic wastes to be converted to cooking fuel, reducing the demand for firewood and consequently leaving the forests better protected against water erosion.

Integrated farming systems should benefit whole community as well as individual farm families. Good systems can be sustainable suppliers while protecting and nurturing natural resources, if they are planned correctly from the start.

2.3 Questionnaire Formats

Questionnaire

No....................

Watershed Management
Kok-Ing-Nan Water Diversion Project

Case Study	□ Kok	□ Ing	□ Nan	
Ban...............	Moo...........	Tambon................	Amphoe..............	Changwat...............
(Village)	(Group)	(Sub-district)	(District)	(Province)

Interviewee
□ Chief of Community (please specify) ....
□ Community Advisor (please specify) ....
□ Others (please specify) ....

---

1. <u>Forestry Management</u>
In your village:

1.1 Electricity use □ Yes □ No
Using gas as fuel for cooking □ Yes □ No
Distance from your village to place where you can buy your cooking fuel .... km

1.2 Community forest □ Yes □ No
In case the answer is "Yes", please specify the area of community forest and distance from your village:
Area = ... rai Distance from your village = ...km

1.3 Do you think villagers are living on the community forest?
□ No
□ Yes, and they want to have the forest area expanded to ....rai

1.4 Do you believe that forest can originate water source for agriculture?
□ Yes
□ No, because..

1.5 It is described that Conservation Forest (Zone C) is watershed area and Economic Forest can be used for cultivation or as area where village is situated.
Do you think that the villagers realise the importance of the conservation forest?
□ No
□ Yes, and they want to have the forest area expanded to ....rai

2. Agricultural Management

In your village:

2.1 Is there any natural stream supplying water all year round?
- ☐ Yes
- ☐ No

2.2 Is there any weir?
- ☐ No
- ☐ Yes, please specify type of the weir ☐ temporary
  - ☐ semi-permanent
  - ☐ permanent

2.3 Do the villagers need the weir?
- ☐ No
- ☐ Yes, they need more weirs to be constructed in the future (from current .... weirs to .... weirs).

2.4 Do you believe that conservation of soil surface will benefit the farmers in term of an increase in agricultural products?
- ☐ Yes
- ☐ No, because ....

2.5 Do you think that the villagers need the conservation of soil surface ?
- ☐ No
- ☐ Yes, they need the conservation on: ☐ only very steep area
  - ☐ only not very steep area
  - ☐ all steep area
  - ☐ others..............................

2.6 If there is a village development fund, providing you a loan without profit, and aimed to help agricultural development in your village, ...

1. Will you need it for farm input of orchard cropping e.g. lychee, longan?
   ☐ Yes (about...............Baht) ☐ No

2. Will you need it for farm input of paddy rice cultivation ?
   ☐ Yes (about...............Baht) ☐ No

3. Land-use Management

3.1 Using the list below, can you weigh how important they are (by using stones to weigh importance)?

1. Weir	Number of stones....................
2. Village Development Fund	Number of stones....................
3. Orchard Cropping	Number of stones....................
4. Paddy Rice Cultivation	Number of stones....................
5. Soil Surface Conservation	Number of stones....................
6. Community Forest	Number of stones....................
7. Watershed Forest	Number of stones....................
8. Forest Fire Barrier	Number of stones....................
9. Others	Number of stones....................

(Please specify..)

3.2 If you could divide your village into 100 parts for different land-use purposes, you would like to divide the area of your village according to those stated below into ;

1. Residential area (...................parts)
2. Agricultural area (...................parts)
3. Watershed (...................parts)
4. Community forest (...................parts)
5. Public area (...................parts)
6. Others (...................parts)

(Please specify..)

4. Community Organisation Management

In your village:

4.1 How those groups as stated below are interested in the environmental conservation?

1. Youth group	☐ Very interested	☐ Not so interested	☐ Not interested
2. Chief of village and Chief of Tambon	☐ Very interested	☐ Not so interested	☐ Not interested
3. Women group	☐ Very interested	☐ Not so interested	☐ Not interested
4. Farmer group	☐ Very interested	☐ Not so interested	☐ Not interested
5. Others	☐ Very interested	☐ Not so interested	☐ Not interested

(Please specify..)

4.2 How do you want those stated below to be formed in order to encourage the villagers to realise the importance of environmental conservation?

1. Village Volunteer Group	☐ Much	☐ Not so much	☐ Not at all
2. Village Training	☐ Much	☐ Not so much	☐ Not at all
3. Tour of inspection in outstanding area	☐ Much	☐ Not so much	☐ Not at all
4. Education program on local radio broadcasting	☐ Much	☐ Not so much	☐ Not at all
5. Demonstration in the village	☐ Much	☐ Not so much	☐ Not at all
6. Others	☐ Much	☐ Not so much	☐ Not at all

(Please specify..)

5. Recommendations

1)..

2)..

Questionnaire

Field survey of soil erosion on sub-watershed Kok-Ing-Nan water diversion project

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Study Area ....
Village ....
Tambon ....
Amphoe ....
Changwat (Province) ....

---

1. **Factors related to physical properties of soil**

a. Texture
   1. Clay ☐
   2. Loam ☐
   3. Sand ☐

b. Soil depth
   1. Deep ☐
   2. Intermediate ☐
   3. Shallow ☐

c. Soil structure
   1. Massive ☐
   2. Granular ☐

d. Soil colour
   1. Black ☐
   2. Red ☐
   3. Brown ☐
   4. Grey ☐

2. **Topography**
   1. Steep slope ☐
   2. Rolling or undulating ☐
   3. Gentle slope ☐
   4. Flat ☐

3. **Cultivation Practices**
   1. Up and down cultivation ☐
   2. Contour cultivation ☐
   3. Stubble mulching ☐
   4. Crop residues left ☐
   5. Crop residues burn ☐
   6. No till cultivation ☐
   7. Crop residues removed ☐

4. Land Use

1. Crop Production

corn	☐
groundnut	☐
mungbean	☐
jute	☐
sorghum	☐
pineapple	☐
cotton	☐
paddy	☐
soy bean	☐
cas	☐
pasture	☐
rubber plantation, orchard	☐
oil palm, coffee with cover	☐
no cover	☐
coconut	☐

2. Forest

degraded forest	☐
cleared forest without cultivation	☐
dry dipterocarp	☐
mixed forest/mixed deciduous forest	☐
mountainous evergreen forest	☐
tropical humid evergreen forest	☐
pine forest	☐
burnt forest	☐

3. Mining

industrial rock mining	☐
mining	☐

5. Characteristic of cover crops or trees

crown	( )..
	( )..
canopy shape	( )..
	( )..
width of canopy	( )..
	( )..
leaf shape	( )..
	( )..
leaf size	( )..
	( )..
crown arrangement	( )..
	( )..

6. **Characteristics of surface**

- ☐ Rock outcrop
- ☐ Gully
- ☐ Exposed root of big tree
- ☐ Shallow water way (creeks)

7. **Other factors affecting soil erosion**

- ☐ Grazing livestock on mountain/hill
- ☐ High rate of runoff
- ☐ Road construction
- ☐ Construction of building

2.4 Introduction to GIS and Remote Sensing Techniques

Geographical Information Systems (GIS) may be defined as computerised database management systems specially designed for spatial data capture, storage, retrieval, analysis and output. GIS is a powerful tool for addressing a broad spectrum of spatial analyses in many fields. Satellite remote sensing is a tool that provides data rich in spatial information and may provide cost-effective accurate land cover information. Remotely sensed data is an ideal data source for use when the environmental conditions over a wide area are to be spatially analysed with GIS. The two technologies are becoming integrated and are able to support decision-makers and planners by providing analysis of data by means of various geographical manipulation and spatial analytical functions.

In this project, GIS techniques were applied in order to evaluate the extent and magnitude of land degradation in the Kok-Ing-Nan Basins by estimating soil erosion using vegetation cover data derived from remote sensing analyses, existing data for soil and other characteristics. Flooding, a major concern in lowland areas, was first accurately mapped by using satellite radar imageries taken in the rainy season and then analysed using GIS to evaluate its spatial relationship with land use distribution. Soil erosion and flooding are considered as major problems resulting from unsustainable watershed management. In addition, the land use area along the diversion route (alignment) was also calculated according to the engineering requirements.

2.5 Satellite Remote Sensing Data Analysis

Satellite Remote sensing data was analysed and used to prepare a database of information, including existing land use and inundation areas. The analytical work may be sub-divided as follows:

1) Purchase of Landsat TM and JERS-1 SAR data.
2) Preliminary image processing of Landsat TM data.
3) Supervised classification of Landsat TM data for land use survey.
4) Preliminary image processing of JERS-1 SAR and combination with Landsat TM.
5) Creation of Landsat TM and JERS-1 SAR fusion images.
6) Field verification.
7) Setting of Land Use classification legend.
8) Land use Interpretation from Landsat TM.
9) Inundation area mapping from JERS-1 SAR fused with TM.

(1) Purchase of Landsat TM and JERS-1 SAR Data

Two full cloud free scenes of Landsat TM data (Path/Row 130/046 and 130/047) dated 25th January 1997 were purchased in digital form from the National Research Council of Thailand (NRCT). Similarly, four scenes (Path/Row 129/267, 129/268, 130/267, 130/268) of JERS-1 SAR data covering the necessary area were purchased from the Remote Sensing Technology Centre of Japan (RESTEC). Since JERS-1 SAR is a radar derived image which is able to penetrate cloud cover, and is able to show land cover conditions, such as inundated areas, even in the rainy season. The SAR images purchased were taken on September 25, 1995 during which time the area was suffering from heavy flooding.

(2) Preliminary Image Processing of Landsat TM Data

After receiving the Landsat TM data, each scene was geo-rectified separately selecting the Ground Control Point (GCP) from topographic map of scale 1:50,000. The scenes were then subsequently combined to create a single seamless image covering the whole study area.

(3) Supervised Classification of Landsat TM Data for Land Use

Digital image classification of the pre-processed Landsat TM data was undertaken in order to assess land use. Various methods of supervised classification including *Maximum Likelihood*, and *Minimum Distance*, were assesses, with *Maximum Likelihood* proving to be the most successful. As a result, the *Maximum Likelihood* method was utilised and prints were created for use as reference material during field survey undertaken in February 1998.

(4) Preliminary Image Processing of JERS-1 SAR and Fusion with Landsat TM

As with the Landsat TM, all the four scenes of JERS-1 SAR were first geo-rectified separately using the rectified Landsat TM data and then were combined in order to create a single seamless image. The purpose of applying JERS-1 SAR data was to map areas that were inundated in the rainy season. In order to make the images easier to interpret they were combined with Landsat TM using data fusion techniques.

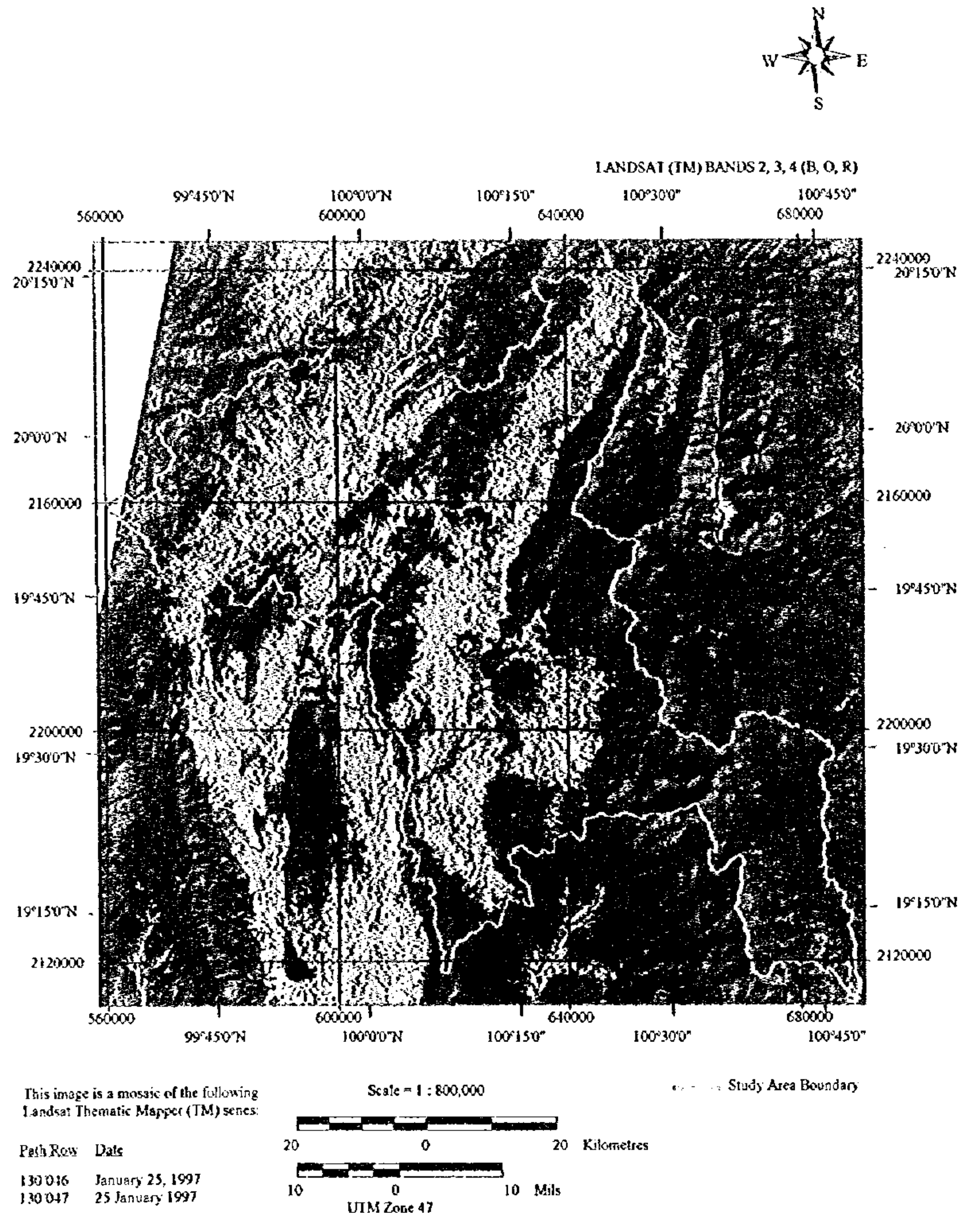
(5) Creation of Landsat TM and JERS-1 SAR Fusion Image

Applying the necessary enhancements to the pre-processed Landsat TM data, a standard false colour print of scale 1:75,000 was created by assigning bands as 2, 3, 4 (B, G, R). These imageries were used in visual interpretation to yield land use classification. The colour composite image of whole study area (scale 1:800,000) is shown in Figure 2.1. From the fused data of JERS-1 SAR and Landsat TM, various band combinations were examined in search of a superior interpretative colour composite that might be used to detect inundated areas. From those assessed, the combination of Landsat TM band 1, Landsat TM band 5, JERS-1 SAR as B, G, R was selected as the optimum and the study area using this combination is shown in Figure 2.2.

