STUDY TO THE RELATION BETWEEN ECOLOGY, AGRICULTURE AND HYDROLOGY FOR LAND AND WATER RESOURCE PLANNING IN CAMBODIA

A PROPOSAL

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1. INTRODUCTION

1.1 Rationale

The Mekong River, with a length of 4200 km, is an important life source for the riparian countries. The Mekong regulates the water supply, influences land settlement patterns, provides spawning ground for fish which is the main protein source, and becomes increasingly important for hydro-electricity.
The Lower Mekong Basin covers a large part of the countries Laos, Cambodia, Thailand and Vietnam.
The importance of the Mekong and its potential for developments are recognized by many people and governments. However, efforts to study, analyze and plan for an optimal use of the resources provided by and through the Mekong are minimal. This study proposal seeks to provide an initial outline for a more sophisticated study of the economic, social and ecological costs of the possible water- and land-use scenarios.

In some areas of the Mekong Basin, (Thailand) interventions in the Mekong rivers have been undertaken for the last thirty years.In countries like Cambodia and Laos, economic development has been insignificant during the last 20 years. This most likely will change in the near future, because of changes in the internal and international politics. For the development of a regional water- and land-use plan for the Central Lowlands of the Mekong Basin, not only a preliminary study has to be conducted to have better grips on the changes in the landscape introduced in the past twenty years, but also lessons can be learnt from the experiences in the neighbouring countries through a systematic review.

1.2 Need for a long term planning

According to a policy document of the former Committee for Coordination of the Lower Mekong Basin (CCILMB), published in 1978, ".... long term land use planning is necessary, because of the increase of population, the risk of overexploitation of natural resources and the risk of large scale applications of modern techniques". A long term planning ".... requires a systematic approach, since the transformation of existing agricultural production into <u>sustained yielding farm systems</u> able to meet future needs, taking into account <u>ecological and other constraints</u> can hardly be achieved on a piece meal basis". Therefor the CCILMB started in the seventies with 10 <u>pioneer agriculture projects</u> of 5,000-10,000 ha, with the idea of a later spreading of the new methodology. Two of these projects were located near agricultural stations in Cambodia: Bana near Batambang and Prek Thnot near Phnom Penh. Another pioneer project was projected along the levees of the Mekong, just North of Phnom Penh: the Muk Kampul pioneer project.

These attempts form a contrast with the short term agricultural programs, which the CCILMB characterized in 1978 by :

- oriented on immediate results with a minimum investment
- oriented on economic growth (Thailand) or on reaching self-sufficiency (Cambodia, Laos, Vietnam)
- oriented on 1 type of farming system, neglecting traditional systems of risk spreading, and relying on water gifts in the dry season

Annex V gives a summary of the plans of the IMC for environmental studies.

1.3 Land use systems

Annex I gives an extensive summary of the natural resources and land use in Cambodia. It may function as the basis for further study.

The Mekong River crosses Cambodia through a floodplain, which widens in the Southern part of the country. Rice cultivation is the most important agricultural activity in large areas between the river banks and upper terraces. Partly, the rice cultivation is not solely dependent on the irregular rainfall, as use can be made of natural flooding and many surface waters. The depth of floods in some areas and the irregular rainfall in other determine the surface area of land dedicated to paddy rice cultivation. Changes in the hydrological regime by the construction of reservoirs and development of irrigation schemes will have a huge impact on the existing land use patterns and the social and ecological situation.

Actually, most of the agriculture is rainfed or floodwater dependent. It is expected that many farmers will continue to live outside the potential scope of centrally controlled surface water irrigation, maintaining their risk spreading production strategies.

1.4 Planned agricultural developments

In the development models of the Mekong Committee the following agricultural developments get priority (see figure 9 of annex I):

1. The reclamation of parts of the 2 main forested and non-forested wetlands:
   a. the Tonle Sap flood plains and
   b. the lower reaches of the Mekong Valley
   In the indicative plan of the IMC (1987) the first doesn't get much attention any more.

2. Improvement of the paddy rice on the lower terraces, especially along the Tonle Sap depression by a change from broadcast to transplanted rice. In the indicative plans of the IMC (1987), 7 irrigation schemes around the Tonle Sap depression are identified, apart from the existing Prek Thnot/Kompong Speu

and Bovel schemes

3. Expanded riverbank agriculture along the Lower part of the Mekong river

4. Irrigation schemes supplied from surface water reservoirs in selected areas on the pediplains: the indicative plan of the IMC identified
   a. 5 irrigation schemes in the coastal zone, west of the Southern Highlands
   b. 5 large irrigation areas in the Se San Basin,
   c. 3 irrigation areas near Kratie

5. Dry land agriculture in selected areas: Batambang plateau and 4 areas on basic rocks: an area N of Kg Cham, and 3 areas along the E border.

Apparently most of the priorities lie in wetland areas. Internationally, wetland areas receive a lot of attention from the side of nature resource protection. Wetlands are very sensitive for disturbance and are essential parts of regional ecosystems, functioning as a retention for floods, a buffer for erosion and a rest place in water fowl migration routes. Especially the fish cycle is much depending on these annually inundating wetlands. The study should pay special attention to this, in view of the fact that fish culture can be a major economic activity. The projected irrigation schemes on the lower terraces have a role in this eco-system and should be studied in relation to the wetlands.

1.5 Modern irrigation schemes

Planned "modern" irrigation schemes, including a double harvest and mono-cropping, should be reviewed in the spirit of this study: what are its long term costs and benefits versus the short term costs and benefits. Some known effects of irrigation schemes elsewhere should be analyzed and projected for the Cambodian situation; e.g. soil fertility, salinization, sensitivity for pests, health risks, and modern management structures.

1.6 Planned hydrological development

In respect to the hydrological development, 48 sites for minor dams are identified in the Indicative Plan of the IMC (1987), whereas 3 major dams have been projected in the Mekong River (Sambor, Stung Treng, and Khone Falls). Especially the Stung Treng reservoir will have a large extension of more than 2,500 km^2. Mainstream dams in upstream countries will have a large influence on the regime of the Mekong River and the Tonle Sap depression. Also in the Tonle Sap River a regulation dam is projected, which may guarantee a base flow of about 2,500 m^3/s. (see figure 9 of annex I).
Of the 48 minor dams, 15 are located in the Tonle Sap Basin, 11 in the Se San Basin, 10 in the basins south of the Se San Basin and 12 on the western slopes of the Southern Highlands.

1.7 Forestation

According to satellite images, the forest cover has been reduced from 73% to under 50% in 20 years (The Nation, 9/7/1991). According to this newspaper, 700,000 cubic metres of wood is cleared, annually. The extensive lowlands that surround the Tonle Sap and Mekong Rivers could be affected by deforestation. The same holds for the pediplains to the north and the south of Lake Tonle Sap and the areas around Kratie and Stung Treng. These developments need to be studied in relation to their impacts on ecology, agriculture and hydrology.

2. OBJECTIVE

The objective of the here proposed study is to develop a framework for the comparison of various land use and water resource development alternatives for Cambodia, given the available land resources (soil, water and vegetation) and the social and economic conditions. Emphasis will be put on the costs for developing economically viable land- and water-use systems and its expected return over a given period.

The study aims to provide scenarios for various options:
- immediate income without investments,
- minor investments and its short term and long term benefits
- and thirdly major investments on a large scale and its expected return over the period of depreciation of the investments.

The study should result in tools and guidelines for the definition and evaluation of future projects. These are meant to compare the costs and benefits and to evaluate the social, economic and environmental impacts of each alternative.
This comparison will serve the Government of Cambodia to develop its own regional land use planning and provide a yardstick in discussions with major donors like the Asia Development Bank, the UNDP etc.

3. METHODOLOGY

The study will consist of the following activities:

1. Inventarization of development plans for Cambodia and the region, made by the government, by the Interim Mekong Committee and by other institutes.

2. Actualization of the data, regarding to natural resources, land and water use and farming systems, works actually under construction and social and economic variables most likely to influence future policies.

3. Specific study of the Tonle Sap ecosystem in order to understand the key-elements in the eco-system

4. Learning from the experiences in neighbouring countries

5. Description of possible future development frameworks with regard to their economical, social and environmental impacts

6. Development of an appropriate set of tools and guidelines, which will serve to the Government of Cambodia for decision making and development planning

3.1 Check of policies

The first activity is required to understand the "environment" of the study.

3.2 Data collection

The second activity of data collection is required to form a sound base for comparison of different alternatives.

a. Natural resources have been analyzed in annex 1 in a summarized way. These are mainly based on studies, made in the seventies. Especially the hydrological information needs to be detailed, including water quality and sediment load aspects. The impacts of the artificial grit of irrigation canals, constructed since 1975, on the hydrological behaviour of an area should be analyzed.

b. The land use information should be actualized:
   - b1. the different farming systems, including inputs and outputs (annex III gives an example check-lists)
   - b2. the rate of logging and the description of farming systems that include agro-forestry
   - b3. the methods of fishing

c. Few data are available about the social (including the views of the peasants) and economic context. It is deemed highly necessary to develop a policy which is endorsed by a large constituency to prevent political uproar.

d. Data should be collected about experiences with the environmental and health impacts of present land use systems in scientifically selected parts of Cambodia.

3.3 Tonle Sap ecological study

It is felt that a separate stage should be defined for a study of the Tonle Sap eco-system, as this is necessary for the judgement about the impact on the water use systems of Cambodia.
The objective of this sub-study is to define the key-elements in the Tonle Sap eco-system in order to define the ranges for the extension of the natural forest, the fluctuations of the water level, the nutrient content, the pesticide content and the sediment content.

3.4 Visit to neighbouring countries

This stage is meant to gain experience from neighbouring countries, as these have experienced already a lot with various development approaches. To make a comparison between the different development alternatives, it can be helpful to study the effectiveness impacts of the different development models in the neighbouring countries in relation to the socio-economic conditions in the region at large.

3.5 Comparative study of selected frameworks

In the fifth stage, a selection of relevant development alternatives are analyzed to experience with the criteria, tools and guidelines for evaluation. Different frameworks are compared with respect to economic, social and environmental outputs.

3.6 Development of guidelines and tools for evaluation

The last stage is meant to develop a guideline for the evaluation of projects in hydrology and agriculture. Annex II gives checklists for the development of such frameworks. Annex VI gives an example for a marine coastal zone.
This stage should also include the institutional aspects of land use planning:
- responsible institution for the planning
- responsible institution for the evaluation of proposed projects
- responsible institution for further environmental studies
- identification of needs for further training within these institutions

A third element in this final activity is the possible definition of the Terms of Reference for the definition of a Master Plan for land and water resources development.

3.7 Training

The survey could be used simultaneously for training of the involved Land Use Office on data collection, remote sensing, land evaluation and environmental surveys. The study can also be used for the training of students of the University of Phnom Penh, which may get the opportunity to do their final research within the project.

4. PHASING

Based on the above mentioned activities, one comes to the following phases. In a pre-phase the Interim Mekong Committee is consulted on the proposed study.

1. Study in Cambodia:
   a. Inventarization of the development plans of the Government, the priorities and the present criteria for appraisal: visits to the Ministries of Planning, and Agriculture (and Hydrology)
   This study of 1 week should result in a paper that sketches the framework for further activities
   b. Data collection
      b1. from literature, by analysis of existing land use surveys (10 maps 1:500,000 195/87; maps of irrigation systems) and by consultations of resource persons, e.g. GRET and IRRI which have collected a lot of information (4 weeks)
      b2. Remote sensing/ use of satellite images for the analysis of land use patterns (4 weeks)
      b3. from literature and consultations of resource persons at the Interim Mekong Committee in Bangkok (4 weeks)
      b4. by field surveys; this is especially required for the collection of information on farming systems (12 weeks)
   This will result in a briefing document; an updated version of annex 1.
   c. Definition of the program for the study of the key elements in the Tonle Sap eco-system (2 weeks)

2. Visits to Thailand and Vietnam (resp. 3 and 2 weeks)
   a. Visit to the Interim Mekong Committee for the presentation and discussion on the results of the first stage of the study
   b. Visits to specific areas
   c. Discussions with authorities responsible for the Mekong, with Civil Servants in the Ministry of Agriculture (including departments of Fisheries, Forestry and Environment) and business people.

3. Study of the key elements in the eco-system of the Tonle Sap. The study should cover at least one hydrological cycle, i.e. one year, and should be done by a hydrobiologist, an hydrologist/limnologist and a land-evaluator/agro-sociologist.

4. Reporting and analysis of the data; comparison of frameworks and the organization of the workshop at the end of the project (8 weeks)

One of the main obstacles in this process is the duration of the ecological study. It is thought that preliminary result will be published and used after half a year, excluding the ecological study.

5. INVOLVED PARTIES

The study will be implemented by an independent institution, preferably from the region: an university, a consultant or a combination of both. The supervision of an external consultant is recommended.

Next to this institute the following parties are involved:

- Project Holder: Ministry of Agriculture
- Counterpart: Land Use Office (Planning Department of the Ministry of Agriculture)
- Internal Advisor: Department for Hydrology
- External Advisors: Interim Mekong Committee, the University of Phnom Penh, GRET and IRRI
- Supervisor: external agency

A potential donor is the Dutch Ministry of International Cooperation, who has a special budget for Cambodia.
The Land Use Office will function as a counterpart, which means that members of the Office will be trained during the survey.

6. INPUTS

External time input can be estimated as follows.
Phases 1,2 and 4 last 40 weeks with a team of 2 people. This requires an external input of 20 man-months. Phase 3 lasts 56 weeks with a team of 3 people, which requires an external input of 39 man-months. Total external input will be about 50 man months. Other external inputs are required for survey equipment, offices, transport etc.
The local requirements for external funds should be defined.

ANNEX I, LAND USE AND NATURAL RESOURCES IN CAMBODIA

Mekong Basin

With a surface area of 609.000 km^2 the Lower Mekong Basin covers 80% of the entire basin. It covers the major part of Cambodia (90%; 154,730 km^2), except for the outmost SW: the western part of the southern Highlands. The total length of the main river is 4,200 km.

geology

The area is underlain by the old Indosinia Crust (granitic and metamorphic rocks), but is mainly covered by Mesozoic sedimentary rocks, whereas patches of basaltic volcanic rocks can be found in the area around Batambang. Outcrops of the Crystalline Basement are found in an extensive hilly area in the south, west of Phnom Penh, and in the central part of the North, west of Stung Treng.

Transgressions occurred in the Mesozoic, from which stem the widespread redbed sandstones and evaporites, which underlie large parts of the pediplains of the Korat and Tonle Sap Plains. The Southern Highlands and the Dangrek range are made out of these redbed sandstones. Remnants of an old platform cover of Upper Carboniferous - Lower Jurassic age are found in a large area, SE of Stung Treng.

In the Late Cretaceous, tectonic activity resulted in a main uplift with rift forming and folding. The uplift resulted in erosion/denudation. The Tertiary is characterized by block faulting. The extensive pediplains were formed during this era. During the Pleistocene there was a tectonic tilting with a downward movement of the SE (Mekong Delta). This tectonical history explains why there are hardly any Pleistocene sediments outside of the delta.

The Holocene is characterized by the rapid rising sea level. Sediments in the Lake of Tonle Sap reach a thickness of 2 m.

general physiography

In Cambodia, one can distinguish uplands (35%), pediplains and terraces (38%) and lowlands (27%), respectively unit A, B and C in Figure 1. Most of the uplands are underlain by acid rocks: granites, metamorphic rocks and sandstones. They form the Northern, eastern and western border of Cambodia; respectively the Dangrek Range, the Annamite Chain and the Southern Highlands. The depressions of Tonle Sap and the Lower Mekong are found in the central part, with the pediplains and terraces in between. Except for the fringe of the floodplains, these plains can be considered as the pediplains and

footslopes of the surrounding mountain zones.
Isolated hills and mountains may disturb this general outline (unit AB), like the central part North of the Tonle Sap Lake and the rolling landscape west of Phnom Penh. Along the west coast one finds the coastal complex with saline soils. Figure 2 gives the main geomorphological units.

climate

The climate of Cambodia is determined by monsoons. The SW-monsoon prevails between May and November, with 80% of the annual rainfall. The NE-monsoon prevails between December and May, in which period the precipitation is under 60 mm/month.

The Lowlands have a tropical climate with wet and dry seasons (Köppen). Annual variation in rainfall is very high; for Siem Reap it is between 466 and 2056 mm with an average of 1431 mm. Lateral variation in the average annual rainfall is between 1000 mm (Tonle Sap) to 1875 mm, except for the delta area, where it may be higher (<2500 mm).
For agriculture, the main problem is the erratic rainfall, also in the wet season. It means that to combat the risks of droughts, one needs supplementary irrigation of 280 mm/yr on the average to 800 mm/yr in one of the 10 years.
With an average of 27° C, temperatures are high, except during the early part of the NE monsoon when occasional outbreaks of cool air from central Asia sweep over the land during a period of a few days to some weeks. Potential evaporation varies from 80 mm in January to 160 mm in July.

The Uplands have a tropical monsoon to subtropical wet and dry climate (Köppen). Most of the uplands receive more than 1875 mm/yr (up to 5000 mm, with the exception of the Northern Highlands which has between 1275 and 1875 mm. Mean temperatures are between 19 and 24° C.

water resources

Mean annual discharge of the Mekong River is 475,000 10E6 m^3, or 0.63 10E6 $m^3/km^2/yr$ or 625 mm/yr. Main part of the discharge comes from the uplands: 70 % from the Northern Highlands and the Annomite Chain, which cover 50% of the area.

Table: Major catchments in Cambodia

		Run off		
	Area km²	Volume m^3/yr	Depth mm/yr	% of Rainfall
Tonle Sap	84.000	32 10^9	380	ca 25 %
Se San	77.000	97 10^9	1260	ca 40 %
Prek Chlong	5.300	3 10^9	570	ca 25 %
Prek Te	3.800	3 10^9	790	ca 30 %

Maximum discharges occur in August/September in the upstream part and September/October in the downstream part. Floodways

in the upper reach are 10 km (Thailand) to 5 km (Laos) wide. South of Kratie banks are overtopped when the river stage is 7 m above sea level.
The Retention by the Great Lake is functioning between May and October when, on the average, 60,000 10^6 m^3 flows into the lake catchment; the outflow is 84,000 10^6 m^3/yr.

From December onward, the main river is only fed by base flow. Minimum discharges occur at the ends of the dry season. Average annual low flow is 3.11 l/s/km² in Chiang Saen (639 m^3/s) and 2.7 l/s/km² in Kratie (1764 m^3/sec). The absolute minima are respectively 543 m^3/s and 1250 m^3/s.

Sediment load increases in the upper part to Kratie (140 10^6 ton/yr) whereafter it diminishes, because of sedimentation. The average reach is 500-1000-1500 ppm. The minimum is about 50 ppm in February. Investigations on the nutrient contribution of the flood sediment to soils in the delta indicate that this contribution is very limited, especially because of the richness of the soil itself. The difference is 1 kg Phosphorous, 3.2 kg Potassium, 4 kg Magnesium and 50 kg Ca per ha. Hence the nutrient supply can easily be changed in a more artificial supply, if needed.

Chemical quality is good up to the mouth of the river, where sea water intrusion is a serious risk. At a (minimum) flow of 2000 m^3/s in Phnom Penh, the intrusion reaches 65 km inland.

Flooding of land is very common, not only in the river valleys and the entire delta, but also on the higher plains. A wide area around the Great Lake are frequently flooded. In total about 10 10^6 ha is flooded in the Lower Mekong Basin, as was analyzed from satellites (Figure 3). The actual farming systems rely on this flooding for rice, but it is uncontrolled and risk of damage is very high depending the velocity, rate of rise, depth and duration. Local rice varieties are much more adapted to these circumstances than introduced ones.
A problem is that many of the flooded plains have drought problems in the dry season, combined with salty soils.

hydrological projects

Flood mitigation and artificial water storage are not widespread in Cambodia. The Prek Thnot dam is the major example. Most of the dams, built in the tributaries of the Mekong, Bassac and Tonle Sap, constructed in the period 1975-1979 have been flushed away, or the rivers have eroded a new bed next to the dam.

The extensive square network of "irrigation canals" in the flood plains, constructed in the same period over an area of a more than a million ha is in a far stage of decay. It never functioned properly (Van der Linden, 1989)

Unless many advanced plans of the Mekong Committee, no major mainstream works have been carried out, so far. In an updated indicative plan of 1987, the Interim Mekong Committee lances a plan for a cascade of mainstream dams, of which the most downstream one is Samhor near Kratie. (see Figure 9). Upstream are the projected Stung Treng dam and the Khone Falls dam at the frontier. Also a main dam in the Tonle Sap is projected near Kompong Chinang. Especially the Stung Treng reservoir will cover a huge surface area of more than 2000 km².

Also a number of minor dams are projected, mainly for irrigation purposes:

- 7 in the northern part of the Tonle Sap Basin
- 8 in the southern part of the Tonle Sap Basin
- 11 in Cambodia's part of the Se San Basin, whereas 21 dams are projected in Vietnam's and Laos's part of the Se San Basin of which 1 is constructed
- 7 in the Prek Te basin
- 3 others in the SE
- 12 dams in western part of the Southern Highlands

soils

"Once flood and drought conditions are improved through water control, soil characteristics become the major constraint for agriculture.." (CCILMB, 1978). In the past a number of efforts have been made for soil surveys and land capability classifications on a reconnaissance scale:

- 1972 Land Capability Map 1/1,000,000 (vd Kevie)
- 1975? Soil Map according to FAO classification
- 1977 Pedo-morphological Map of the Lower Mekong Basin 1/1,000,000 (Ceruse), giving an indicative picture for preliminary agricultural planning; the screening of alternative agricultural systems.

In this study, use is made of the pedo-morphological map of Cambodia, scale 1:500,000, presented by the LUMO office, here presented on a minor scale (Figure 4). Figure 5 gives the soils, according to the FAO classification, whereas Figure 6 gives the soil capability of the pedo-morphological units.

In the sandstone and quartzitic areas (80%) podzolic and lateritic soils are dominant (mainly acrisols). The podzolic soils are characterized by a nutrient deficiency. In the eastern part of the Mekong Plains in Cambodia, planosols and plinthitic soils are common (ferric cambisols and acrisols). Lateritic soils are mostly formed under former groundwater conditions and are found on the pediplains. Limestones and basalts (10%) are covered by red and brown soils with a higher fertility (ferralsols).
Alluvium has young soils. Fluvisols are found directly along the river banks. Well drained cambisols are found on the levees of the Mekong and gleysols are dominant in the remaining part of the flood areas.
Paddy soils (under influence of the rice cultivation) have hydromorphic characteristics, have a very low Cation Exchange

capacity and are mainly classified as low humic gleysols.

Table 1 gives a characterization of the different pedo-morphological zones.