(6) Field verification

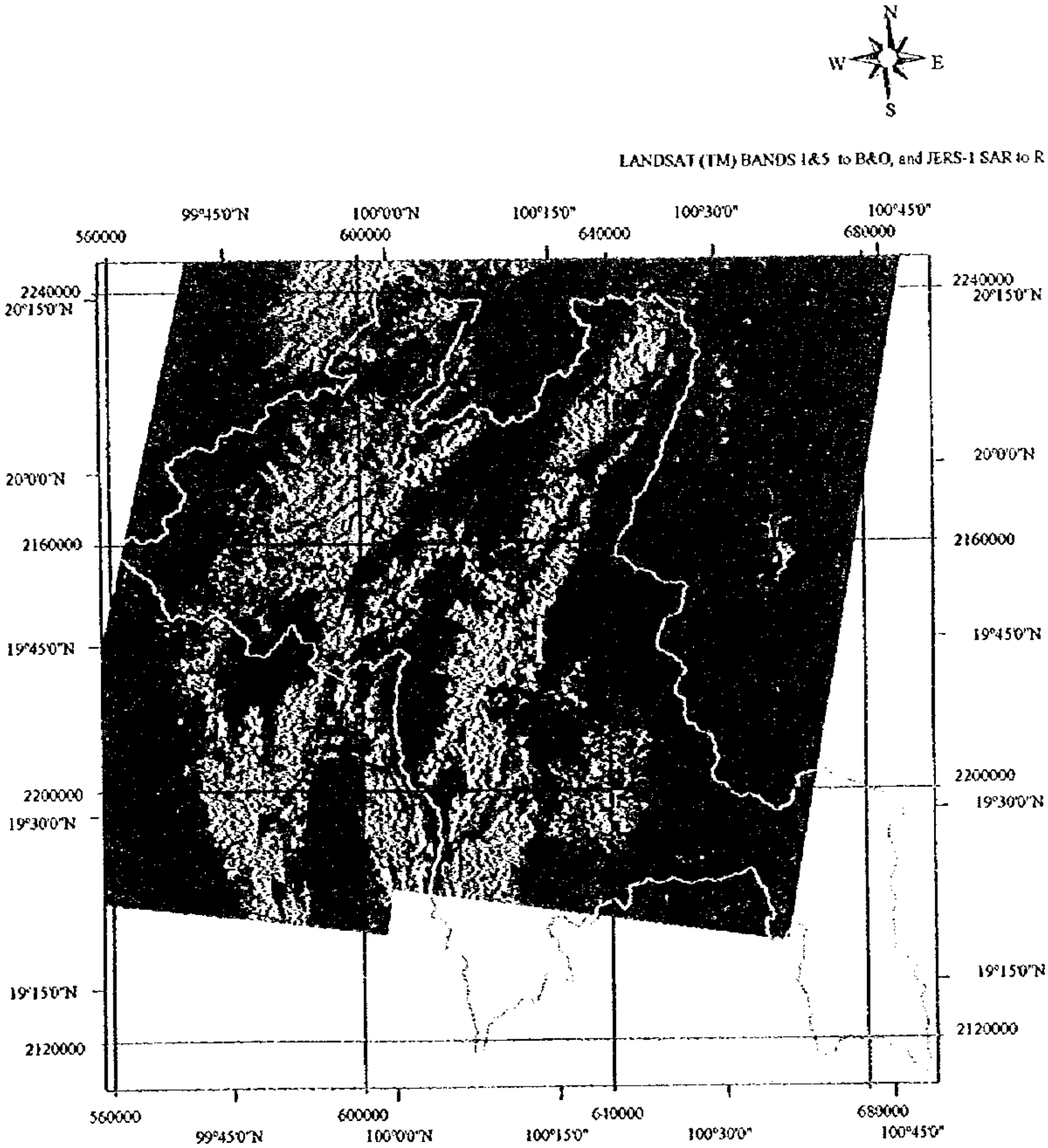
Field verification exercises were carried out for a duration of one month commencing in the last week of January 1998. The field verification survey was carried out during similar seasonal conditions as to those that were prevalent when the Landsat TM data was acquired. This survey fulfilled the following objectives:

- To establish the interpretation keys, necessary to decide different classes to be included land use classification through visual interpretation of TM prints.
- To become familiar with the land use pattern along the tunnel/canal alignment and in other locations.
- To become more familiar with the relationship between land use and topography, slope etc.,
- To verify the result of supervised classification for land use.
- To become more familiar with the inundated area.



JICA Japan International Cooperation Agency

ENVIRONMENTAL STUDY THE KOK-ING-NAN WATER DIVERSION PROJECT	**Figure 2.1** **Landsat (TM) Colour Composite Image**
JAPAN INTERNATIONAL COOPERATION AGENCY	



This image is a mosaic of the following

Satellite Data	Path/Row	Date
Landsat (TM)	130/046; 130/047	January 25, 1997
JERS-1 SAR	129/267; 129/268	September 28, 1995
	130/267; 130/268	September 29, 1995

Scale = 1 : 800,000

20 0 20 Kilometres

10 0 10 Mils

UTM Zone 47

Study Area Boundary

Japan International Cooperation Agency

ENVIRONMENTAL STUDY THE KOK-ING-NAN WATER DIVERSION PROJECT	**Figure 2.2** **JERS-1 SAR and Landsat (TM) Fusion Image**
JAPAN INTERNATIONAL COOPERATION AGENCY	

(7) Setting of Land Use Classification Legend

Based on the field observations of the land use patterns, 17 classes were set for the land use classification legend. The conceptual criteria of these classes are given as follows:

- Urban/Built-up Areas: These refer to the areas with settlements.

✧ City/Town (Uc): This comprises the densely inhabited permanent settlement areas. In general, these areas have too little space for any agricultural activity, or if present it is only on a nominal scale.

✧ Infrastructure(Ui): This includes specific types of infrastructure like airfield.

- Agricultural Land: These refer to lands used for agricultural purposes.

✧ Paddy field (Ar): This refers to land permanently used for rice cultivation. Most paddy fields occur in flat low-lying areas, such as on the plain or in the delta of basin. However, some of them can also be found in valley bottoms where rice is cultivated in small plots. In some fields, where irrigation infrastructure exists, pea crops are cultivated during the winter season.

✧ Field crops (Au): This refers to agricultural land typically occurring above the seasonally inundated (during monsoon) area, from plain to high terrace. Crops in this category may include corn, tobacco, etc.

✧ Orchard/Village garden crops (Aov): This includes areas used for fruit tree cultivation either formal orchards or village fruit and garden crops. Orchards are often located on lower hills, and on the plains. Village garden crops occur in proximity of village.

✧ Swidden agriculture (Slash and burn) (As): This refers to areas where the forest or other vegetation cover has been cut and burnt for temporal agricultural cultivation. In general, this zone occurs in between agricultural and forest/shrub lands, with a greater likelihood of occurrence in regions where high upland terraces give way to hills and mountains. Cultivation activity is easily recognisable because these lands are typically used for a few years and then the plot will remain fallow, allowing for growth of secondary vegetation, until the next rotation begins. Crops in such area may include hill rice, corn and cassava.

- Grass/Shrub lands: These include areas covered by either grass or shrub or both.

✧ Dry grass and shrub land (Gsd): This refers to infertile or degraded land on which no trees are able to grow due to mainly to dry conditions. Shrubs may also be found in the zone between permanent agriculture and forest, as the secondary vegetation regenerating after swidden cultivation.

✧ Wet grass and shrub land (Gsw): This refers to the areas covered with grass and/or shrubs that remain flooded during the significant part of the year. There are generally low-lying areas. The plant species, known locally as Maiyalab is common in such shrubby areas.

- Forest Cover: This includes areas with significant tree cover.

✧ Evergreen broad leaf forest (Fe): This refers to the multi-storey forest dominated by evergreen species. This category of forest is found in areas usually not subjected to inundation, such as upland regions. However, broad leaf evergreen habitat may also occur in plains where flooding is minimal. In the study area, this type of forest is found in large blocks.

- ✧ Forest (Fd): This includes deciduous tree species that are fire resistant and have thick bark.
- ✧ Bamboo forest (Fb): Bamboo forest occurs in areas where primary forest has been cut in the past and subsequently abandoned. Generally, pure stands of bamboo occupying the large parts of the hill.
- ✧ Mixed forest (Fx): This refers to the forest with mixed, evergreen and/or bamboo species.
- ✧ Degraded forest (Fdr): This forest results from primary forest that has been degraded due to logging, shifting cultivation, or forest fire. It often occurs in the zone between agricultural land and closed forest, and near to settlement areas.
- ✧ Forest Plantation (Fp): This refers to man-made forests. Such forests are mostly established with fast growing or valuable exotic species. These are often established in easy accessible areas, such as along roads, tracks or near built up areas.

- Water features: These include different water bodies in various forms:

- ✧ River (Wri): This refers to the natural flowing or lotic water systems.
- ✧ Lake/Reservoir (Wl): Lake refers to enclosed natural water bodies or lentic systems. Reservoir refers to man-made water bodies that are used as water resources for domestic supply or irrigation.

- Others:

- ✧ Barren (Qb): This includes non-productive lands, which may be as result of chemical, physical or man-induced stresses.

(8) Land Use Interpretation from Landsat TM

A visual interpretation of Landsat TM prints (scale 1:75,000) was undertaken to delineate the different boundaries of the different land use classes.

(9) Inundated Area Mapping from JERS-1 SAR Fused with TM

Based on the field assessment and recognition of the spectral signature pattern, inundated areas were mapped by employing supervised classification of JERS-1 SAR plus TM fused digital data.

(10) GIS Database Establishment

Spatial data were compiled into a database for the purpose of undertaking the GIS applications in conjunction with the watershed environmental analysis. The following spatial data were databased prior to the application development.

- ✧ Topography (elevation) - from topographical maps at a scale of 1:50,000.
- ✧ Watershed boundaries - prepared by the study team based on topographical map data.
- ✧ River drainage networks - existing digital data (Thailand on Disk).
- ✧ Administrative boundaries - existing digital data (Thailand on Disk).

- ✧ Population statistics - existing digital data (Thailand on Disk).
- ✧ Road networks - existing digital data (Thailand on Disk).
- ✧ Current land use - from remote sensing analysis.
- ✧ Inundated areas - from remote sensing analysis.
- ✧ Soils - from soil maps at a scale of 1:100,000.
- ✧ Rainfall - existing meteorological data.

All these data were principally processed by ARC/INFO, while the remote sensing image data were processed by ERDAS IMAGINE.

(11) GIS Application Development

Environmental problems are very complex in nature, and are dependent on a wide variety of factors and characteristics. GIS is a powerful tool that facilitates not only the efficient handling of enormous quantities of data, but is also able to simulate future developments and future values for the criteria by which scenario's are judged. The final outputs of GIS may be used to help formulate various management strategies according to the user's defined scenario. This process is generally known as GIS application development. The following sections describe three (3) tasks that have been carried out relating to the project using GIS applications

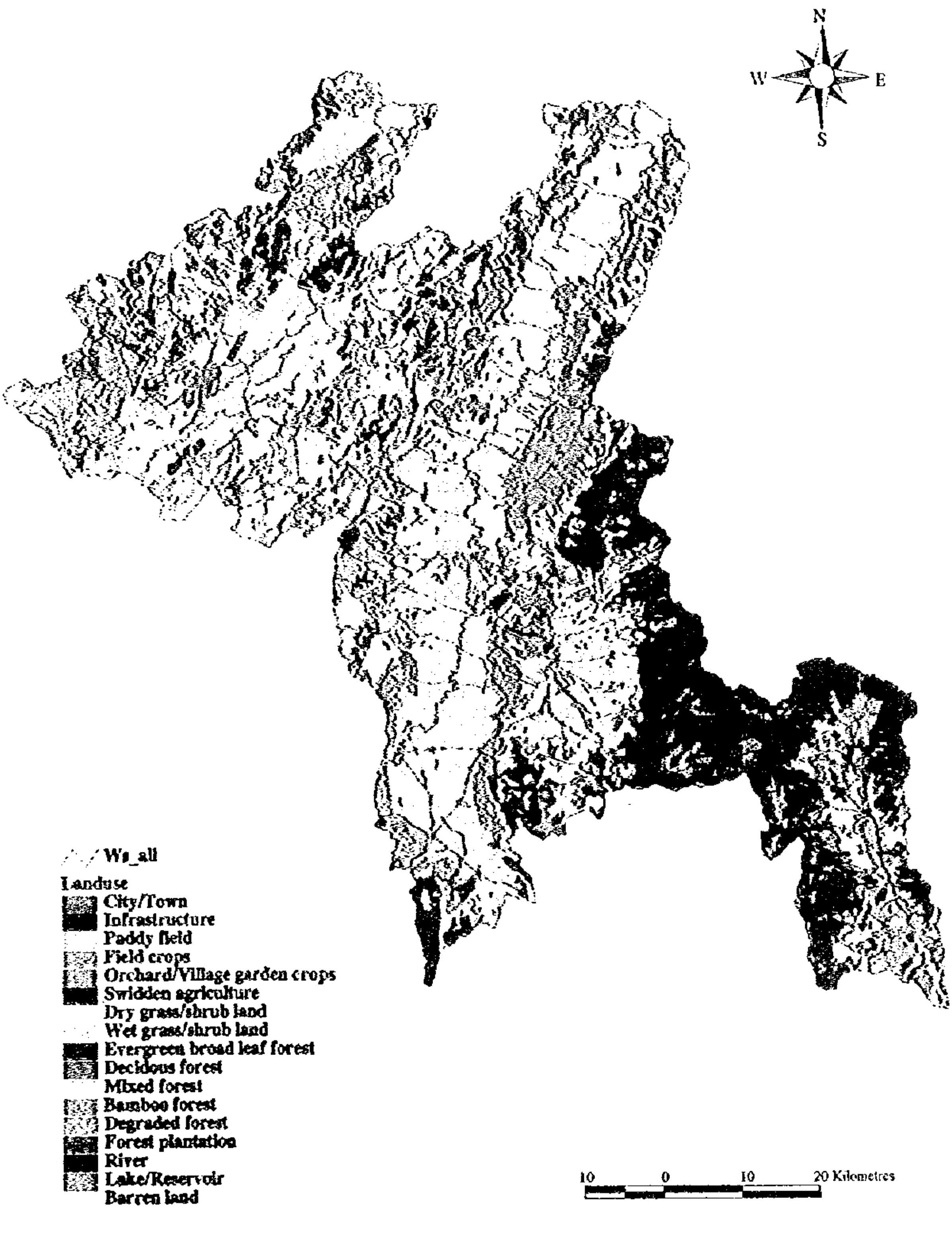
(12) Land use area calculation

Using GIS, land areas may be calculated in various ways depending upon the user requirements. In this project, the analysis of land use area was performed as follows:

- Land use area in each basin; and
- Land use area along the planned alignment route.