Poor internal drainage, difficult tillage of the B-horizont, poor structure of the upper horizon and a very low mineral content are the main restrictions of most of the soils, except for the lower valley soils.

land use

Most of the "natural vegetation" is secondary forest. Forest type is mainly relying on altitude, rainfall and soil type. Natural resources in the forests vary from food and timber to medicines, resins, gums, pesticides and wildlife. Timber is used for fuel (1 - 2 m^3/cap/yr), construction and paper.

The CCILMB distinguished 9 types of land use in Cambodia in the late seventies (Figure 7):

1. Swamp forest and inundated woody vegetation in all the floodplains of the Lower part of the Mekong Valley and the Tonle Sap depression; 680,000 ha in 1978 (15%)
2. Non forested wetlands in small areas at the northern margin of the Tonle Sap flood plains (2%)
3. Paddy fields on the lower terraces and in the tributaries with an exception of the eastern part of the lower terraces in the SE (very poor quality; 15%)
4. Two units of rubber plantations, North of Kg Cham (1%)
5. A small unit of Brushwood, north of Siem Reap (1%)
6. Agricultural land with some forest in 3 relatively small areas on the pediplains (2%)
7. predominant forest with little cultivation on the pediplains NW of Phnom Penh and in a few mountain areas (4%)
8. Sparse to clear forest, especially on the pediplains (35%)
9. Dense forest, especially on the mountains (25%)

According to satellite images, the forest cover has been reduced from 73% to under 50% in 20 years (The Nation, 9/7/1991). According to this newspaper, 700,000 cubic metres of wood is cleared, annually. The lowlands that surround the Tonle Sap and Mekong Rivers (unit 1) are the first to be deforested. Second are the pediplains to the North of the Lake and third timber logging to the south of the lake and around Kratie and Stung Treng.

In a tentative land use model, the CCILMB study gives priority to the following zones (Figure 8):

1. the reclamation of the first 2 areas (forested and non-forested wetlands)
2. improvement of the paddy rice on the lower terraces, by a change from broadcast to transplanted rice

3. expanded riverbank agriculture along the Lower part of the Mekong river
4. dry land agriculture in selected areas: Batambang plateau and 4 areas on basic rocks: an area N of Kg Cham, and 3 areas along the E border.

It is remarkable, that most of the priorities lie in wetland areas. Wetlands are very sensitive for disturbance and are essential parts of regional ecosystems, functioning as a retention for floods, a buffer for erosion and a rest place for animal migration routes. Especially the fish cycle is much depending on these annually inundating wetlands.

In the indicative plan of the Interim Mekong Committee, a number of large scale irrigation areas are projected, apart from the existing Prek Thnot/Kompong Speu and Bovel schemes (Figure 9):
- the entire valley of the Mekong from Kratie to the Vietnam frontier
- 7 irrigation areas of 200 - 1200 km² are projected around the Tonle Sap Basin. Most of them will receive the water from upstream reservoirs and only the downstream parts lay in the traditional flood areas.
- 5 irrigation areas are planned in the coastal zone, west of the Southern Highlands
- 5 large irrigation areas in the Se San Basin, ranging in size from 200 - 1000 km².
- 3 irrigation areas near Kratie

farmer systems

<u>swidden agriculture</u>
Farmer systems in the uplands are mainly characterized by swidden burned field agriculture with a cycle of 10 years and a minimum of inputs (almost no tools). A family needs about 30 ha of land. For protein one is relying on small domestic animals, fish and game. There are about 75 varieties of food crops.
The principal crop is rice. The initial yields are very high (1-1.6-4 ton/ha) but diminish with 25% each following year. Indicative yields of other crops are: 175 kg/rai for cotton, 428 kg/rai for maize (quickly diminishing), 185 kg/rai for peanuts in the second year and 178 kg/rai for peanuts in the second year. Fruit trees and irrigated rice are only practised on the best soils.
If swidden agriculture is applied in the traditional way on basic soils and without too much land pressure, it is little destructive for the environment, because it includes a number of traditional conservation measures:
- preservation of stands of timber
- fire control
- early cutting for moisture conservation
- careful rotation with short plantations to avoid the entrance of grass (Imperata)

- control of weeds: the main reason to abandon a field
- minimum disturbances of the top soil
- game cropping

Because of the increased land pressure and the intensification of logging, these traditional measures come under threat. Cycles are shortened, people have to move to poorer soils on the acid rocks and people apply longer occupations, especially for opium.

About 20% of the lowland farmers apply a certain type of swidden agriculture. As this is not rooted in traditional farming systems, it is very destructive for the environment. In this respect, the uncontrolled fires in the northern part of the country (CCILMB, 1978).

<u>traditional bonded field farming/ rainfed rice</u>
Already since 2000 years, bonded field farming is practised in the SE of Cambodia, especially in the areas with a high risk of acidification on the lower terraces. In this respect, the traditional water management is essential to prevent the soil from turning acid and to maintain a certain nitrogen cycle. The system is designed to keep the rainwater on the fields. Networks of small canals distribute the flood waters over the fields. There is a fallow period during the dry season.
It is very labour intensive and requires agricultural tools and draft animals. Required land size is 1.5 to 3.0 ha/family. Bonded field farming is mono-cropping of rice. Yields are comparable to the yields of swidden agriculture: 1 - 1.5 - 4 ton/ha and increase when the size of the plots reduce.
In many areas, bonded field farming is at the limit of maximum extension and productivity.

<u>Flood recession irrigated rice</u>
When the water level on the flood plains start to recede - in October, November, the fields are prepared for flood recession rice. When the rains stop, the fields are irrigated with the available flood water using a complicated system of small dikes, and traditional water lifting devices.

<u>Extractive agriculture</u>
Extractive agriculture refers to exploitation systems that deplete the soil or vegetation in an irreversible way. It gives an immediate high return at relatively low short term costs, but at the expense of basic natural resources. In the past, the Khmer cultures have applied this type of agriculture in the northern part of Cambodia, leading to the degradation of the soils on the pediplains. Actually, this kind of agriculture is often applied for rapid returns to raise the national economy of the country. Care must be taken to ensure that at the appropriate time, extractive agriculture be transformed into more sustained yielding systems, and this will require that some of the profits obtained from extractive agriculture be re-invested in the more productive systems. Especially the upland crops are produced in this way: cotton, sugar, kenaf, cassava and maize. Logging of timber can be considered to belong to the same type of extractive

agriculture.
The long term costs of the effects of extractive agriculture may be very high: soil erosion/conservation, silting of reservoirs and traditional canal systems etc.

modern sustained yield agro-ecosystems
In the 1978 study of the CCILMB the following alternative modern sustained yield agro-ecosystems were mentioned:

1. ranching
Extensive ranching is an acceptable extensive land use system in dry temperate grassland areas, lacking population pressure. A few areas fulfil the criteria for this use: northern and easter Cambodia, which are sparsely populated grassy savannas, where mixed ranching of domestic and wild herbivores may be applied.

2. integrated livestock
Domestic herbivores are managed as part of an integrated crop and livestock enterprise. Animals subsist on waste crop residues and provide draft power and produce nutrients. Cattle serves as a buffer in capital. The most promising approach is the rotational system of grass/legumes pasture with rainfed cash crops. Studies indicate a farm size of 8 to 10 ha in the upland areas. In contrast to the swidden agriculture, this system is based on the rotation of crops. But since this system is new in Cambodia, much assistance, both technical and financial, will be required if it is to become established.

3. Agro-forestry
Crops of trees are grown along with cash crops in the uplands. Agro-forestry can transform extractive forestry into a long term sustained yield system. Management of the capital (of trees) will require a longer term proposition. Forest Farmers Cooperatives can act as middleman between farmers and industry. The product can also be used for fuels like ethanol etc. Finally, forest farming would also provide extensive employment opportunities.

4. Commercial plantations
Highly specialized commercial fruit and vegetable growing may be applied on the fertile valley soils, but require a good management system, and a well advanced transport, storage and market system. These conditions are yet difficult to fulfil. Coffee, rubber and tea may be alternative crops in areas with specific climatological and soil conditions.

5. Irrigated farm systems
The above mentioned systems can never fulfil the future food demand. The only possibility to reach a level of food production is to develop and extend the irrigated farm systems. Annex IV gives a summary of the constraints for the development of modern irrigation.

fishery

Nearly all farmers in the lowlands engage subsistence fishing. It is estimated on 100,000 ton/year. Aquaculture is already developed in Vietnam, where fish ponds produce about 37 ton/ha.
The traditional fishery is relying on the natural cycle in the fish migration. Flooding and especially the cycle of the Tonle Sap Lake is essential for this cycle. About 85% of the fish species make use of the inundations of land during the rainy season.
The fish-ecosystem study of the Mekong Committee in 1974-77 didn't result in the full comprehension of the complex migratory eco-system.
The fishery in the Tonle Sap Lake is depleting since long. In 1940 the production was 80.000 ton/yr, in 1965 25,000 ton. It is not known why the production is declining. One of the possibilities is overexploitation, the other is deforestation of the wetlands.

Literature

- Committee for the Coordination if Investigation of the Lower Mekong Basin (1978, draft) AGRICULTURE IN THE LOWER MEKONG BASIN

Table 1: Characteristics of the pedo-morphological units

mapping unit	Main unit, sub unit,	Main soil types	Salt content of the soil	Cation Exchange Capacity	Content in Organic Matter	pH (N = Neutral)	Water Holding Capacity	Internal Drainage	External Drainage	Flood Risk	Present land use	Potential land use	Required land improvement
	LOWLANDS												
	Coastal Complex												
14	Low tidal flats	gl. solonch. alluvial soils	H	L	M	N	+	-	-	VH	Paddy Rice	Paddy Rice	Perm.irr., leaching, Drainage, dikes
(14)	High tidal flats	Gleysols	M	H	M	L	+	-	+	H	Paddy Rice Coconuts	Paddy Rice Dry food	Drainage
(14)	Sand ridges	Regosols ?	M	L	L	N	-	+	+	L	Dry food cr Palms, fruits	Dry food cr Vegetables	sm.sc.irr, fertilizer
(14)	Inland depressions	Humic Gleysols Peat soils	?	H	H	L	+	?	?	VH	Not used	Paddy ?	?
	Delta Lands												
6	Inland delta	Thionc Gleysols	H	H	?	L	+	-	-	VH	SO4<50 cm:no; deeper: Paddy	Paddy	Inundation, High grw. Start frm river
	Flood Plains												
(2)	Levees	Rego/Cambisols	L	M	L	N	-	+	-	M	dry food,fruit	dito	Soil&water management; fertil., irr
1	River Banks	Fluvisols	L	H	M	N	+	-	-	H	dry food? paddy?	dry food	protection
2,4	Back swamps	Eutr. Gleysols	L	H	L	N	+	-	-	H	little	Paddy	Soil&water management, continuously flooding
3	Tonle Sape depression	Eutr. Gleysols	L	H	M	N	+	-	M	H	floating rice	dito	flood protect. from tributuaries
	Pediplains (terraces)												
8	Lower terraces	Gl. Acrisols,	L	L	L	L	+	-	M	M	Paddy	dito	leaching, drainage, controlled fertilizer
9	Battambang Pl.	Gl Luvisols	M	H	L	N	+	M	+	M	Dry food Paddy	Paddy Upland crops	flood protection
10	middle ter/ pediplains	Ferric Cambisols	L	L	L	N	-	M	+	-	Very dry fd Fertilizer	Dry food	Management,
11	Higher ter/ pediplains	Ferric Acrisols	L	L	L	L	-	+	-	M	Grassland	Grassland	Impossible
	MIDDLE TO HIGHER PLATEAUS AND MOUNTAINS												
15-17	Basalt plateaus	Black&red s. Rhod. Ferralsols	L	M	L	N	+	+	+	-	Rainfed, high yields	All crops	Management
23	Mountainous areas	Litosols, Orthic Acrisols	L	H	L	N	M	+	+		Forest	Small areas - with micro-cl	

VH= Very High
H = High
L = Low
M = Medium
N = Neutral
+ = High
- = Low

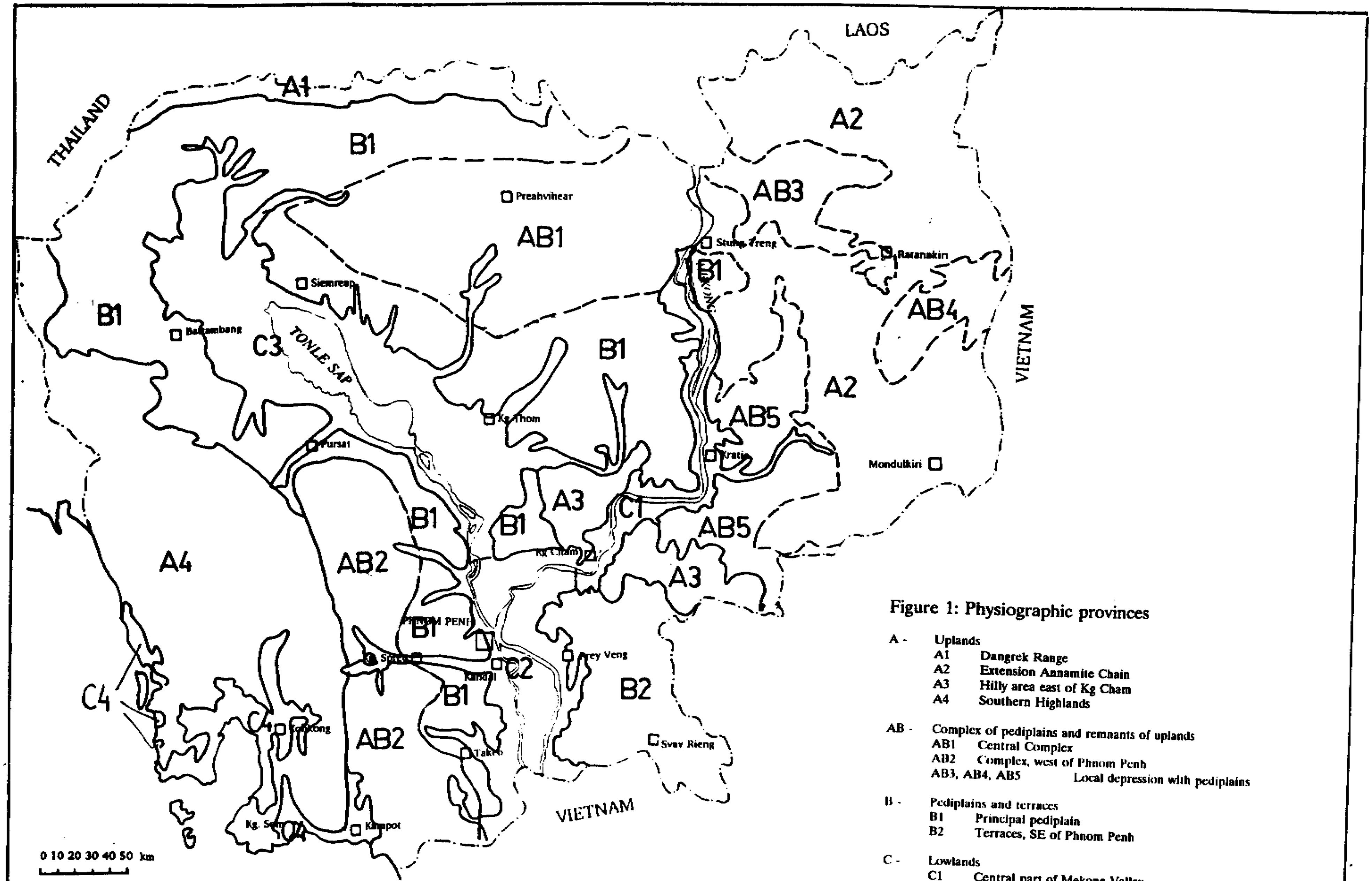

Figure 1: Physiographic provinces

- A - Uplands
  - A1 Dangrek Range
  - A2 Extension Annamite Chain
  - A3 Hilly area east of Kg Cham
  - A4 Southern Highlands
- AB - Complex of pediplains and remnants of uplands
  - AB1 Central Complex
  - AB2 Complex, west of Phnom Penh
  - AB3, AB4, AB5 Local depression with pediplains
- B - Pediplains and terraces
  - B1 Principal pediplain
  - B2 Terraces, SE of Phnom Penh
- C - Lowlands
  - C1 Central part of Mekong Valley
  - C2 Lower Mekong Valley
  - C3 Tonle Sap Depression
  - C4 Coastal Complex

(this map is partly derived from the "Carte pedo-geomorphologique du Cambodge", original scale 1:500,000)

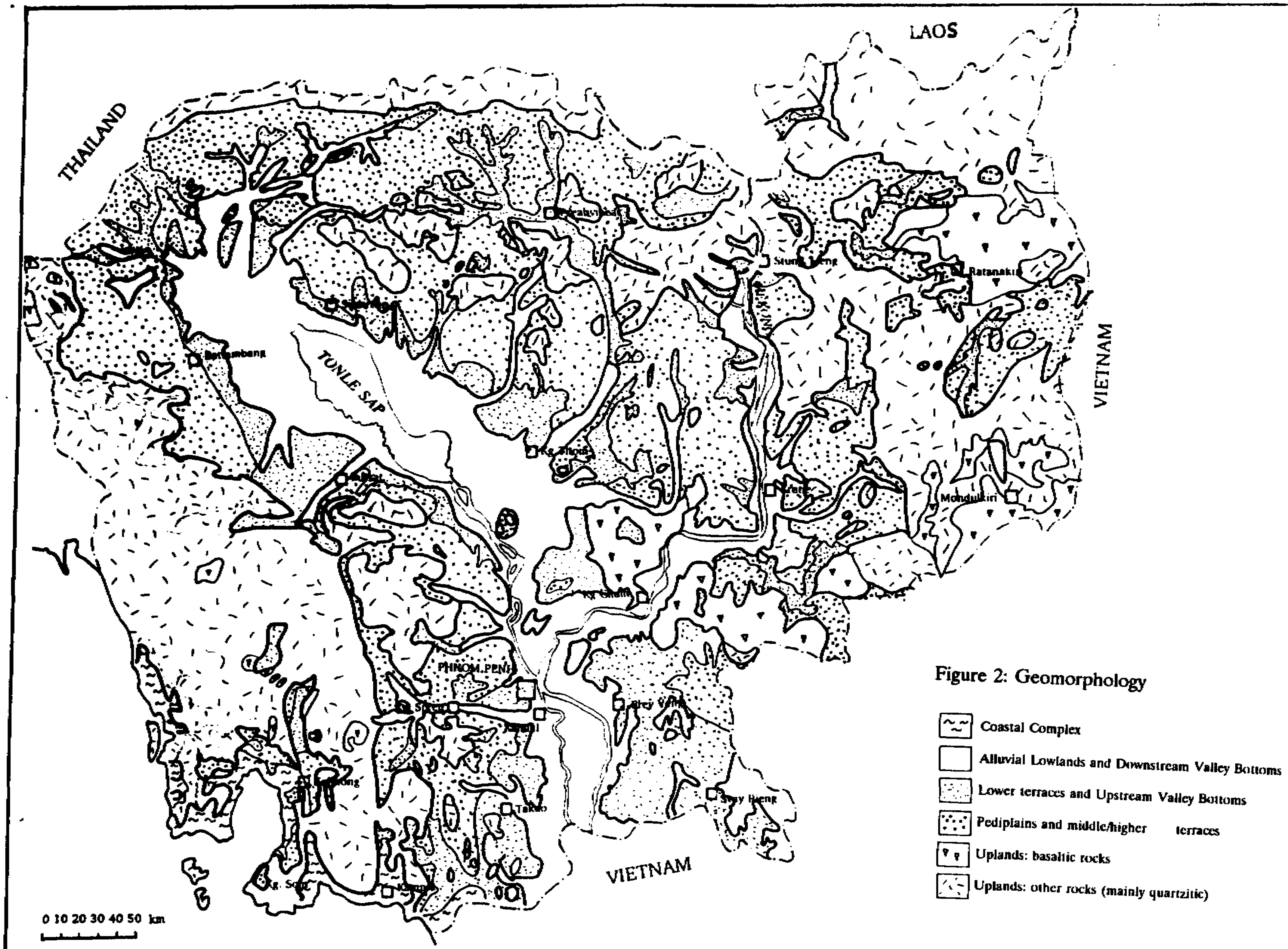

Figure 2: Geomorphology

(this map is partly derived from the "Carte pedo-geomorphologique du Cambodge", original scale 1:500,000)

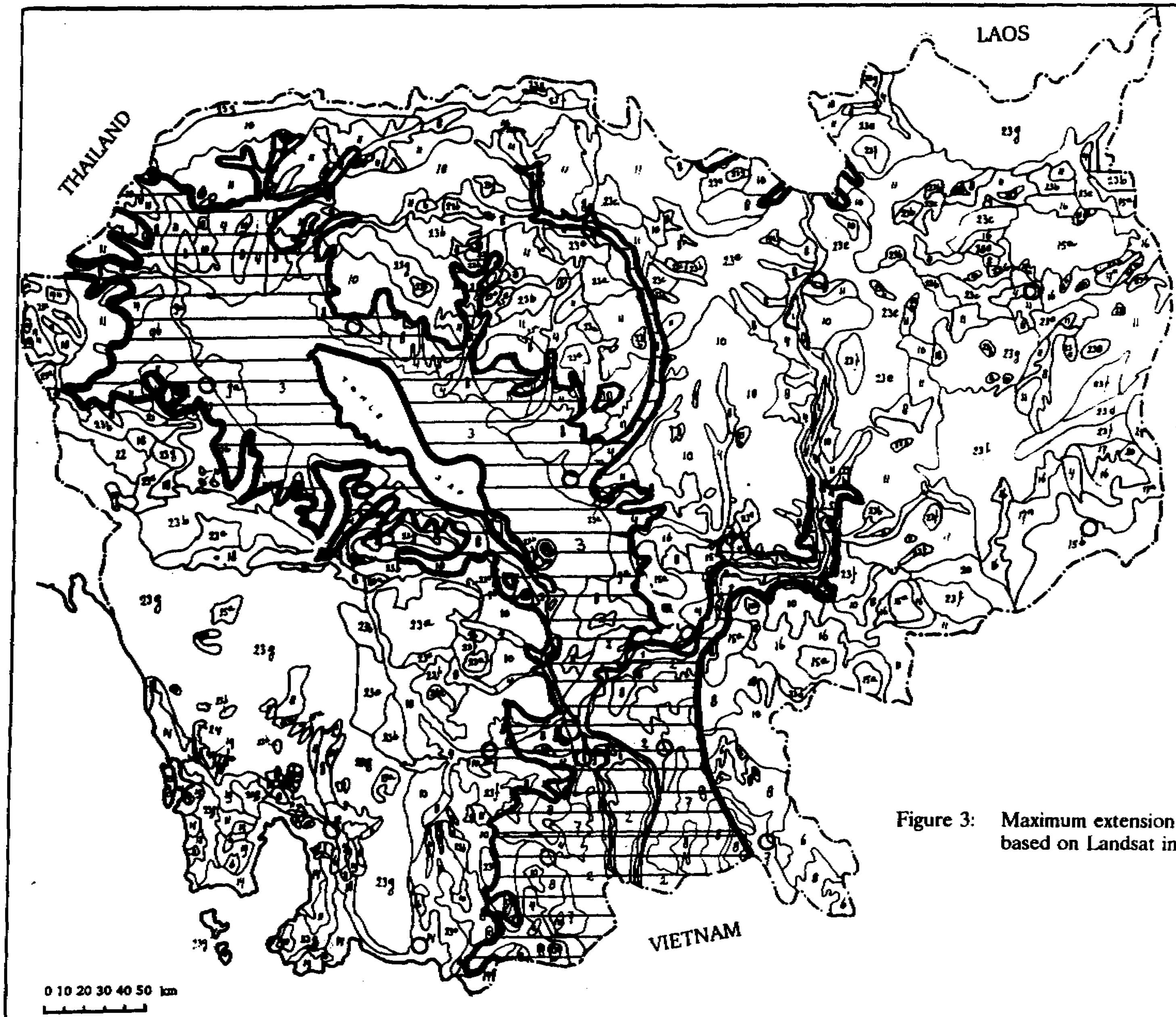

Figure 3: Maximum extension of inundated area (after CCILMB 1978, based on Landsat interpretation)