(13) Land use area in each basin

The areas of different land use, obtained from the remote sensing analysis, were overlain with the river basin boundary data in order to compare the land use types in different basins. The comparison was made merging eighteen land use types into six major groups. The results indicate that the land use pattern in Kok and Ing basins are very similar while that in the Nan (Yao) basin is considerably different as shown in Figure 2.3 and summarised in Table 2.1. Compared to 32.4 and 48.7 % of forest cover in Kok and Ing basins, respectively, Yao basin has forest cover of up to 75%. In the Yao basin less area (13.7%) is used for agricultural land use compared to 57.7 and 48.9% in Kok and Ing basin, respectively. Also, it should be noted that the Yao basin has a much less diverse land use than is present in the Kok and Ing basins.



ENVIRONMENTAL STUDY THE KOK-ING-NAN WATER DIVERSION PROJECT	Figure 2.3 Land Use Map
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 2.1. Comparison of Land Use in the Different Basins

Land Use	Kok basin		Ing basin		Yao basin		Total LU area (ha)	
Type	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Uc	934	0.5	197	0.1	0	0.0	1,131	0.2
Ui	584	0.3	31	0.0	0	0.0	615	0.1
Ar	72,379	39.5	156,614	39.4	905	1.2	229,898	34.9
Au	4,533	2.5	9,367	2.4	1,996	2.5	15,896	2.4
Aov	6,594	3.6	9,584	2.4	247	0.2	16,325	2.5
As	22,114	12.1	18,500	4.7	7,658	9.8	48,272	7.3
Gsd	1,126	0.6	835	0.2	8,819	11.2	10,780	1.6
Gsw	12,702	6.9	4,348	1.1	0	0.0	17,050	2.6
Fe	3,001	1.6	61,742	15.5	35,054	44.6	99,797	15.0
Fd	1,123	0.6	31,741	8.0	22	0.0	32,886	5.0
Fx	14,592	8.0	47,577	12.0	4,594	5.9	66,763	10.1
Fb	22,331	12.2	6,505	1.6	8,540	10.9	37,376	5.7
Fdr	18,489	10.0	46,289	11.6	10,703	13.6	75,481	11.5
Fp	14	0.0	7	0.0	0	0.0	21	0.0
Wri	1,542	0.8	2,290	0.6	0	0.0	3,832	0.6
Wl	1,397	0.8	1,754	0.4	0	0.0	3,151	0.5
Ob	25	0.0	9	0.0	107	0.1	141	0.0
Total (ha)	183,480	100.0	397,390	100.0	78,545	100.0	659,415	100.0
Comparison by Grouping Land Use Types								
Urban	1,518	0.8	228	0.1	0	0.0	1,746	0.3
Agriculture	105,620	57.7	194,065	48.9	10,706	13.7	310,391	47.1
Grass/ Shrub	13,828	7.5	5,183	1.3	8,819	11.2	27,830	4.2
Forest	59,550	32.4	193,861	48.7	58,913	75.0	312,324	47.3
Water body	2,939	1.6	4,044	1.0	0	0.0	6,983	1.1
Barren Land	25	0.0	9	0.0	107	0.1	141	0.0

Note: Land Use Type:
Uc- City/Town; Ui- Infrastructure; Ar- Paddy field; Au- Field crops; Aov- Orchard/Village garden crops; As- Swidden agriculture; Gsd- Dry grass/shrub land; Gsw- Wet grass/shrub land; Fe- Evergreen broad leafed forest; Fd- Deciduous forest; Fx- Mixed forest; Fb- Bamboo forest; Fdr- Degraded forest; Fp- Forest plantation; Wri- River; Wl- Lake/Reservoir; Ob- Barren land

(14) Land Use Area Along the Planned Alignment Route

In order to analyse the existing land use types on both sides of the planned alignment route, three levels of buffers were created, i.e. one, two and three kilometres. The results are presented in Table 2.2, and show that along the tunnel route and its adits, the majority of the area is under forest cover. Conversely, in the case of the route of the sections of culvert and open canal the land use is predominantly agricultural in nature. The alignment along the river is mostly all paddy field and wet grassland on both sides.

Table 2.2. Area Calculation of Land Use along the Alignment at Various Buffers

Route Type	Land Use Type	1 km. Buffer	2 km. Buffer	3 km. Buffer	Route Type	Land Use Type	1 km. Buffer	2 km. Buffer	3 km. Buffer
Tunnel	Ar	389	877	1,917	Open cannel	Uc	0	14	196
	Au	544	1,119	1,508		Ui	16	98	193
	Aov	15	56	103		Ar	5,859	11,174	16,458
	As	699	1,550	2,326		Au	198	465	675
	Gsd	25	56	258		Aov	563	1,251	1,725
	Gsw	1	17	70		As	32	49	84
	Fe	7,237	14,457	21,790		Gsd	0	21	72
	Fd	53	175	456		Gsw	391	763	1,082
	Fx	978	1,857	2,869		Fd	99	214	290
	Fb	392	921	1,557		Fx	41	253	517
	Fdr	1,809	3,499	4,321		Fb	0	19	101
	Wri	0	0	2		Fdr	13	181	634
	Wl	28	55	67		Wri	60	132	192
	Ob	0	0	21		Wl	8	84	130
	Total	*12,170*	*24,640*	*37,264*		*Total*	*7,279*	*14,717*	*22,351*
Culvert	Uc	0	17	32	River path	Ar	912	1,924	2,799
	Ar	2,150	4,036	5,570		Au	0	0	2
	Au	356	670	808		Aov	0	0	15
	Aov	284	456	605		Gsw	456	580	645
	As	313	535	713		Fd	0	0	12
	Gsd	44	96	96		Fdr	35	232	558
	Gsw	33	43	84		Wri	21	49	75
	Fd	333	567	872		*Total*	*1,424*	*2,786*	*4,106*
	Fx	93	518	996	Tunnel adits	Ar	234	667	1,576
	Fb	0	21	220		Au	223	432	608
	Fdr	225	508	959		Aov	0	88	221
	Wri	98	152	192		As	329	821	1,514
	Wl	5	100	209		Gsd	0	0	33
	Total	*3,933*	*7,716*	*11,355*		fe	3,626	9,284	15,983
						Fd	45	334	565
						Fx	287	1,220	2,380
						Fdr	184	716	1,856
						Wl	10	38	55
						Total	*4,938*	*13,601*	*24,790*
						Grand Total	29,745	63,459	99,866

Note: The full names of land use types are as shown in Table 2.1

2.6 Land Degradation Analysis

Undulating topography, steep slopes and high rainfall have resulted in Northern Thailand being vulnerable to soil erosion which ultimately leads to land degradation. The existing land cover/land use plays an important role in determining the extent and intensity of such land degradation. Previous studies have recognised that significant deforestation, an important factor for enhancing soil erosion has been progressing significantly, especially in Nan (Yao) river basin.

The evaluation and comparison of the main basins and sub-basins, in terms of land degradation, by estimating soil erosion volume was identified as a primary task of the GIS analysis. For this, the USLE (Universal Soil Loss Equation) was applied. This is the most popular and widely used method of estimating soil erosion, since its original development by Wischmeier and Smith in 1965[1]. Since the original development, several people have contributed to the development of USLE equation and modifications still continue as the knowledge of soil erosion phenomena increases.

USLE is a parametric model that computes soil loss per unit area as the product of six major factors affecting sheet and rill erosion caused by water and is calculated by the following equation:

E = RKLSCP

where:

- E = Mean annual soil loss, expressed in units selected for K and for periods selected for R;
- R = Rainfall erosivity index given by number of erosion index units (EI);
- K = Soil erodibility factor;
- L = Slope length factor;
- S = Slope steepness factor;
- C = Crop management and vegetation cover factor; and
- P = Erosion control practice or soil conservation factor.

At a particular location, values of these factors may be expressed numerically enabling the model to be easily adapted for GIS analysis. In addition, USLE is a parametric model involving two steps; the first, to allocate ratings to all factors followed by combination of the factors into an empirically derived equation that yields the amount of soil loss.

(1) The Rainfall Erosivity Index (R)

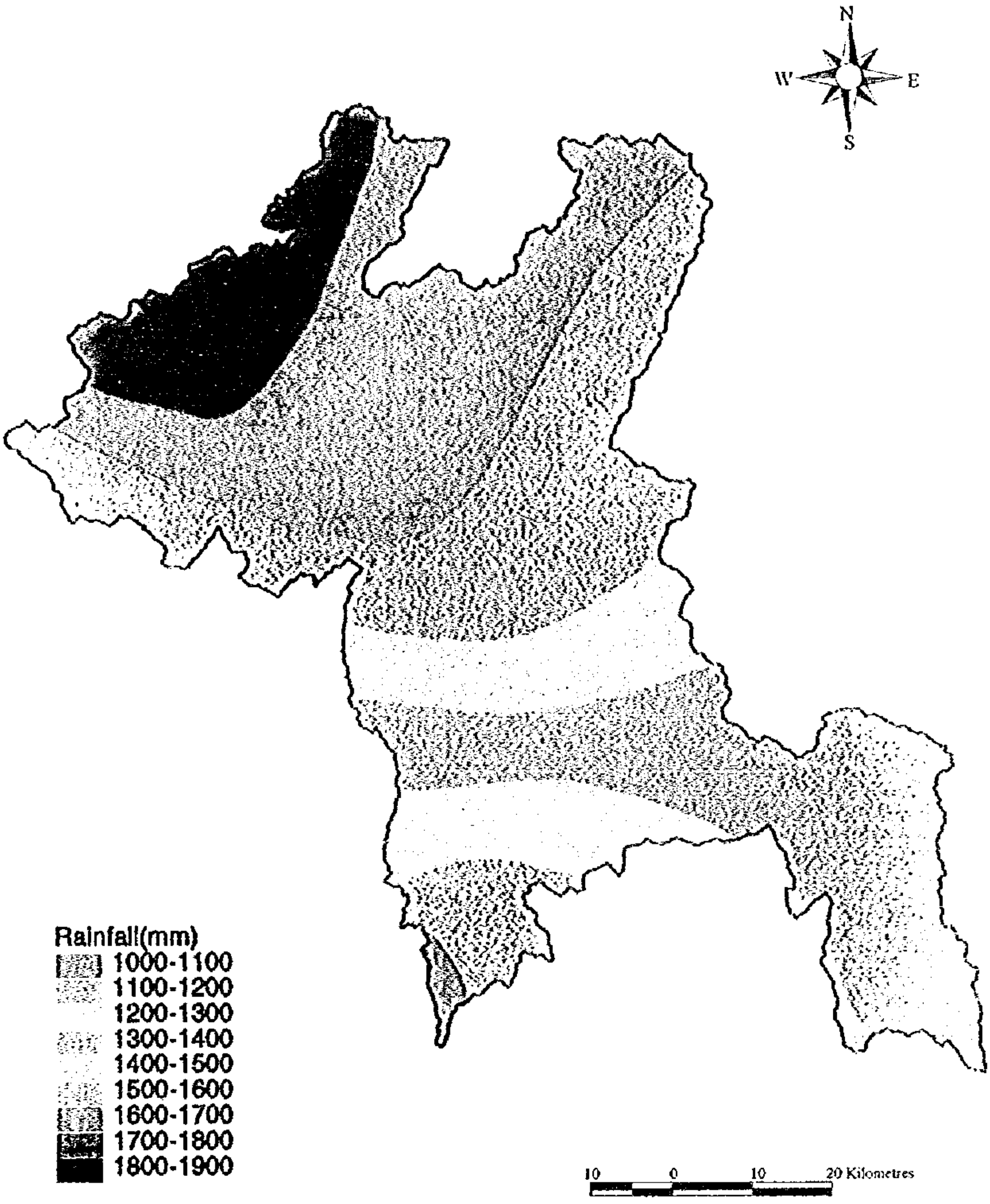
Rainfall erosivity is an expression of the ability of erosive agents to cause soil detachment and its transport. This is the principal factor of USLE and is solely responsible for derivation of the amount of soil loss. In this study, the available Isohyetal map (based on 30 years record) was used as rainfall data. Considering that the data present on this map was in terms of millimetres per year, the equation used to calculate R is as follows:

R = 38.5 + 0.35 r

Where r = total rainfall amount per year in mm.

Altogether, nine rainfall regimes were found in the study area ranging from 1,000 – 1,100 to 1,800 - 1,900 mm per year with the respective range of R as 406 to 686 (see Table 2.3). As it is clear from Figure 2.4, the northern part of the study area has a higher rainfall regime than the southern part. The computed R factor for each rainfall regime was encoded into the respective spatial data in the GIS (ARC/INFO).