(this map is partly derived from the "Carte pedo-geomorphologique du Cambodge", original scale 1:500,000)

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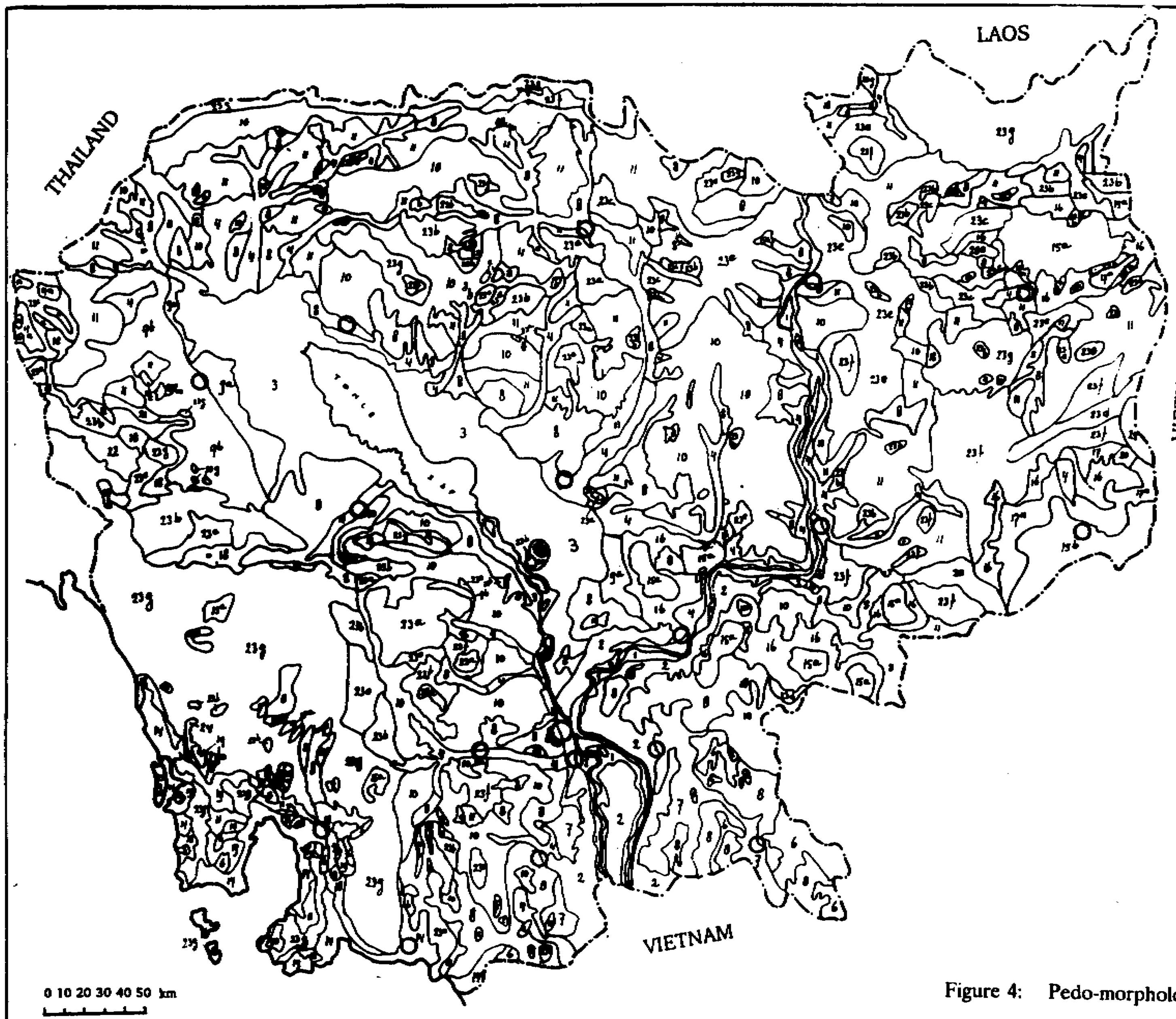


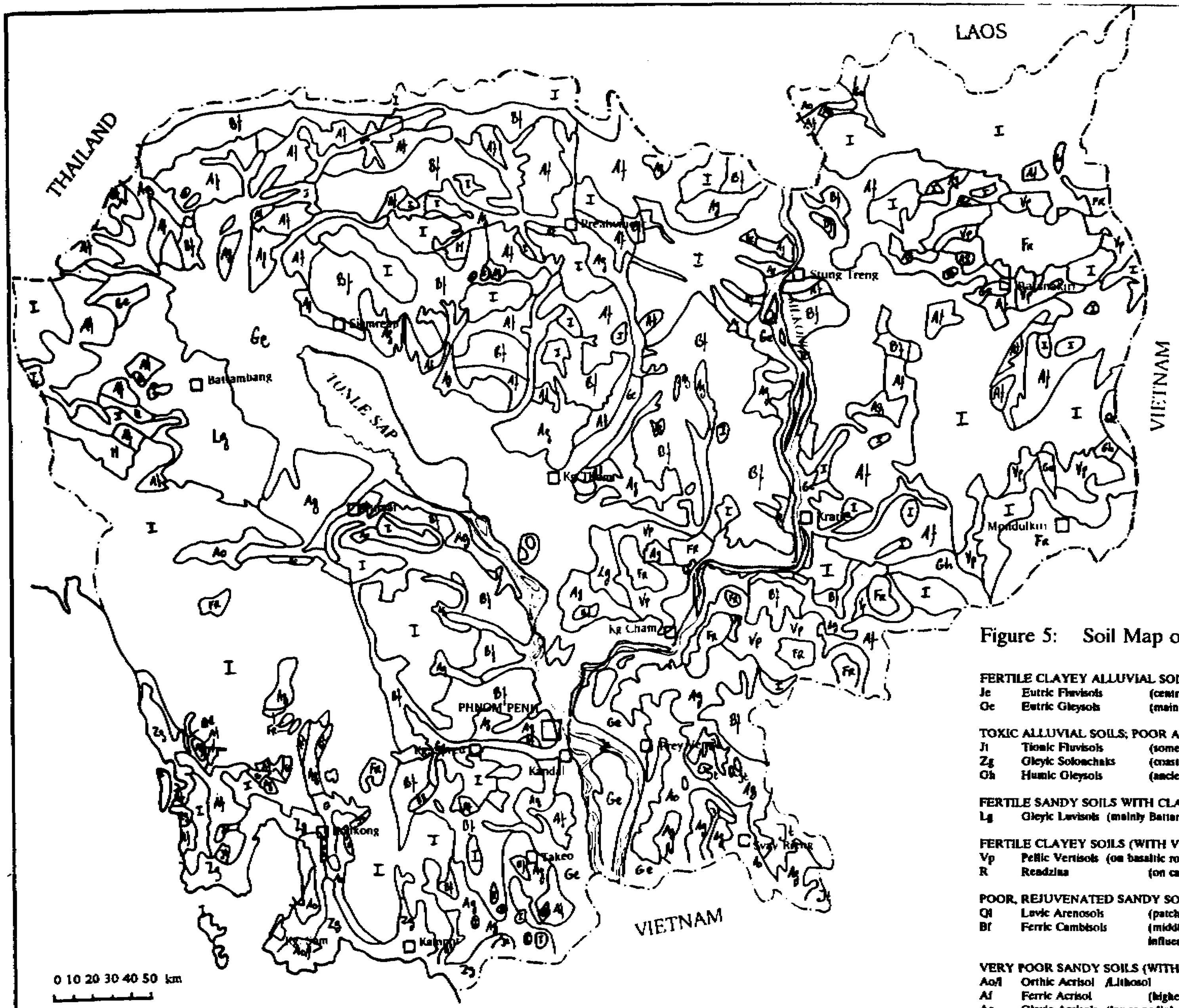
Figure 4: Pedo-morphological map of Cambodia

For legend: see next page

(this map is partly derived from the "Carte pedo-geomorphologique du Cambodge", original scale 1:500,000)

Morphological Unit		Soil Unit			
Group	Unit	(French)		FAO	Character*
BASSIN D'ACCUMULATION	Berge de fleuve	Sols alluviaux bruns de berges	1	Eutric fluvisols	2.3.5
	Marais d'arrière-berge	Sols alluviaux	2	Eutric gleysols ass. à Mollic gleysols	4.3.5
	Plaine d'inondation centrale	Dépôts lacustres	3	Eutric gleysols	3.3.5
	Plaine d'inondation rubannée	Sols alluviaux	4	Eutric gleysols ass. à Eutric fluvisols	3.3.2
	Dépression centrale	Sols alunés	[illegible]	Thionic fluvisols ass. à Humic gleysols	1.1.1(a)
PAYSAGE D'ABLATION ET D'ACCUMULATION	Basse terrasse	Sols alluviaux	7	Ferric cambisols	3.1.2
		Sols hydromorphes culturaux Sols hydromorphes gris Planosols	8	Gleyic acrisols ass. à Dystric planosols	3.1.2
		Sols hydromorphes bruns	9a	Gleyic luvisols ass. à Eutric gleysols	4.3.3
	Haute et moyenne terrasses	Sols hydromorphes bruns	9b	Gleyic luvisols ass. à Orthic fluvisols	4.3.3
		Sols podzoliques rouges-jaunes	10	Ferralic cambisols ass. à Ferric acrisols	2.2.1
		Argiles latéritiques	11	Ferric acrisols ass. à Plinthic acrisols	2.2.1
		Sols alluviaux	12	Sols alluviaux non-différenciés	2.1.2
	complexe côtier	Complexe côtier	[illegible]	Gleyic solonchaks ass. à Thionic fluvisols et Eutric fluvisols	2.2.2(s)
PAYSAGE DE MONTAGNE ET HAUT PLATEAU	Plateau basaltique cendre	Latosols basaltiques	15a	Rhodic ferralsols	3.3
	Plateau basaltique coulée	Lithosols basiques	15b	Rhodic ferralsols ass. à Orthic ferralsols	3.3
	Coulée basaltique basse	Regurs basaltiques	16	Pellic vertisols ass. à chromic vertisols	3.3
	Dome basaltique	Lithosols basiques	[illegible]	17n Lithosols ass. à Haplic phaeozems	1.1.
	Colline calcaire	Lithosols basique	[illegible]	17m Lithosols ass. à Haplic phaeozems	1.1.
	Éboulis sur pente	Sols podzoliques rouges-jaunes	[illegible]	Orthic acrisols ass. à Dystric nitosols et à Ferralic cambisols	1.2.
	Eboulis sur crête	Sols podzoliques rouges-jaunes	19	Ferric acrisols, phase cuirassée	1.2
	Alluvions de vallée suspendue	Sols hydromorphes latéritiques	[illegible]	Humic gleysols ass. à Dystric gleysols phase cuirassée	1.1.
	Karsts	Régurs calcimorphiques	21	Rendzines ass. à Pellic vertisols et Calcaric cambisols	3.3.?
	Bassin de décantation	Latosols	22	Dystric nitosols ass. à chromic cambisols	1.2.2
	Dome granitique	Lithosols acides	[illegible]	Orthic acrisols ass. à Lithosols	2.1.
	Dome rhyo-dacitique		[illegible]		2.1.
	Plateau de schiste argileuse		[illegible]		2.1.
	Plateau de marne		[illegible]		2.1.
	Plateau de calcaire argileuse		[illegible]		2.1.
	Plateau de schiste greseux Dévono-carbon.		[illegible]		2.1
	Plateau de grès conglomératique Jurassique-Crétacée		23g		2.1.
			24	Luvic arenosols	1.1.