[1] Predicting Rainfall Erosion Losses from Cropland East of the Rocky Mountains – a Guide for Selection of Practices for Soil and Water Conservation. (1965) W H Wischmeier and D D Smith, US Department of Agriculture Handbook No. 282.



Source: Isohyetal Map, Royal Thai Survey Div, 1969

ENVIRONMENTAL STUDY THE KOK-ING-NAN WATER DIVERSION PROJECT	**Figure 2.4**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Annual Rainfall Map**

Table 2.3 Rainfall Regime with Computed R factor

Rainfall amount (mm)	Average	Computed R
1,000 – 1,100	1,050	406
1,100 – 1,200	1,150	441
1,200 – 1,300	1,250	476
1,300 – 1,400	1,350	511
1,400 – 1,500	1,450	546
1,500 – 1,600	1,550	581
1,600 – 1,700	1,650	616
1,700 – 1,800	1,750	651
1,800 – 1,900	1,850	686

(2) The Soil Erodibility Factor(K)

This is the integrated effect of processes that regulates rainfall acceptance and the resistance of soil to particle detachment and subsequent transport. These processes are influenced by soil properties, such as particle size distribution, structural stability, organic matter content and nature of clay minerals, of which soil texture is an important factor.

Thus the K factor may be estimated from soil texture, organic matter percentage, permeability class and structure class. When the equation given in Wischmeir and Smith (1978) is converted to SI units ($t.h.MJ^{-1}.mm^{-1}$), it reads,

$$K = 1.317*10^{-3}*(2.1*10^{-4}*M^{1.14}*(12-a) + 3.25*(b-2) + 2.5*(c-3))$$

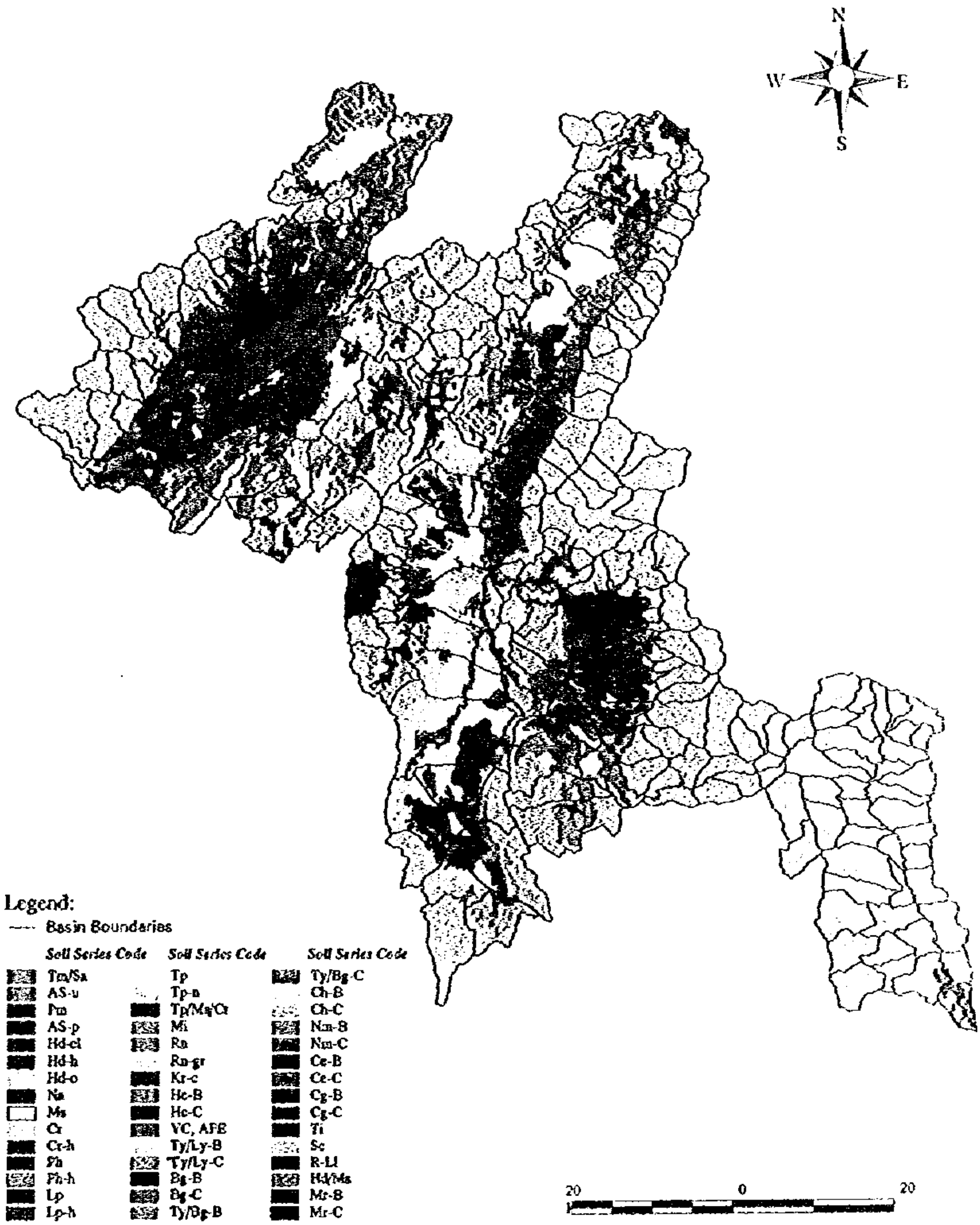
where,
M= (% fine sand + % silt) * (100 - % clay)
a = % Organic matter
b = Soil structure class
c = Soil permeability class

The data required for soil structure and soil permeability classes were taken from the legend of a detailed soil map published by the Soil Survey Division of Thailand. Also, the percent organic matter of respective soil series was calculated from the percent organic carbon (as mentioned in that legend) using a conversion factor 1.724 (i.e., 57% of organic carbon present is in the form of organic matter). Taking the soil series from the map, data for sand, silt and clay were taken from the reference 'Soil Information System' published by the Soil Survey Division of Thailand. Values for the alluvial complexes were derived from other soil series of representative soil properties. The soil map produced for the studt area is shown in Figure 2.5. The computed K factor (in SI Units) for each soil series was encoded into the GIS coverage. The K factor for various soil series ranged from 0.0130 to 0.0772 with mean value as 0.0500.

(3) Topographic (LS) Factor

When the slope length factor 'L' and slope steepness factor 'S' are combined they are known as the topographic factor, commonly expressed as the LS factor. To predict erosion at a point in the landscape the LS-factor may be written as:

$$LS = (n + 1) * (As/22.13)^{n} * (\sin\beta/0.0896)^{m}$$



Source: *Soil Map, 1:100000 (1972-73), Soil Survey Division, DLD, THAILAND*

ENVIRONMENTAL STUDY THE KOK-ING-NAN WATER DIVERSION PROJECT	**Figure 2.5** **Soil Map**
JAPAN INTERNATIONAL COOPERATION AGENCY	

Where,
$n = 0.4$
$m = 1.4$
As = The specific catchment area
β = The slope angle

This equation was derived from unit power theory by Moore and Burch (1986)[2] and is more applicable to landscapes with complex topography than the original empirical equation given by Wischmeier and Smith, because it explicitly accounts for flow convergence and divergence through the As term in the equation.

The elevation of the study area ranges from 200m to slightly more than 1600m. However, significant areas have an elevation of less than 1000m (see Figure 2.6). In this study, digitised contour data was used to create a Digital Elevation Model (DEM) (see Figure 2.7) of pixel size 30m (30m in the grid module of ARC/INFO). The DEM was then used to calculate slope angle that was used in the above equation to yield LS value. In the study area, the LS factor ranged from zero to 9.14 with mean value 0.82.

(4) Crop Cover Factor (C) and Conservation Practice Factor (P)

The C factor is the ratio between the amount of soil loss from land cropped under specified conditions as compared to that from clean-tilled, continuous fallow. P factor is the ratio of soil loss with the specific conservation practice to the corresponding loss with upslope and downslope cultivation. These two factors are important in determining soil erosion because of the fact that different land cover types have different resistance to the impacts of runoff and resultant soil loss amount. Furthermore, cropping system, cropping pattern, productivity level, length of growing season, tillage practices, residue management and expected time of the distribution of erosion events may also result to varying degrees in runoff resistance and protection from detachment of soil.

For this analysis, the present land use derived during this study was used as the unit of C factor analysis. The C value for all land use types was adopted as referenced in the report published by the Soil and Water Division of DLD, Thailand, except Swidden agriculture (As), Village garden crops (Av) and Barren land (Ob) that were not included. The C value for these three classes was assigned as for the nearest classes among the land use types. C value of all agricultural classes was higher than those of forest classes (see Table 2.4). In the study area, no intensive conservation practices could be found on small scale. Hence, P factor was not considered in this analysis.

(5) Overlay Result

The second step of the USLE analysis, i.e. combining the factors into the empirically derived equation was done under the grid module of ARC/INFO.A grid size of 30m was used for this analysis. The results of the analysis have shown that the rate of potential soil erosion ranged from as low as zero for water bodies to 76.90 t/ha/yr. To infer more from the result, the erosion rate was regrouped into six hazard severity classes. As presented in Table 2.5, the majority of the study area (79.00%) has the least severe class of erosion hazard with less than 1.0 ton/ha soil loss annually. Such areas are prevalent in the flood plain areas of the Kok and Ing rivers (see Figure 2.8). Altogether 5.47% of total study area has soil erosion rates in excess of 5.0 ton/ha/yr of potential soil erosion rate.

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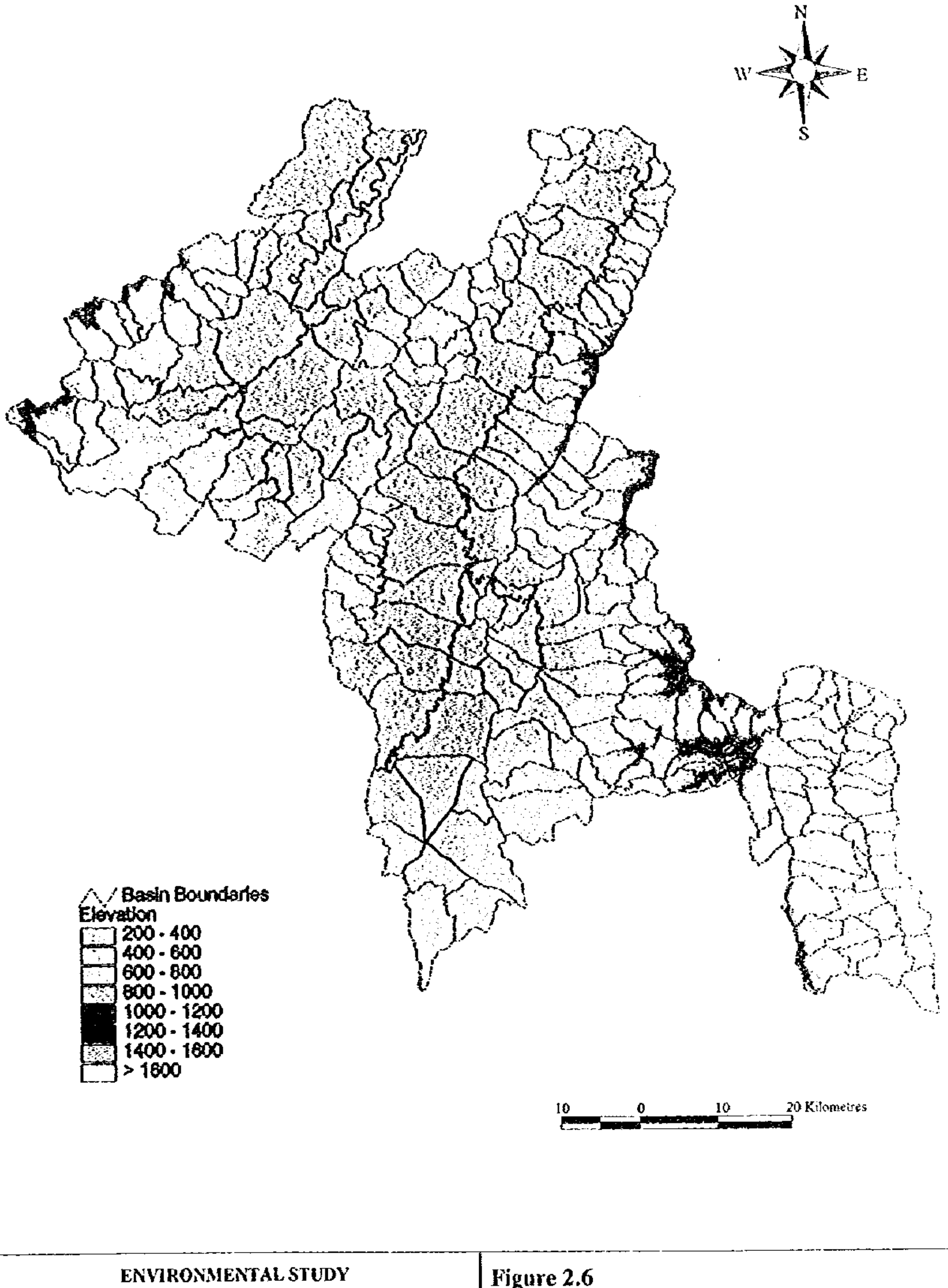
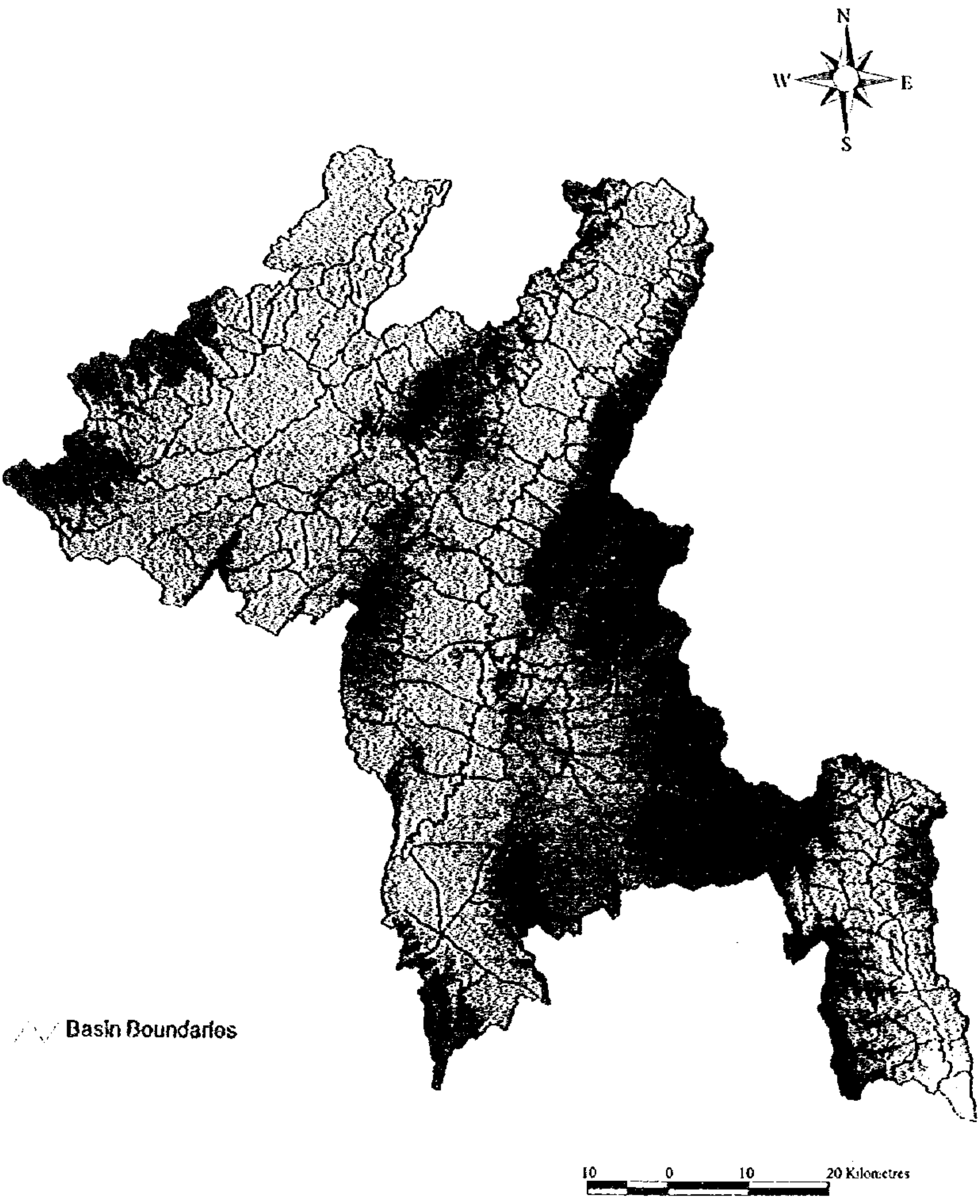
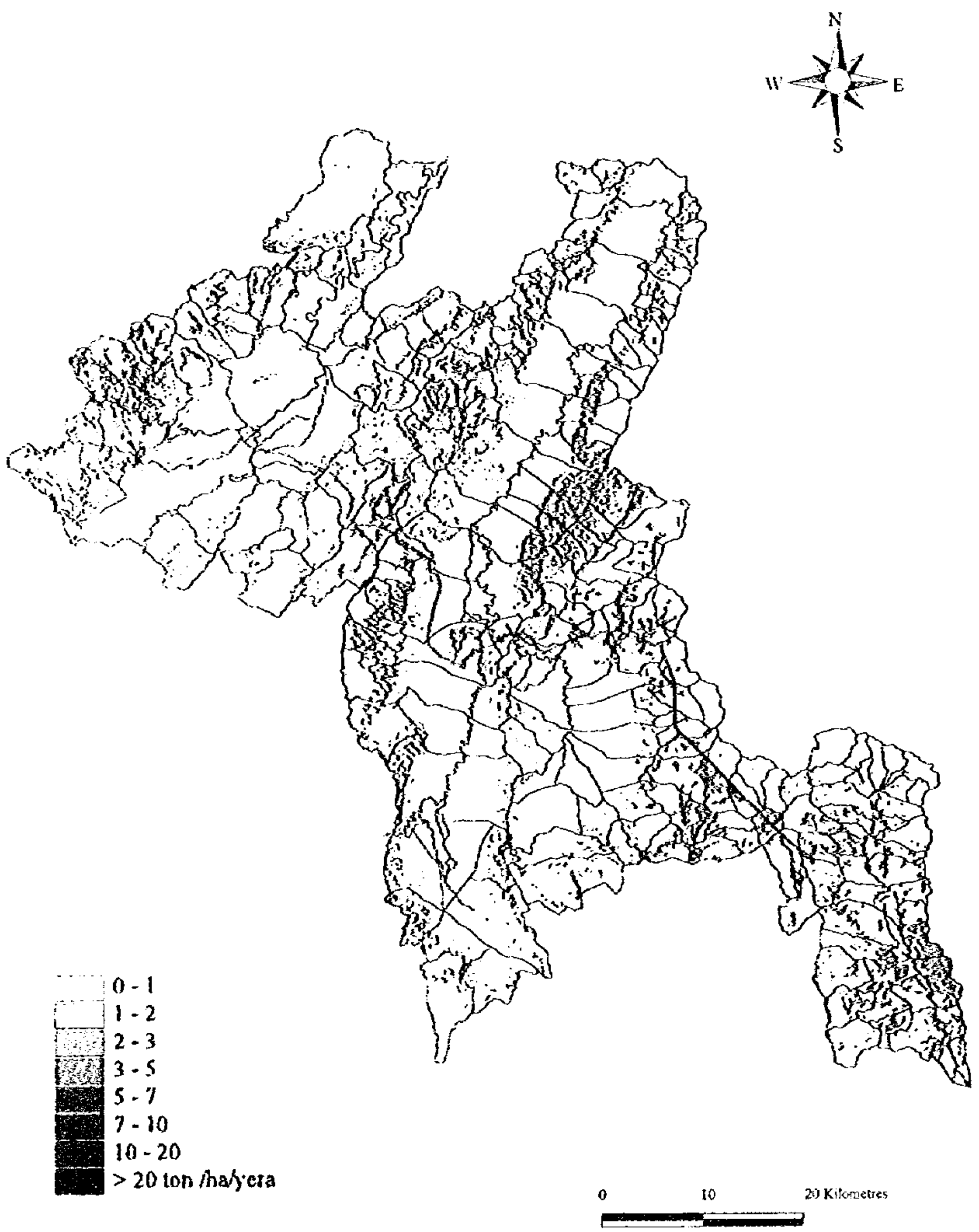
[2] The Physical Basis of the Length-Slope Factor in the Universal Soil Loss Equation, I D Moore and G J Burch, (1986) Journal of the Soil Science Society of America.



ENVIRONMENTAL STUDY THE KOK-ING-NAN WATER DIVERSION PROJECT	Figure 2.6 Elevation Map
JAPAN INTERNATIONAL COOPERATION AGENCY	



ENVIRONMENTAL STUDY THE KOK-ING-NAN WATER DIVERSION PROJECT	Figure 2.7 Digital Elevation Model (DEM) Map
JAPAN INTERNATIONAL COOPERATION AGENCY	



ENVIRONMENTAL STUDY THE KOK-ING-NAN WATER DIVERSION PROJECT	**Figure 2.8** **Potential Soil Erosion Map by USLE Analysis**
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 2.4 Land Use Types with Respective C-factor Value

S. N.	LU code	Land Use Type	C factor
1	Uc	City/Town	0.010
2	Ui	Infrastructure	0.020
3	Ar	Paddy field	0.240
4	Au	Field crops	0.240
5	Ao	Orchard	0.300
6	Av	Village garden crops	0.160
7	As	Swidden agriculture	0.240
8	Gsd	Dry grass/shrub land	0.020
9	Gsw	Wet grass/shrub land	0.020
10	Fe	Evergreen broad leafed forest	0.001
11	Fd	Deciduous forest	0.048
12	Fx	Mixed forest	0.008
13	Fb	Bamboo forest	0.017
14	Fdr	Degraded forest	0.064
15	Fp	Forest plantation	0.088
16	Wri	River	0.000
17	Wl	Lake/Reservoir	0.000
18	Ob	Barren land	1.000

Table 2.5 Potential Soil Erosion Classes and Rating

Class No.	Rating (ton/ha/yr)	Area (ha)	Hazard Severity	% of Total
1	< 1.0	520,920	least severe	79.00
2	1.0 - 2.0	52,074	less severe	7.90
3	2.0 - 3.0	24,669	moderate severe	3.74
4	3.0 - 5.0	25,627	more severe	3.89
5	5.0 - 7.0	12,493	most severe	1.89
6	>7.0	23,611	critical	3.58
	Total	659,393		100.00

After calculating the potential soil erosion rate classes, it was important to assess which kind of land uses were most prone to soil erosion. Such information is essential in order to formulate conservation measures for such areas. Soil erosion rates were therefore overlaid with land use types. This indicated that excluding barren areas, swidden agriculture areas have the highest mean soil erosion rate at 5.81 ton/ha/yr (see Table 2.6). According to the above hazard severity classification, swidden agriculture falls under most severe class. Field crop areas have second highest average soil erosion rate at 2.96 ton/ha/yr.. Table 2.6 indicates that soil erosion rates in forested areas range from 0.08 to 1.94 ton/ha/yr and rates in cultivated areas range from 0.50 to 5.81 ton/ha/yr. Comparing world-wide soil erosion rates, Morgan[1] reports that among soils covered by natural vegetation, cultivated soils and bare soil, soils covered by natural vegetation have least soil erosion and bare soils have the highest erosion rates.

According to Onchan[2], soil loss from forested areas ranges from 0.02 to 0.2 ton/ha/yr and soil loss from cultivated areas may reach levels of up to 132.0 ton/ha/yr.

The comparison of soil erosion in various sub-basins (total 230) has shown that 210 sub-basins

[1] Soil Erosion and Conservation, R P C Morgan, 1986, Longman Scientific and Technical.
[2] Land Use Conservation and Sustainable Land Management in Asia, T Onchan, 1993, Rural Land Use in Asia and the Pacific, Asian Productivity Organisation, Tokyo, Japan.

have either least severe, less severe or a moderately severe class of soil erosion (see Table 2.7). These basins may be considered as safe from soil erosion severity hazard. The remaining 20 sub-basins are classified as more severe, most severe or critical class of soil erosion and out of these, 6 are in Kok basin, 8 in Ing basin and 6 in Yao basin.

2.7 Inundation Area Analysis

The lowlands along the Kok River and the Ing River regularly suffer from heavy flooding in the rainy season. For this reason, the spatial distribution of the inundated area was analysed using the satellite radar image data taken on September 25, 1995. The radar data, being one band data, was overlain by a Landsat TM satellite image taken on January 25, 1997 (dry season) in order to delineate the flood prone area clearly.

The analysis has shown that out of 183,480 ha of the total Kok basin area, 19,065 ha is prone to deep flooding and 33,494 ha to shallow flooding. The total flood prone area is 52559 ha (about 29 %). Similarly, out of 359,454 ha of the total Ing basin area, 19,505 ha is prone to deep flooding and 23, 542 ha to shallow flooding. The total flood prone area is about 45,000 ha (about 12.5 %). In terms of land use, paddy fields and wet grass/shrub land that are along the Kok and Ing rivers are the most prone to flooding (see Figure 2.9).

Table 2.6 Rate of Soil Erosion in Various Land Use Types

Land Use Type	Total (ha)	area %	Mean Soil Loss Rate (ton/ha/yr)	Total Soil Loss (ton/yr)	% Soil Loss	Potential Soil Productivity (year)
City/Town	1,130	0.17	0.01	0	0.00	
Infrastructure	615	0.09	0.01	0	0.00	
Paddy field	229,898	34.86	0.57	131,663	17.47	4,365
Field crops	15,896	2.41	2.96	47,105	6.25	844
Orchard/Village garden crops	16,323	2.48	0.50	8,170	1.08	4,995
Swidden agriculture	48,272	7.32	5.81	280,538	37.25	430
Dry grass/shrub land	10,780	1.63	0.66	7,120	0.95	3,785
Wet grass/shrub land	17,050	2.59	0.01	0	0.00	
Evergreen broad leafed forest	99,797	15.13	0.08	8,383	1.11	29,762
Deciduous forest	32,886	4.99	1.92	62,993	8.36	1,305
Mixed forest	66,763	10.12	0.42	28,114	3.73	5,937
Bamboo forest	37,376	5.67	0.85	31,863	4.23	2,933
Degraded forest	75,481	11.45	1.94	146,222	19.41	1,291
Forest plantation	21	0.00	0.19	0	0.00	
River	3,831	0.58	0.03	0	0.00	
Lake/Reservoir	3,152	0.48	0.02	0	0.00	
Barren land	141	0.02	7.80	1,100	0.15	320
Total	659,412	100.00		753,269	100.00	

Table 2.7 Average Soil Erosion of Various Sub-basins

Rating (ton/ha/yr)	Hazards class	Total Sub-basins	in Kok basin	in Ing basin	in Yao basin
< 1.0	Least severe	109	24	68	17
1.0 - 2.0	Less severe	74	14	45	15
2.0 - 3.0	Moderate severe	27	3	20	4
3.0 - 5.0	More severe	15	4	7	4
5.0 - 7.0	Most severe	3	2	1	0
>7.0	Critical	2	0	0	2
	Total	230	47	141	42