*	first number texture	second number thickness of arable soil	third number suitability	Toxidity
1.	sandy	0 - 30 cm	low	a. acid
2.	sandy loam	30 - 50 cm	medium	
3.	clayey loam	> 50 cm	high	s. saline
4.	clay			



(this map is partly derived from the "Carte pedo-geomorphologique du Cambodge", original scale 1:500,000)

Figure 5: Soil Map of Cambodia (FAO classification)

FERTILE CLAYEY ALLUVIAL SOILS
Je Eutric Fluvisols (central part of main valley; unit includes levees with sandy soils)
Ge Eutric Gleysols (main part flooded areas)

TOXIC ALLUVIAL SOILS; POOR ALLUVIAL SOILS
Jt Thionic Fluvisols (some coastal/delta plains in S; toxic/acid)
Zg Gleyic Solonchaks (coastal complex; saline soils)
Gh Humic Gleysols (ancient valley bottoms; 2 patches in E)

FERTILE SANDY SOILS WITH CLAYEY B-HORIZON
Lg Gleyic Luvisols (mainly Battambang Plains)

FERTILE CLAYEY SOILS (WITH VERTIC CHARACTERISTICS)
Vp Pellic Vertisols (on basaltic rocks)
R Rendzina (on calcareous rocks)

POOR, REJUVENATED SANDY SOILS
Ql Luvic Arenosols (patches on old sandstone plateau: poor)
Bf Ferric Cambisols (middle pediplains, probably on reworked sands of pediplain; influence ancient groundwater table)

VERY POOR SANDY SOILS (WITH CLAYEY B-HORIZON)
Ao/l Orthic Acrisol /Lithosol (main unit of uplands)
Af Ferric Acrisol (higher pediplains, influence ancient groundwater table)
Ag Gleyic Acrisols (lower pediplains; terraces; associated to Planosols; more suitable than other acrisols)

ANCIENT SOILS
Fr Rhodic Ferralsols (on basalt plateaus; rather fertile)
N Nitosols (1 unit E of Battambang)

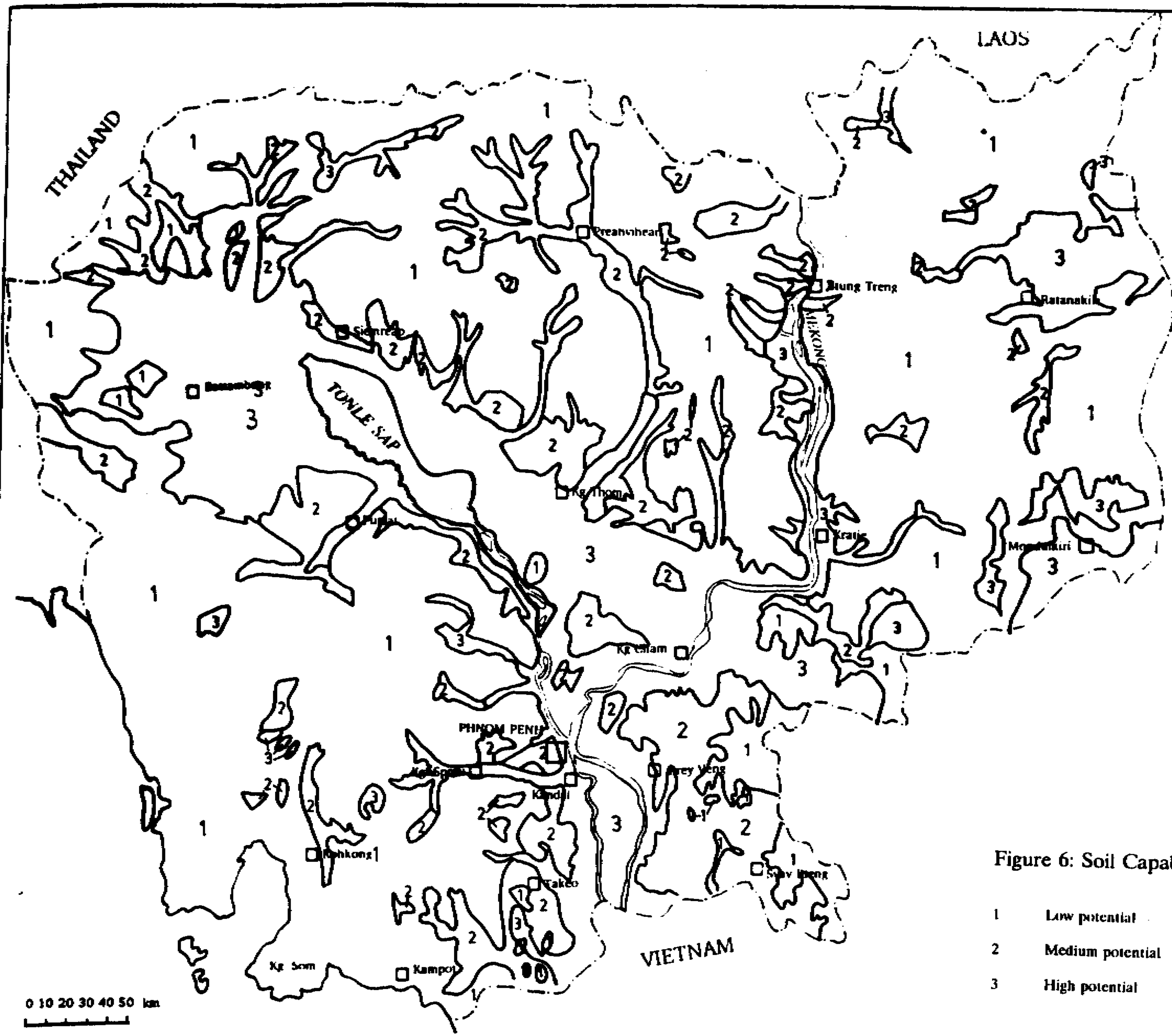


Figure 6: Soil Capability for agricultural development

		pedo-morphological units/soil units
1	Low potential	6,10,11,14,17,18,19,20,23,24 Jt,Bf,Af,Zg,I,Ao,Gh,Ql
2	Medium potential	7,8,12,22 Af, Ag, N
3	High potential	1,2,3,4,9a,9b,15a,15b,16,21 Je,Gc,Lg,Fr,Vp,R

(this map is partly derived from the "Carte pedo-geomorphologique du Cambodge", original scale 1:500,000)

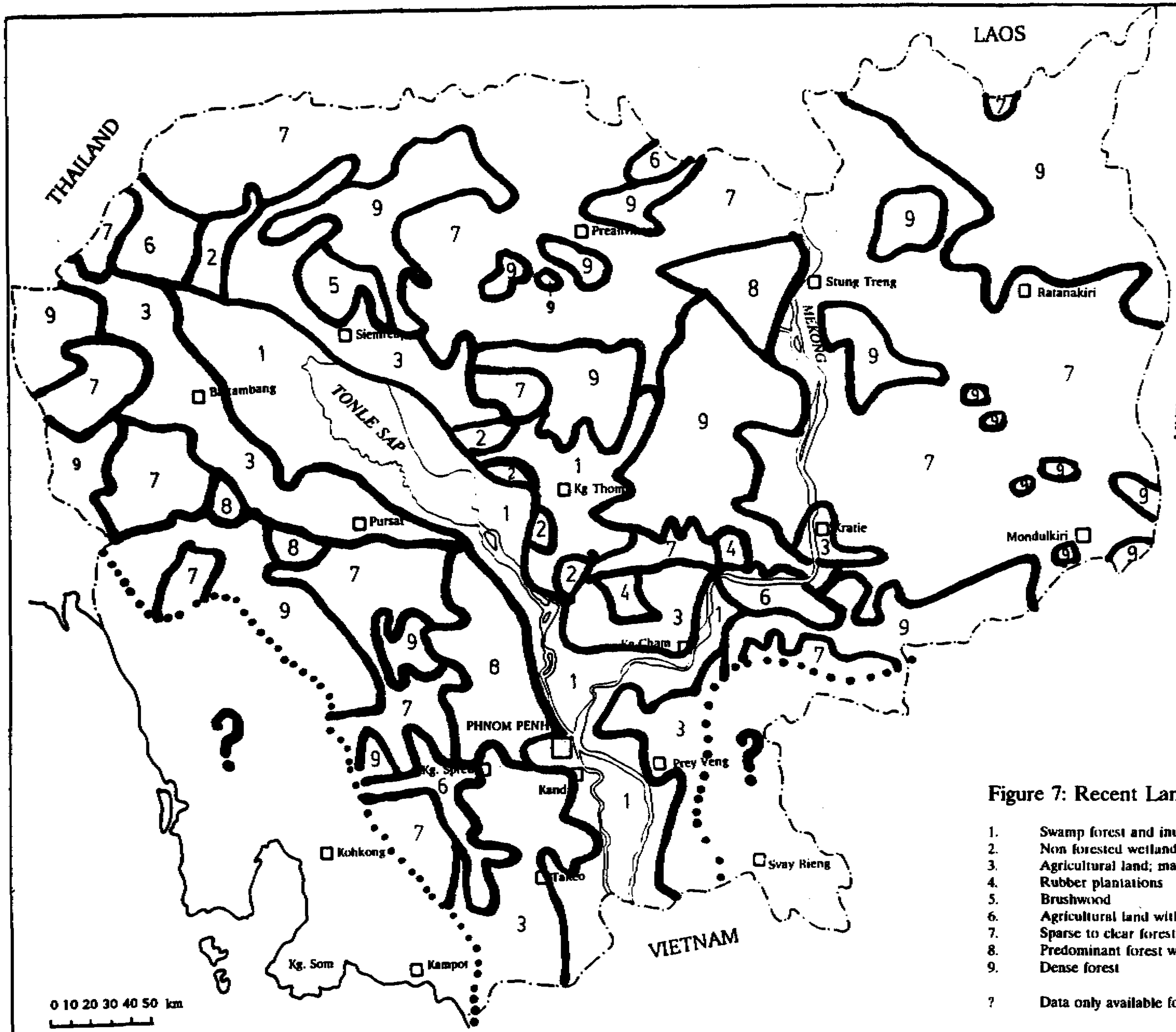


Figure 7: Recent Land Use (after CCILMB 1978)

1. Swamp forest and inundated woody vegetation
2. Non forested wetlands
3. Agricultural land; mainly paddy rice
4. Rubber plantations
5. Brushwood
6. Agricultural land with some forest
7. Sparse to clear forest
8. Predominant forest with little cultivation
9. Dense forest

? Data only available for Lower Mekong Basin

(this map is partly derived from the "Carte pedo-geomorphologique du Cambodge", original scale 1:500,000)

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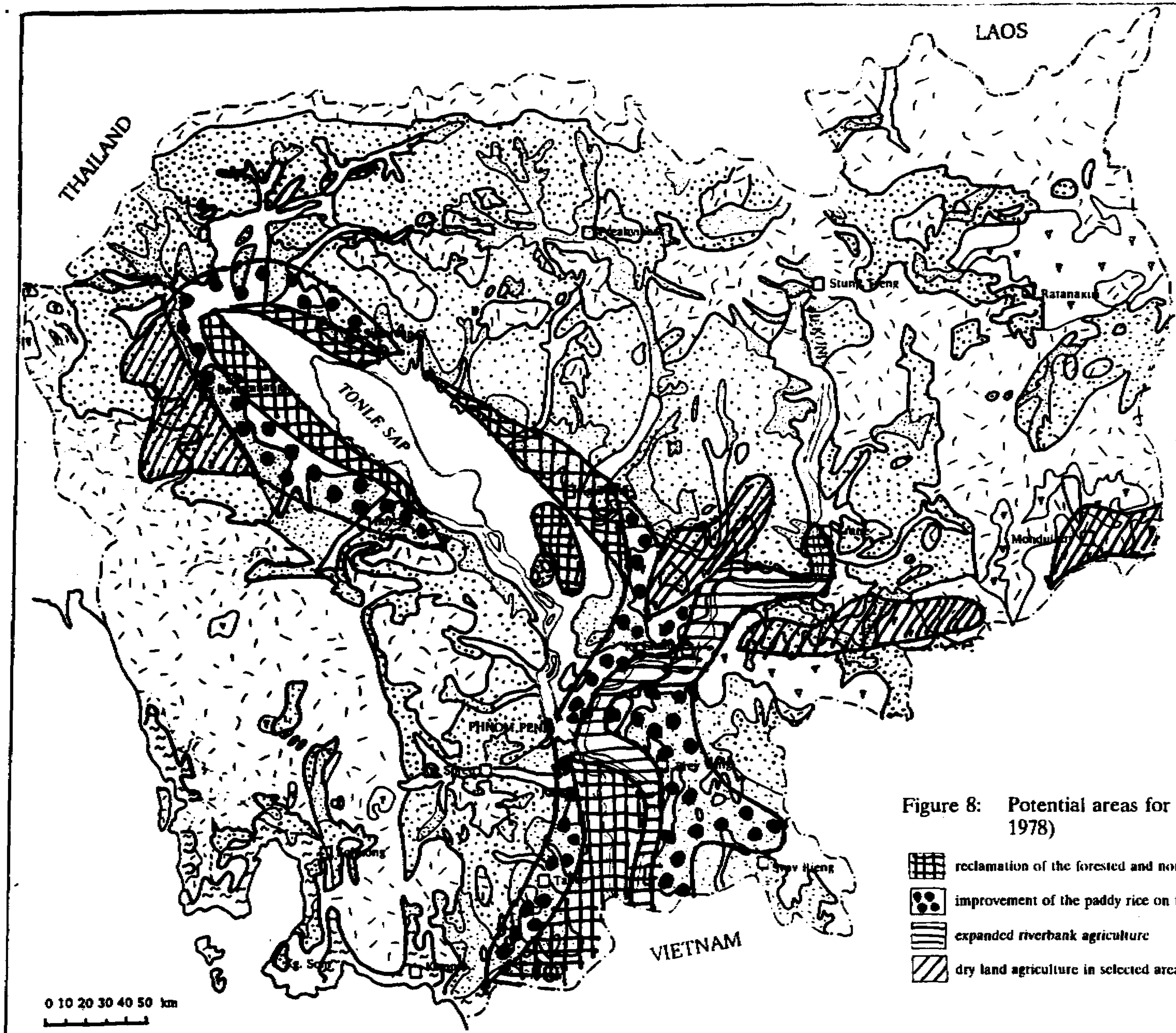


Figure 8: Potential areas for agricultural development (after CCILMB 1978)

- reclamation of the forested and non-forested wetlands
- improvement of the paddy rice on the lower terraces
- expanded riverbank agriculture
- dry land agriculture in selected areas

(this map is partly derived from the "Carte pedo-geomorphologique du Cambodge", original scale 1:500.000)

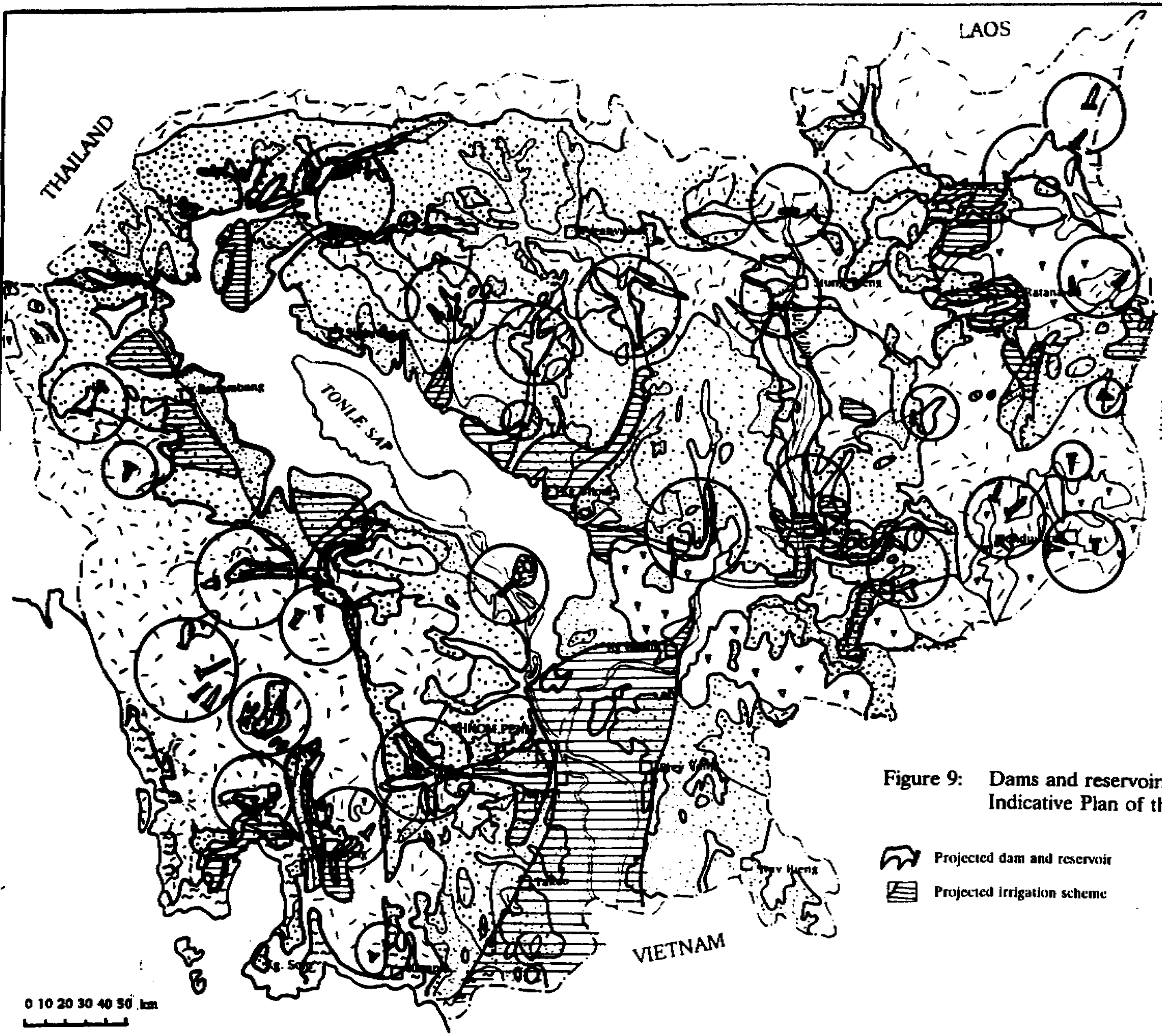


Figure 9: Dams and reservoirs and Irrigation schemes, projected in the Indicative Plan of the Interim Mekong Committee (1987)

Projected dam and reservoir

Projected irrigation scheme

(this map is partly derived from the "Carte pedo-geomorphologique du Cambodge", original scale 1:500,000)

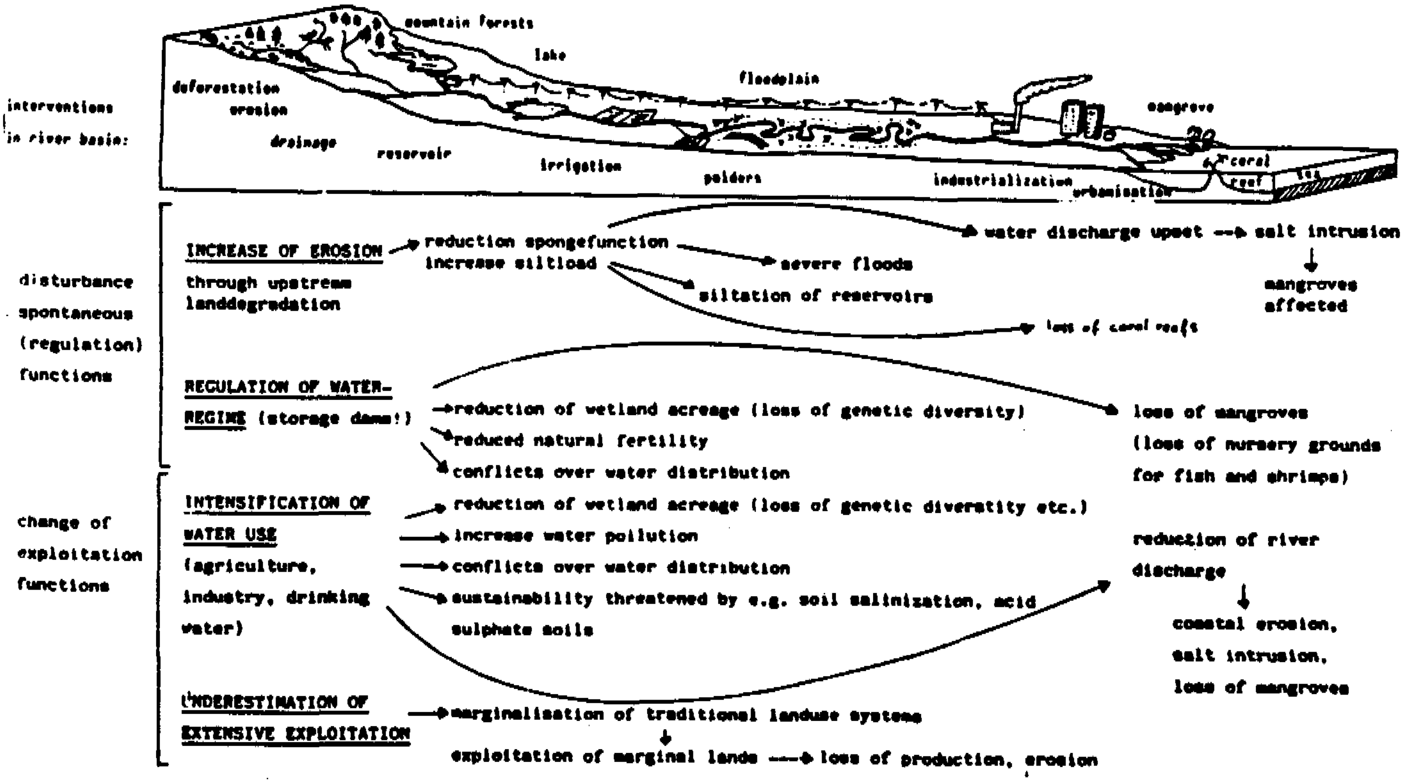
ANNEX II: GUIDELINES FOR RIVER-BASIN MANAGEMENT AND IMPACT MATRICES

(source: Marchand M, Toornstra F.H. (1986) Ecological Guidelines for River Basin Development, Centrum voor Milieukunde Rijksuniversiteit Leiden)