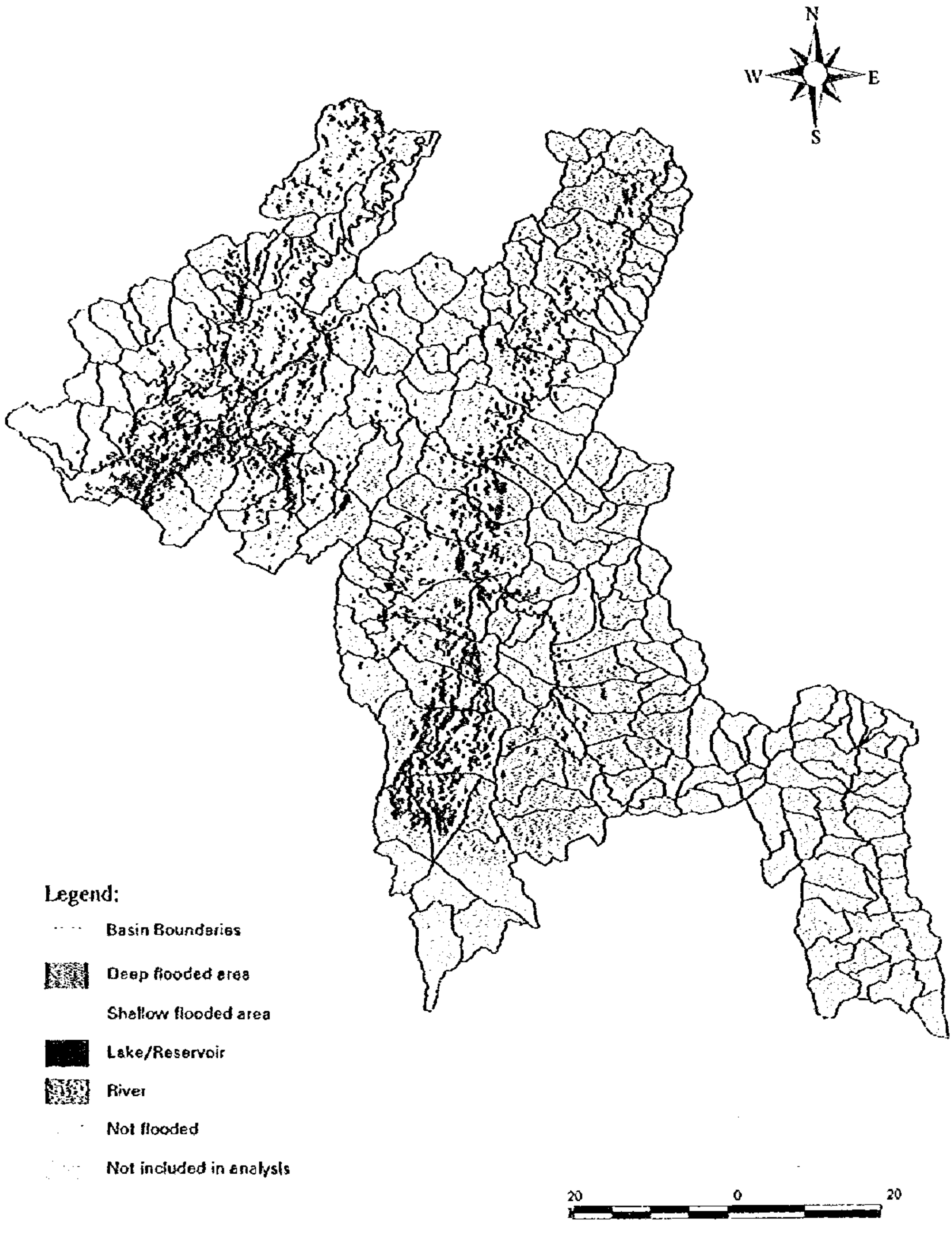


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Figure 2.9

Inundated Area Map

2.8 Watershed Classification

The Office of Environmental Policy and Planning (OEPP) has developed the watershed classification system in Thailand on the basis of available physical data including such parameters as slope, elevation, landform, geology, soil and forest cover. The watershed classification is mapped and the maps accurately reflect differences between the adjacent landscape units. The watershed classification system is one of the strategies for the utilisation and conservation of natural resources in Thailand balancing development and conservation.

The watershed classification system classifies land into the five major watershed classes as follows:

- WSC1 - Class 1A are the areas of conservation forest and headwater source areas, usually at higher elevations and with very steep slopes. These areas should remain under permanent forest cover. Class 1B are areas of similar physical features and environment to Class 1A but some parts of these areas have been cleared for agricultural use or are occupied by villages. These areas require special soil conservation and protection measures and where possible should be replanted as forest or maintained under permanent agro-forestry.

- WSC2 - Class 2 represents areas of protection and/or commercial forests (usually commercial forest), usually at higher elevations with steep to very steep slopes. Landforms are less prone to erosion than WSC1A or 1B. Areas may be used for grazing or certain crops with soil conservation measures.

- WSC3. - Class 3 represents the areas of uplands with steep slopes and less erosive landforms. These areas may be used for commercial forestry, grazing, fruit trees, or certain agricultural crops with need for soil conservation measures.

- WSC4. - Class 4 represents the areas of gently sloping lands suitable for the row crops, fruit trees, and grazing with a moderate need for soil conservation measures.

- WSC5. - Class 5 represents areas that are gently sloping to flat and that are used for paddy fields or other agricultural uses with few restrictions.

As the existing data for the watershed classification is available for the areas adjacent to the proposed route of the water diversion, an overlay analysis of the project area may be undertaken using the USLE results and map. The purpose of this analysis is to examine the status of land degradation by comparing the USLE results with the watershed classification map.

Figure 2.10 shows the result of overlaying the watershed classification with the basin boundaries. The area of the different classes of watershed classification for each basin and the hazard class from the USLE analysis is presented in Table 2.8. Although Yao-L-3(1) and Yao-L-2(1) are the most critical in terms of the potential soil erosion, only 3.3% and 10.1% of each basin is classified as WSC1A, and WSC1B respectively. Swidden agriculture is observed on the hill slopes without any countermeasures for soil conservation. Yao-R-4(1), located on the opposite side of the above two basins, also has high potential for soil erosion where only 6.2% of the basin is classified as WSC1A and WSC1B. As these basins are very close to the main Yao River and will influence sediment loads in the river, it will be necessary to take some measures for soil conservation before the completion of the water diversion.

IngLao-R-10(2) and IngLao-R-4(3) are also critical basins in the Ing watershed, where 26.3% and 35.7% of the basins are classified as WSC1A and WSC1B respectively. Forested areas cover 36% and 68% of each basin respectively, while the upland cultivation covers 39% and 26% respectively, although the land is designated as conservation forest (see Figure 2.11).

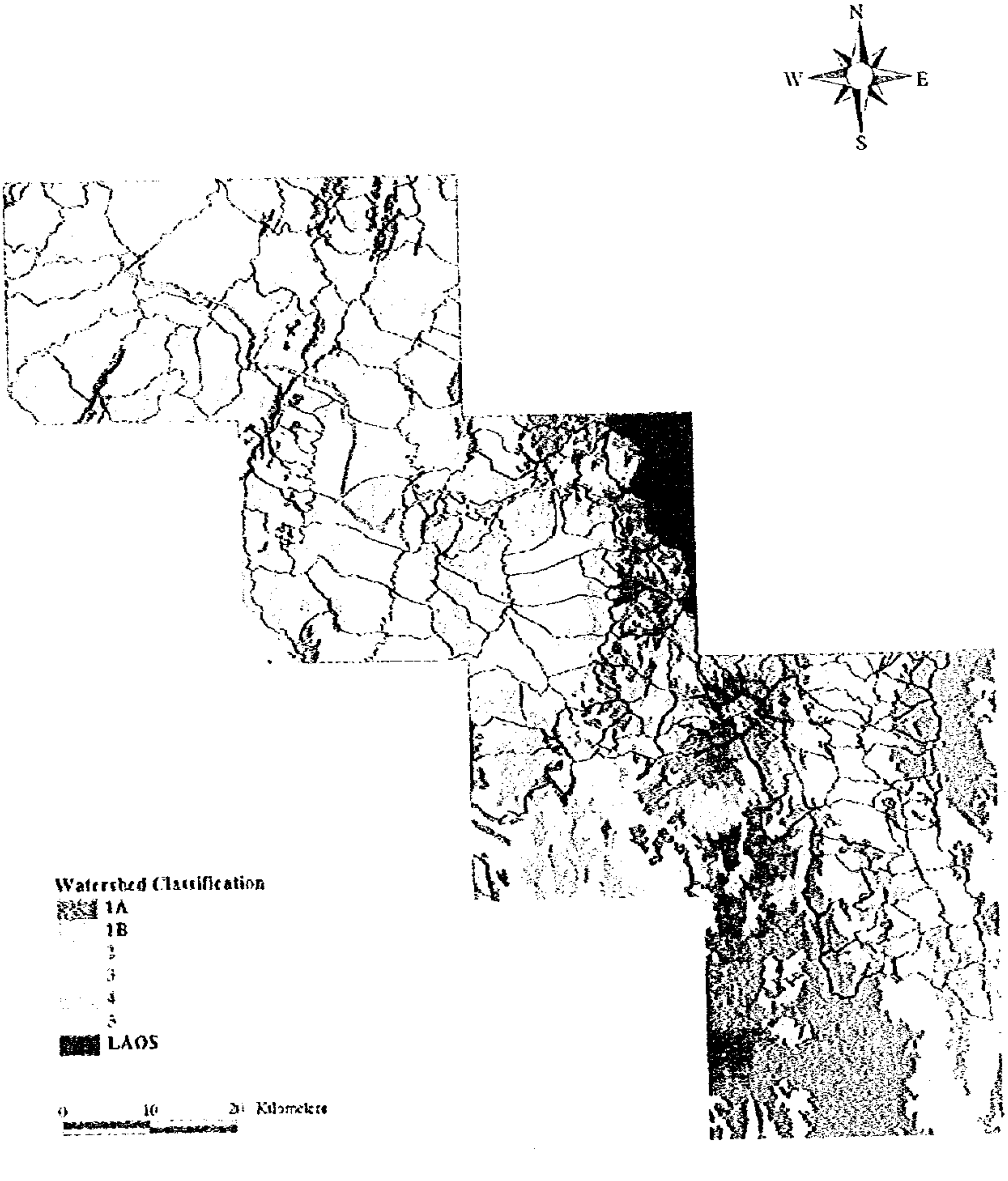

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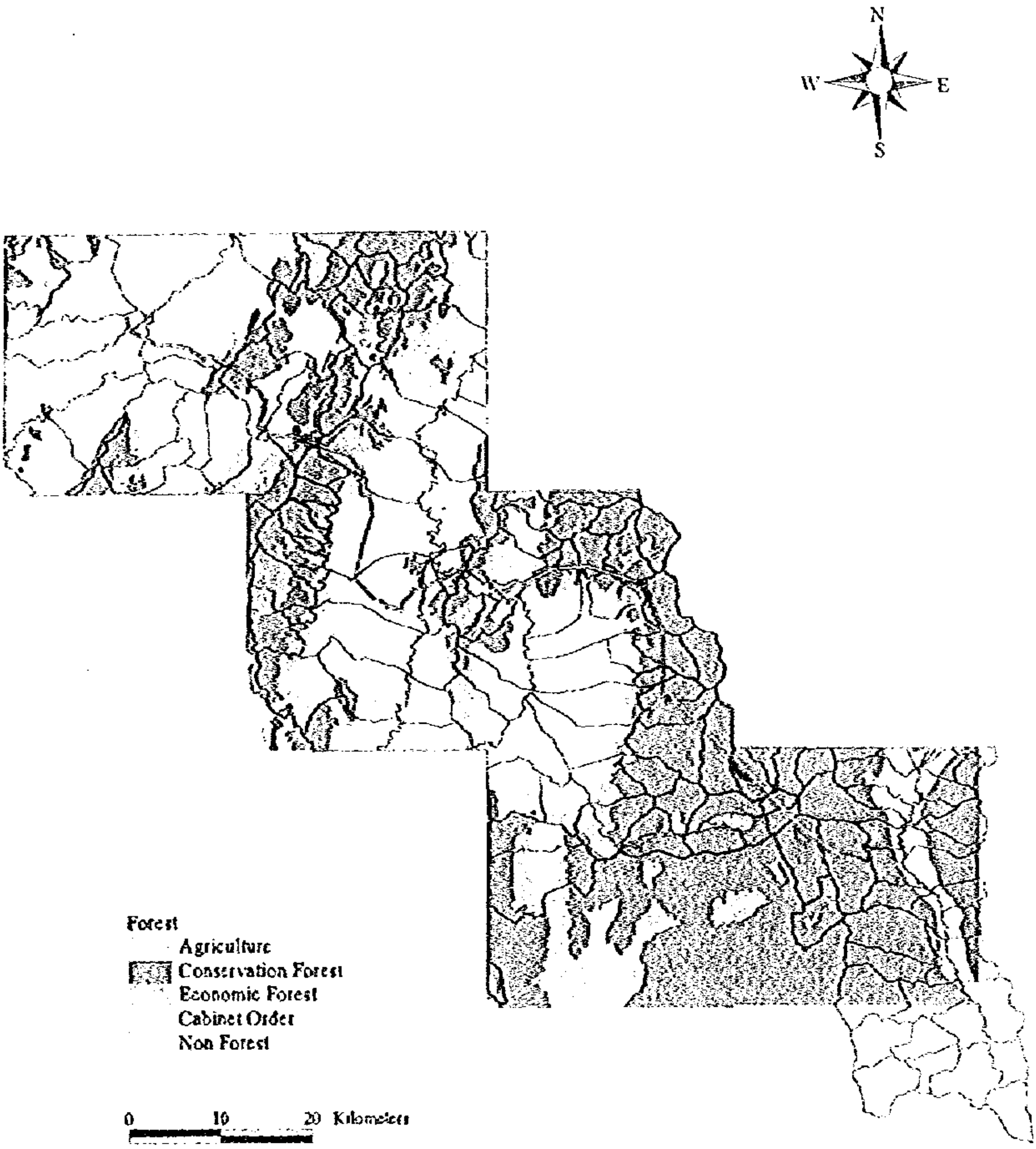
Figure 2.10

Watershed Classification Map



ENVIRONMENTAL STUDY THE KOK-ING-NAN WATER DIVERSION PROJECT	Figure 2.11 Forest Status Map
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 2.8. Area Calculation of Watershed Classification for Each Basin.

The calculation was undertaken for the areas where Watershed Classification maps are available.

Watershed Basin		Critical Class	1A		1B		2		3		4		5		Total
Name	Code	by USLE	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)
Kok-R-4(1)	11041	1 (*)											32.17	100	32.17
Kok-R-5(1)	11051	1 (*)	144.17	5.1			313.28	11.0	345.65	12.1	346.52	12.2	1,695.84	59.6	2,845.47
Kok-R-5(2)	11052	2	475.07	19.4			369.21	15.1	754.64	30.8	708.72	28.9	142.70	5.8	2,450.33
Kok-R-6(1)	11061	1	82.65	0.7			188.92	1.6	437.81	3.7	1,021.37	8.6	10,083.37	85.4	11,814.12
Kok-R-7(1)	11071	1 (*)	21.67	0.5	0.07	0.0	18.83	0.4	157.08	3.3	1,146.61	24.2	3,394.35	71.6	4,738.62
Kok-R-8(1)	11081	2 (*)					19.72	1.8	371.55	34.1	554.02	50.9	143.63	13.2	1,088.92
Kok-R-5-1(1)	11511	1 (*)	532.39	45.1			82.93	7.0	120.45	10.2	236.77	20.0	209.10	17.7	1,181.64
Kok-R-6-1(1)	11611	1	10.51	0.5			138.88	6.3	302.81	13.7	233.26	10.6	1,519.93	68.9	2,205.40
Kok-L-5(1)	12051	1 (*)									493.43	6.7	6,913.85	93.3	7,407.27
Kok-L-6(1)	12061	1 (*)			53.47	1.0	58.00	1.1	626.71	12.3	1,372.93	26.9	2,998.46	58.7	5,109.57
Kok-L-6(2)	12062	2 (*)	35.55	3.1			73.05	6.3	239.62	20.6	502.35	43.2	312.75	26.9	1,163.32
Kok-L-7(1)	12071	4 (*)	55.28	1.5			683.48	18.5	1,571.21	42.4	423.86	11.4	969.91	26.2	3,703.75
Kok-L-7(3)	12073	4 (*)	9.23	97.9					0.19	2.1					9.42
Kok-L-7(4)	12074	4 (*)	44.92	20.7	57.66	26.6	42.07	19.4	34.65	16.0	36.65	16.9	1.07	0.5	217.02
Kok-L-7(5)	12075	5 (*)			48.68	19.0	34.51	13.5	71.01	27.7	86.83	33.9	14.94	5.8	255.98
KokLao-R-1(1)	13011	1	473.36	8.9			36.97	0.7	893.06	16.8	2,107.10	39.5	1,817.41	34.1	5,327.89
KokLao-R-1(2)	13012	1 (*)	150.70	3.1			332.39	6.8	446.39	9.1	1,726.24	35.3	2,231.43	45.7	4,887.14
KokLao-L-1(1)	14011	1 (*)							92.48	1.1	820.94	10.1	7,233.53	88.8	8,146.95
NongLuang(1)	15011	1							82.98	3.7	602.29	26.7	1,568.93	69.6	2,254.20
NongLuang(2)	15012	1					72.37	1.7	493.62	11.6	1,398.02	32.8	2,297.57	53.9	4,261.57
NongLuang(3)	15013	1 (*)					62.40	4.0	57.82	3.7	204.98	13.1	1,244.25	79.3	1,569.45
NongLuang(4)	15014	1	89.05	3.2			66.06	2.4	419.30	15.2	1,059.28	38.4	1,124.95	40.8	2,758.64
NongLuang(5)	15015	1	214.29	4.4	158.11	3.3	236.62	4.9	215.63	4.5	1,101.08	22.8	2,893.82	60.0	4,819.55
Ing-R-7(1)	21071	3 (*)											196.75	100	196.75
Ing-R-7(2)	21072	2 (*)											1,043.27	100	1,043.27
Ing-R-7(3)	21073	2 (*)	1.06	0.1									999.37	99.9	1,000.42
Ing-R-8(1)	21081	1 (*)	503.34	12.9	17.31	0.4	48.58	1.2			79.83	2.0	3,247.48	83.3	3,896.54
Ing-R-9(1)	21091	2 (*)	490.40	9.2	302.85	5.7	529.00	9.9	427.29	8.0	244.18	4.6	3,355.00	62.7	5,348.72
Ing-R-10(1)	21101	1	122.93	8.3			241.48	16.3	293.72	19.8	112.58	7.6	711.63	48.0	1,482.34
Ing-R-11(1)	21111	1	112.47	4.1			116.50	4.2	217.79	7.9	294.66	10.7	2,000.52	73.0	2,741.94
Ing-R-12(1)	21121	1									0.83	0.0	2,152.94	100	2,153.78
Ing-R-13(1)	21131	1 (*)					20.90	0.9	20.65	0.9	119.97	5.1	2,179.52	93.1	2,341.04
ing-R-13-2(2)	21152	1 (*)	16.63	2.7			36.94	6.0			559.86	91.3			613.43
ing-R-13-3(3)	21163	1 (*)									15.54	100			15.54
Ing-L-5(1)	22051	1 (*)							43.57	9.6	128.18	28.3	280.68	62.0	452.43
Ing-L-5(2)	22052	5 (*)							42.27	63.3	24.53	36.7			66.80
Ing-L-6(1)	22061	1 (*)	13.11	0.4			83.64	2.3	347.72	9.6	980.17	26.9	2,213.18	60.8	3,637.82
Ing-L-6(2)	22062	2	493.75	35.0			14.86	1.1	373.70	26.5	501.50	35.5	27.16	1.9	1,410.98
Ing-L-6(3)	22063	2	516.34	33.6			38.86	2.5	644.88	41.9	337.79	22.0			1,537.87
Ing-L-6(4)	22064	3 (*)	467.17	24.0	24.33	1.2	373.95	19.2	1,072.99	55.1	9.30	0.5		0.0	1,947.74
Ing-L-6(5)	22065	3 (*)					11.22	20.2	19.92	35.8	24.48	44.0		0.0	55.61
Ing-L-7(1)	22071	1 (*)	170.48	2.1			80.81	1.0	968.04	11.7	2,374.15	28.7	4,687.46	56.6	8,280.94
Ing-L-8(1)	22081	1	17.50	0.4			214.55	5.2	486.82	11.8	874.63	21.2	2,531.34	61.4	4,124.83
Ing-L-9(1)	22091	1	125.56	1.9			411.04	6.1	650.23	9.7	771.82	11.5	4,752.20	70.8	6,710.85
Ing-L-10(1)	22101	1					150.97	1.7	466.03	5.4	124.21	1.4	7,909.60	91.4	8,650.80
Ing-L-10(2)	22102	2	201.88	14.7	79.36	5.8	487.32	35.6	447.41	32.7	106.66	7.8	46.11	3.4	1,368.74
Ing-L-10(3)	22103	1	59.68	5.8	252.34	24.5	255.31	24.8	290.97	28.3	170.83	16.6			1,029.13
Ing-L-10(4)	22104	4	75.16	12.4			269.75	44.4	202.48	33.3			59.78	9.8	607.17
Ing-L-10(5)	22105	4	189.21	13.2	164.86	11.5	543.19	38.0	405.70	28.4	113.81	8.0	11.26	0.8	1,428.03
Ing-L-10(6)	22106	3					69.87	19.1	247.20	67.6	48.43	13.2			365.49
Ing-L-10(7)	22107	2	380.05	18.5			425.36	20.7	1,028.97	50.0	47.72	2.3	174.60	8.5	2,056.71
Ing-L-11(1)	22111	2	3.96	0.1			460.38	7.7	543.62	9.1	608.88	10.2	4,352.87	72.9	5,969.70
Ing-L-11(2)	22112	2	81.16	12.8			284.65	44.8	209.71	33.0	42.40	6.7	17.87	2.8	635.79
Ing-L-11(3)	22113	3	150.06	5.7			496.61	19.0	1,632.90	62.5	326.78	12.5	6.55	0.3	2,612.89
Ing-L-12(1)	22121	1	29.95	0.5			160.30	2.7	245.34	4.1	690.76	11.6	4,849.40	81.2	5,975.75
Ing-L-12(2)	22122	3	158.31	30.1			216.33	41.1	125.26	23.8	26.02	4.9			525.93
Ing-L-12(3)	22123	1	61.30	2.3			888.61	33.2	1,510.70	56.5	213.48	8.0			2,674.09
Ing-L-13(1)	22131	1	137.19	2.8			102.56	2.1	116.03	2.3	640.60	12.9	3,952.41	79.9	4,948.79
Ing-L-13(2)	22132	2	41.93	0.9			786.92	16.1	1,199.73	24.6	1,327.76	27.2	1,517.45	31.1	4,873.78
Ing-L-14(1)	22141	2 (*)	753.93	19.7			238.86	6.2	442.56	11.5	14.81	0.4	2,386.33	62.2	3,836.49
Muang-1(1)	23011	2	81.58	2.5	63.75	1.9	364.64	11.0	643.77	19.3	557.18	16.7	1,616.98	48.6	3,327.92
Muang-1(2)	23012	1	355.03	17.7	5.18	0.3	295.95	14.8	455.36	22.8	442.00	22.1	447.28	22.4	2,000.81
Muang-2(1)	23021	2 (*)	1,452.36	46.7	141.62	4.6	419.40	13.5	646.65	20.8	335.50	10.8	116.27	3.7	3,111.81
Muang-2(2)	23022	2 (*)	847.84	71.0	24.05	2.0	208.23	17.5	38.28	3.2	74.92	6.3			1,193.32
Muang-2(4)	23024	2 (*)	231.08	85.4	39.64	14.6									270.72
tak-R-1	24011	2	392.41	15.2			563.34	21.8	695.81	26.9	568.15	21.9	369.81	14.3	2,589.52
tak-L-1(1)	24021	3	194.05	6.1			376.58	11.8	1,112.18	35.0	514.16	16.2	984.63	30.9	3,181.60
tak-L-1(2)	24022	3	433.45	20.2	14.45	0.7	310.08	14.5	1,004.34	46.9	298.69	13.9	80.69	3.8	2,141.69
tak-L-1(3)	24023	4	93.56	6.8	71.47	5.2	301.34	21.8	687.50	49.8	227.39	16.5			1,381.26

Watershed Basin Name	Code	Critical Class by USLE	1A		1B		2		3		4		5		Total
			Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)
tak-2	24031	2	306.68	5.3	14.84	0.3	655.24	11.2	1,832.24	31.4	1,411.64	24.2	1,608.72	27.6	5,829.37
tak-R-3	24041	4	440.00	9.3	1.42	0.0	1,128.35		1,175.57	24.8	1,056.00	22.2	945.96	19.9	4,747.30
tak-L-3	24051	1			129.23	2.7	228.79	4.8	1,426.48	30.1	1,910.83	40.3	1,046.22	22.1	4,741.55
tak-4	24061	2 (*)	713.16	18.8	113.54	3.0	325.67	8.6	685.43	18.1	1,367.97	36.1	584.11	15.4	3,789.88
IngLao-R-1(1)	25011	1					106.53	12.1	151.39	17.3	25.08	2.9	594.21	67.7	877.21
IngLao-R-2(1)	25021	1					72.21	6.7	160.41	14.8	90.98	8.4	758.51	70.1	1,082.11
IngLao-R-3(1)	25031	1	329.79	7.6			336.32	7.8	527.49	12.2	1,291.59	29.9	1,832.22	42.4	4,317.40
IngLao-R-4(1)	25041	2	51.07	1.3			162.29	4.0	465.30	11.5	690.26	17.0	2,680.70	66.2	4,049.61
IngLao-R-4(2)	25042	1	414.27	17.7	0.03	0.0	209.64	9.0	461.12	19.7	683.99	29.2	570.88	24.4	2,339.94
IngLao-R-4(3)	25043	4	399.46	28.4	102.30	7.3	305.10	21.7	600.94	42.7					1,407.80
IngLao-R-4(4)	25044	1	2,003.97	86.7	67.58	2.9	164.19	7.1	40.43	1.7	33.98	1.5			2,310.14
IngLao-R-4(5)	25045	2	784.66	37.2	333.75	15.8	562.74	26.7	308.54	14.6	120.37	5.7			2,110.06
IngLao-R-4(6)	25046	2	1,014.84	49.4	318.34	15.5	336.72	16.4	207.20	10.1	176.71	8.6			2,053.82
IngLao-R-4(7)	25047	3	703.69	53.7	186.21	14.2	102.55	7.8	317.60	24.2		0.0			1,310.04
IngLao-R-5(1)	25051	1	0.20	0.0			29.22	0.7	165.08	4.2	170.58	4.3	3,557.98	90.7	3,923.06
IngLao-R-5(2)	25052	1	157.40	11.6			170.75	12.6	253.84	18.7	340.48	25.1	432.53	31.9	1,354.99
IngLao-R-5(3)	25053	1	489.21	79.4			86.49	14.0	29.62	4.8	11.12	1.8			616.43
IngLao-R-5(4)	25054	1	1,361.47	68.7			273.84	13.8	226.65	11.4	118.51	6.0			1,980.47
IngLao-R-5(5)	25055	1	1,458.30	78.4	25.78	1.4	359.98	19.4	15.07	0.8					1,859.14
IngLao-R-6(1)	25061	1	73.19	1.9	12.71	0.3	183.68	4.8	299.07	7.7	611.50	15.8	2,686.37	69.5	3,866.50
IngLao-R-6(2)	25062	1	890.01	61.1	117.13	8.0	382.98	26.3	67.47	4.6					1,457.59
IngLao-R-7(1)	25071	1	74.16	1.9			68.41	1.7	156.52	4.0	210.42	5.3	3,450.92	87.1	3,960.44
IngLao-R-8(1)	25081	1	534.36	21.0			260.56	10.3	460.73	18.1	279.79	11.0	1,003.46	39.5	2,538.90
IngLao-R-8(2)	25082	2	821.82	45.8	329.66	18.4	383.79	21.4	257.95	14.4	0.41	0.0			1,793.63
IngLao-R-9(1)	25091	1	839.86	42.1			923.21	46.3	109.64	5.5			123.08	6.2	1,995.79
IngLao-R-10(1)	25101	3	371.71	33.1	0.22	0.0	437.57	38.9	166.75	14.8	148.04	13.2			1,124.28
IngLao-R-10(2)	25102	5	56.52	3.1	425.74	23.2	1,110.04	60.4	107.44	5.8	137.22	7.5			1,836.96
IngLao-R-11(1)	25111	2	395.57	23.9	717.88	43.3	359.23	21.7	125.61	7.6	58.56	3.5			1,656.85
IngLao-R-11(2)	25112	3	223.86	33.4	327.82	49.0	117.78	17.6							669.45
IngLa-R-7-1(1)	25711	2	1,091.01	59.0	435.87	23.6	219.96	11.9	102.96	5.6					1,849.80
IngLa-R-7-2(1)	25721	2	1,097.81	31.1	642.69	18.2	1,103.63	31.2	539.12	15.3	149.74	4.2			3,533.00
IngLa-R-7-3(1)	25731	2 (*)	578.99	19.0	1,172.82	38.5	1,006.09	33.1	284.36	9.3	1.14	0.0			3,043.39
IngLa-R-7-3(2)	25732	1	971.32	58.4	244.91	14.7	298.51	17.9	148.42	8.9					1,663.16
IngLa-R-7-3(3)	25733	1 (*)	239.78	33.1	396.29	54.7	88.67	12.2							724.74
IngLa-R-7-3(4)	25734	1 (*)	651.79	53.2	541.51	44.2	31.95	2.6							1,225.25
IngLa-R-7-3(5)	25735	1 (*)	660.16	54.3	554.49	45.7									1,214.65
IngLao-L-1(1)	26011	1	25.16	4.7			80.00	15.0	101.07	18.9	145.83	27.3	182.55	34.1	534.62
IngLao-L-2(1)	26021	2	355.62	21.7			174.35	10.7	402.51	24.6	700.19	42.8	3.57	0.2	1,636.24
IngLao-L-2(2)	26022	1	23.91	1.8			60.19	4.4	242.76	17.8	480.60	35.3	552.59	40.6	1,360.05
IngLao-L-3(1)	26031	1	50.06	1.4			151.44	4.2	657.47	18.2	856.96	23.7	1,898.29	52.5	3,614.22
IngLao-L-4(1)	26041	1	57.93	2.2			39.66	1.5	207.66	7.8	729.69	27.4	1,629.45	61.2	2,664.40
IngLao-L-5(1)	26051	1 (*)					31.36	0.8	155.93	4.2	20.62	0.6	3,511.20	94.4	3,719.10
IngLao-L-6(1)	26061	2	148.81	10.0	68.21	4.6	302.91	20.3	438.25	29.3	410.64	27.5	124.76	8.4	1,493.57
IngLao-L-7(1)	26071	3	10.50	0.8	304.93	23.7	639.80	49.7	259.82	20.2	71.08	5.5			1,286.12
IngLao-L-8(1)	26081	2	783.71	48.6	76.92	4.8	465.38	28.9	244.69	15.2	41.74	2.6			1,612.43
IngLao-L-8(2)	26082	1	959.84	75.9	2.92	0.2	261.84	20.7	39.55	3.1					1,264.15
IngLao-L-8(3)	26083	2	573.54	83.5			113.08	16.5							686.62
IngLa-L-5-1(1)	26511	1		0.0			56.05	1.9	377.19	12.9	1,092.80	37.3	1,402.70	47.9	2,928.74
IngLa-L-5-2(1)	26521	1 (*)	32.96	0.9			197.52	5.7	407.46	11.7	1,070.79	30.8	1,770.63	50.9	3,479.36
IngLa-L-5-2(2)	26522	1	92.56	4.3					136.31	6.3	671.70	31.0	1,269.30	58.5	2,169.88
IngLa-L-5-3(1)	26531	1 (*)	540.21	17.6			521.81	17.0	1,045.13	34.0	766.81	25.0	195.55	6.4	3,069.51
IngLa-L-5-4(1)	26541	1 (*)	1,003.32	15.5			1,237.12	19.1	1,809.29	27.9	2,065.96	31.9	364.20	5.6	6,479.89
Yao-1(1)	31011	3							99.53	4.8	927.20	44.7	1,048.52	50.5	2,075.25
Yao-R-1(1)	32011	2	83.74	2.8			556.20	18.5	963.57	32.0	1,072.17	35.6	336.49	11.2	3,012.16
Yao-R-2(1)	32021	2		0.0	16.64	0.9	1,160.56	64.2	629.69	34.8					1,806.88
Yao-R-3(1)	32031	4	81.15	3.5	912.85	39.4	1,081.58	46.7	241.11	10.4					2,316.69
Yao-R-3(2)	32032	1	1,203.02	34.9	251.24	7.3	1,173.18	34.0	822.23	23.8					3,449.67
Yao-R-4(1)	32041	4	31.72	2.9	36.04	3.3	650.26	60.0	365.72	33.7					1,083.74
Yao-R-4(2)	32042	1	714.17	31.8	271.41	12.1	1,254.95	55.8	8.26	0.4					2,248.80
Yao-R-4(3)	32043	2	664.55	16.7	77.02	1.9	2,759.24	69.2	485.39	12.2					3,986.19
Yao-R-5(1)	32051	2	311.70	31.0			310.83	30.9	384.42	38.2					1,006.95
Yao-R-5(2)	32052	2					776.69	51.5	730.94	48.5					1,507.64
Yao-R-6(1)	32061	1	13.13	0.9			881.62	57.9	629.00	41.3					1,523.75
Yao-R-6(2)	32062	3	39.30	3.7			411.47	38.8	610.31	57.5					1,061.07
Yao-R-6(3)	32063	2	339.42	19.7			726.39	42.2	654.13	38.0					1,719.94
Yao-R-7(1)	32071	2	1,317.72	42.2	248.36	8.0	303.31	9.7	1,253.70	40.1					3,123.08
Yao-R-7(2)	32072	2	4.46	0.3	103.09	7.9	300.03	22.9	900.14	68.8					1,307.72
Yao-R-7(3)	32073	1	200.65	7.5	88.94	3.3	1,034.83	38.6	1,355.87	50.6					2,680.29
Yao-R-2-1(1)	32211	3	194.55	11.1	185.71	10.6	1,143.69	65.1	233.83	13.3					1,757.78
Yao-R-2-1(2)	32212	3	1,092.64	43.6	221.74	8.8	666.12	26.6	528.04	21.0					2,508.54
Yao-R-2-2(1)	32221	4	127.01	9.2	174.68	12.7	970.24	70.5	103.51	7.5					1,375.43
Yao-R-2-2(2)	32222	1	1,797.18	61.9	226.05	7.8	878.65	30.3							2,901.88
Yao-R-6-1(1)	32611	1	188.27	8.0			1,268.87	53.6	818.77	34.6	91.76	3.9			2,367.66
Yao-R-6-2(1)	32621	2	2,036.88	62.3			794.47	24.3	65.40	2.0	373.51	11.4			3,270.26

Watershed Basin Name	Code	Critical Class by USLE	1A Area (ha)	1A (%)	1B Area (ha)	1B (%)	2 Area (ha)	2 (%)	3 Area (ha)	3 (%)	4 Area (ha)	4 (%)	5 Area (ha)	5 (%)	Total Area (ha)
Yao-R-6-2(2)	32622	1	1,188.71	52.9			805.94	35.9	250.03	11.1	1.57	0.1			2,246.25
Yao-L-1(1)	33011	4	4.61	0.3			217.89	14.6	702.92	47.1	443.30	29.7	122.18	8.2	1,490.90
Yao-L-2(1)	33021	6	280.04	10.1			1,583.64	57.4	896.86	32.5					2,760.55
Yao-L-3(1)	33031	6	59.78	3.3			1,493.97	81.8	273.74	15.0					1,827.48
Yao-L-4(1)	33041	2	265.08	23.0			764.37	66.3	123.26	10.7					1,152.72
Yao-L-4(2)	33042	2	580.00	44.1	99.34	7.6	588.38	44.7	47.99	3.6					1,315.71
Yao-L-5(1)	33051	2	1,219.19	47.9	142.50	5.6	882.62	34.7	298.65	11.7					2,542.96
Yao-L-6(1)	33061	2	414.76	28.0	59.62	4.0	562.94	38.0	442.45	29.9					1,479.77
Yao-L-6(2)	33062	1	1,621.08	78.5	0.06	0.0	266.98	12.9	177.68	8.6					2,065.79
Yao-L-7(1)	33071	2	346.11	41.6			215.39	25.9	270.42	32.5					831.93
Yao-L-7(2)	33072	1	797.82	52.8			471.79	31.2	241.00	16.0					1,510.61
Yao-L-8(1)	33081	1	373.55	42.0			313.56	35.2	203.26	22.8					890.37
Yao-L-8(2)	33082	1	720.61	100											720.61
Yao-L-9(1)	33091	1 (*)	465.62	71.5			83.00	12.7	103.02	15.8					651.64
Yao-L-9(2)	33092	1 (*)					62.57	64.9	33.80	35.1					96.37
Yao-L-9(3)	33093	1 (*)					158.54	48.6	167.35	51.4					325.89
Yao-L-10(1)	33101	2 (*)					365.81	49.2	377.82	50.8					743.63
Yao-L-10(3)	33103	1 (*)	173.05	29.5	30.91	5.3	268.66	45.8	114.59	19.5					587.21
			55,604	14.3	12,331	3.2	58,871	15.2	62,764	16.2	54,306	14.0	144,430	37.2	388,251

Remarks:

Watershed Class 1: least severe 2 : less severe 3 : moderate severe 4 : more severe 5 : most severe 6 : critical

(*) indicates basins where the Watershed Classification map does not fully cover the study area.

The areas were calculated by overlaying the USLE result map with the Watershed Classification map using GIS.

2.9 GIS Analysis for Watershed Management

More intensive study has been carried out on those basins where soil erosion rates have ben shown to be critical. GIS analysis has been conducted in parallel with watershed management planning works on site. Three basins were selected for detailed case studies from the major watersheds, namely Kok, Ing and Yao basins. Although the criteria of the selection are principally based on the result of USLE analysis, the basins nearby the proposed route of the water diversion have been given priority.

Yao-L-3 (1), IngLao-L-2 (1) and Kok-L7 (2) were finally selected for the case study areas and the necessary information for those basins have been collected during field assessments. Aerial photo interpretation was also carried out to map present land use conditions in more detail. Each basin has different characteristic in terms of agricultural land use the physical resources present. The methodology for this analysis is also GIS based USLE but the data used are scaled up to 1:50,000 or larger, 20m interval counter lines derived from the topographical maps and current land use derived from the latest aerial photography.

(1) Kok-L-7(2)

The land use pattern and slope distribution in this basin are shown in Figures 4.1.3. and 4.1.4. in the Main Report. In this basin the topography is mostly mountainous in nature and slash and burn or swidden agriculture is distributed on the middle and upper slopes although still not common.

(2) IngLao-L-2(1)

The land use pattern and slope distribution in this basin are shown in Figures 4.1.7. and 4.1.8. in the Main Report. In this basin slash and burn or swidden agriculture is distributed on the slopes lass than 13 degrees and is the impact on soil erosion is therefore less. In addition, the forest on the steeper slopes is well preserved and soil erosion rates are not critical.

(3) Yao-L-3(1)

The land use pattern and slope distribution in this basin are shown in Figures 4.1.11. and 4.1.12 in the Main Report. The upland fields are largely used for swidden agriculture and are widely distributed on the slopes steeper than 13 degree. Field rice and corn have been continuously cultivated on these slopes for more than 10 years without any fallow periods. According to the local farmers from the Yao hill tribe, the soil has been eroded and continues to be eroded during heavy rain because no soil conservation practices (countermeasures) are used in the fields.

In general, whenever sloping soil is to be cultivated and exposed to erosive rains, the protection offered by sod or close-growing crops in the system needs to be supported by practices that will slow the runoff water and thus reduce the amount of soil it is able to carry. The USLE analysis for the whole did not take into account artificial soil conservation practices on the process of calculation of potential soil erosion loss rates. The most important of these supporting cropland practices are contour tillage, strip cropping on the contour, and terrace systems. Stabilised waterways for the disposal of excess rainfall are also a necessary component of these practices. By definition, the P factor in the USLE is the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down slope culture. Example values for the P factor are shown in Table 2.9 below:

Table 2.9 Indicative Values for Conservation Practices or P-factor

Slope Range	Contouring	Strip Cropping	Terracing
0-1	1.0	1.00	1.00
1-3	0.6	0.3	0.12
3-9	0.5	0.25	0.10
9-13	0.6	0.30	0.12
13-17	0.7	0.35	0.14
17-21	0.8	0.40	0.16
21-25	0.9	0.45	0.18
>25	1.0	1.00	1.00

The USLE calculations have been carried out on the GIS database so that various scenarios may be explored. In this study, 4 types of calculation were undertaken for the three study basins:

- under present land management conditions (no soil conservation practices);
- with the use of contour cultivation for all upland fields;
- with the use of strip copping for all upland fields; and
- with the use of terracing for all the upland fields.

Figures 4.1.5., 4.1.9., and 4.1.13., in the Main Report and Table 2.10 below shows the results of the USLE calculations illustrating the differences in soil erosion loss between the 4 conditions in the three study basins.

In the Kok-L-7(2) study basin, the soil losses from slash and burn are largely reduced by the adoption of some form of soil conservation practice. However, large volumes of potential soil loss still remain on the middle and upper slopes in the basin, primarily because of the large areas of relatively steep slopes.

In the IngLao-L-2(1) basin the adoption of soil conservation practices makes little difference to potential soil loss rates, partly because overall potential soil loss rates in this basin are low, and partly because a relatively high proportion of the basin still remains covered with well preserved forest.

In the Yao basin, the soil loss from upland fields distributed on the upper slopes may be largely reduced by strip cropping or terracing practices. Contour cultivation also appears to be effective to some extent. However, in reality it is likely to be more practical to adopt a combination of strip cropping on the upper slopes and terracing on the lower slopes.

Table 2.10 Simulated Soil Erosion Loss Under Various Soil Conservation Measures

Study Basin	Kok		Ing		Nan (Yao)	
Soil Loss	Ton/year	Ton/ha/year	Ton/year	Ton/ha/year	Ton/year	Ton/ha/year
Under the present conditions	11,372	4.0	3,166	1.9	8,939	4.9
Contour Cultivation	10,873	3.8	2,801	1.7	6,880	3.8
Strip Cropping	10,239	3.6	2,571	1.6	4,894	2.7
Terracing	9,858	3.5	2,433	1.5	3,702	2.0