One can distinguish several values of the river eco-system:

a. natural values (rarity, degree of virginity, degree of diversity, potential value if artificially managed, function for water fowl)
b. spontaneous function (source for genetic material of aquatic organisms and plants, self regulation of the water regime, self-regulation of erosion/sedimentation, impact on climate, self-purification function)
c. extensive exploitation functions (fishery, livestock, floating rice and recession cultures, trad. irrigation systems, hunting, transport)
d. intensive exploitation function (intensive irrigated agriculture, power generation, intensive transport, water supply, sewage drainage)
e. health function

Next figure gives a summary of the vulnerability areas of a river eco-system:



IMPACT/ ACTIVITY	Disruption of Migration	Over-exploitation	Habitat Changes	Wildlife Conservation	Aesthetics/ Landscape	Social Changes	Health & Safety	Noise & Vibration	Debris & Solid Waste	Atmosphere Pollution	Water Pollution	Salinity Changes	Changes in Soil Characteristics	Hydrology Changes	Coastal Erosion	Hydrography Changes	Sedimentation	Increase in Sediment Load	Soil Erosion	Land-take/ Displacement
Cross-Sectoral	X1	X2	X3			X4	X5	X6	X7	X8				X9			X10	X11		
Impacts	X12	X13				X14	X15	X16	X17	X18				X19				X20		
	X21		X22	X23	X24	X25	X26	X27	X28	X29				X30				X31		X32
	X33		X34	X35	X36		X37	X38	X39	X40								X41	X42	X43
			X44		X45	X46														
			X51	X52	X53	X54														
					X59	X60														
	X61			X62	X63															
			X64		X65	X66			X67											
		X68				X69														
			X70	X71	X72	X73								X74						
						X75				X76	X77	X78	X79	X80		X81				
	X82		X83				X84	X85	X86	X87		X88		X89						
					X90		X91					X92								
	X93		X94	X95	X96	X97				X98	X99	X100	X101	X102		X103	X104	X105		

4.5 Guidelines for river-basin management

1) Preservation or improvement of the spontaneous functions fulfilled by the river, by:
   - restoring erosion/sedimentation processes, through countering increased silt loads caused by upstream erosion (improvement of watershed management!);
   - preserving genetic diversity, through conserving natural areas and threatened species;
   - preserving the selfpurifying capacity of the river, through combatting pollution (water-treatment plants, at-source anti-pollution measures).

2) Conservation of the natural values of the river basin, by:
   - preventing deterioration/destruction of natural resources, by means of legislation (incl. compulsory environmental impact assessments) directed towards industrial development, impoldering schemes and drainage activities;
   - establishing reserves in the most vulnerable ecosystems, with surrounding buffer areas;
   - establishing environmental education programmes;
   - initiating programmes to promote sound, durable exploitation of ecosystems (particularly fisheries, herding and forestry).

3) Conservation of the river basin's extensive exploitation functions, by:
   - guaranteeing the protection of productive zones, such as flood plains, estuaries and lakes, by allocating appropriate quantities of water (in relation to 4) and by means of the programmes mentioned sub 2);
   - implementing reafforestation schemes for supply of firewood, in relation to sound watershed management (cf. 1).

4) Development of sustainable intensive exploitation functions, by:
   - drawing up a water allocation plan for the entire river basin, to achieve a better match between water demand and supply; this should give due consideration to the water requirements of the spontaneous functions (1), natural values (2) and extensive exploitation functions (3);
   - developing small-scale projects e.g. irrigation, fishponds, forestry;
   - improving product processing, sales and marketing, e.g. by making better use of the river as a transport route;

- ensuring that detailed plans for the above objectives are thoroughly checked against the other criteria (1-3 and 5) within the framework of an environmental impact assessment procedure.

5) **Improvement of the overall health situation in the river basin, by:**
- combatting waterborne diseases;
- improving the food situation, both quantitatively and qualitatively;
- establishing a drinking-water programme for rural areas, with the objective of making clean, healthy water available for the whole population;
- ensuring that detailed plans for the above objectives are thoroughly checked against the other criteria (1-4) within the framework of an environmental impact assessment procedure.

6) **Guiding principles for regional planning** (from: De Groot & Van Tilburg, 1985):
- work with, not against the environment;
- start work from the existing situation, i.e. existing infrastructure, technical know-how, perceptions of subsistence security, cultural needs etc.;
- protect the authentic evolution of local culture, institutions and know-how;
- when undertaking action or introducing social change, prefer those actions involving decision-making at the lowest possible level;
- assess the carrying capacity of extensive agricultural and water-use systems, as well as their present value;
- assess the required inputs for intensive systems of land and water use and their value if a growing number of people are to be fed;
- intensify or introduce intensive land- and water-use systems at locations with the best soil and superior climatological and market conditions;
- preserve, develop and utilize nature's spontaneous functions;
- when planning reserves for species or ecosystems, endeavour to make them as large, as varied and as interconnected as possible;
- preserve rare species and ecosystems in their authentic ecological setting, giving due consideration to the long-term effects of isolation;
- avoid land- and water-use systems exhibiting irreversible dependence on a single crop or market (especially narrow or foreign markets), also on the input side.

APPENDIX: IMPACT MATRICES OF INTERVENTIONS AND RECOMMENDED MEASURES

This appendix is especially made for those who are engaged with a specific intervention in a river basin. It gives quick reference of the expected impacts and shows on which target variables these impacts have their influence (e.g. on the health of people or on the functions of the river basin). This is denoted with an 'X' in the column of the influenced target variable.

Each 'X' is accompanied with one or more numbers refering to possible alternatives c.q. mitigating or compensating measures. Every list of recommended measures begins with 'Recommendation 0': this recommendation stresses the importance of a pre-project inventory and an evaluation of possible alternatives. Depending on the kind of intervention and on the characteristics of the project area some aspects will get more attention during the inventory phase than others. The alternatives too, will differ significantly for one intervention or the other.

As stressed above, each plan for an intervention must be preceded by an inventory of the pre-project situation. In this inventory, the following elements always need to be assessed:

- physical environmental conditions (soil- and vegetation mapping, hydrology, climat);
- valuable nature areas, threatened flora and fauna;
- spontaneous functions of the river basin and existing land use systems;
- social structures and political context.

INTERVENTION: Earthen dam in minor tributaries EFFECT – CHAINS	natural values	sponta-neous functions	intensive exploi-tation	exten-sive ex-ploitation	health
a) location – more water available ⟶ more agricultural possibilities ⟶ concentration of cattle (esp. in arid regions) and people ⟶ deforestation and overgrazing	x^1	–	–	$x^{0,1,6}$	–
b) water quantity					
– possibilities for irrigation	–	–	x^2	–	–
– many dams may have a cumulative impact ⟶ decreased peak discharges and less water availability downstreams	x^2	x^2	–	x^2	–
c) water quality					
– development of waterborne diseases and aqatic weeds in the stagnant water behind the dam	–	–	–	–	$x^{3,4}$
– drainagewater can be contaminated with pesticides and fertilizer ⟶ water quality downstreams deteriorates	x^4	x^4	–	$x^{4,5}$	$x^{4,5}$
d) disposition of natural resources					
– dry farming becomes less important ⟶ marginalisation esp. of women	–	–	–	$x^{1,3}$	$x^{1,3}$
– commercialisation of natural resources; deforestation	–	–	–	$x^{1,6}$	–
e) secondary impacts					
– development of aquaculture		see 'aquaculture development'			
– sedentarisation of nomads ⟶ social conflicts	–	–	–	x^6	–

(target variables: natural values, spontaneous functions, intensive exploitation, extensive exploitation, health)

Alternatives & mitigating measures for earthern dams in minor tributaries.

0. Inventory of the pre-project situation: take special notice of traditional land use systems: importance of wet and dry farming. Take also special notice of the original water management system(s). Alternative: development of dry farming.

1. A sound land use planning to prevent deforestation and overgrazing of the land and to assure a diversified land use. Use of the natural resources has to be kept within the boundaries of the carrying capacity. This can conflict with the wish to fulfil everymans basic needs. A solution can only be reached if social structures are not upset and if extra imputs for the agricultural and foresty sectors are provided.

2. Development of a watermanagement plan based on traditional customs in order to effectively and justly distribute the water, to ensure adequate drainage and to prevent waterrelated diseases.

3. Agricultural extension which is also directed towards and executed by women.

4. Instruction on how to use pesticides and fertilizer.

5. Creation of drinkingwater wells.

6. Intensive supervision and creditprogramme together with the development of alternative sources of income in order to facilitate the compulsory sedentarisation of cattle nomads.

INTERVENTION: Earthen dam in coastal creeks

EFFECT - CHAINS	target variables: natural values	sponta-neous functions	intensive exploi-tation	exten-sive ex-ploitation	health
a) <u>location</u> - risk of development of acid sulphate soils ('cat clays')	-	-	x^2	x^2	-
- destruction of mangroveforests --▶ negative impact on shrimp fishery	x^1	x^1	-	x^1	-
- destruction of traditional fish methods in creeks	-	-	-	$x^{0,1}$	-
- maintenance problems --▶ erosion	-	-	x^4	-	-
b) <u>water quantity</u>					
- more water available for wet rice culture --▶ concentration of people and cattle	-	-	-	x^3	-
c) <u>water quality</u>					
- stagnant water behind the dam give rise to waterrelated diseases and development of aquatic weeds	-	-	x^4	x^4	x^2
d) <u>disposition of natural resources</u>					
- earnings from fishery by women become impossible --▶ mal-nourishment and social conflicts	-	-	-	$x^{0,1}$	$x^{0,1}$
- intensification and monoculture of agriculture destroys trad. agriculture --▶ socio-econ. differentiation and conflicts	-	-	$x^{0,1}$	$x^{0,1}$	-
e) <u>secondary impacts</u>					

Alternatives & mitigating measures for earthern dams in coastal creeks.

0. <u>Inventory of the pre-project situation:</u> take notice of the ways by which the local people prevented or mitigated the development of Acid-sulphate soils. Are there any other specific traditional water-management aspects of present polders?
   <u>Alternative:</u> improvement of existing dykes.

1. Cost-benefit analysis must include social costs (e.g. loss of womens income from fishery).

2. Development of a watermanagement plan to prevent waterborne diseases and cat clays. E.g. cat clay development can be counteracted by periodical flushing with seawater in dry season (brachish water has the capacity to wash out the acid 10 times faster than fresh water does). The salt can then be washed out with rain water. (Pons, 1984; Oosterbaan, 1982.)

3. A sound land-use planning to prevent an overexploitation by man and cattle.

4. Development of a maintenance programme for dams and polders.

L.J. Pons: Kort rapport van een bezoek aan het Nederl. DGIS-Cultuurtechnisch Projekt no. 2: Projecto Engeharia Rural, Regio Quinara, in Guinee-Bissau. Wageningen, 1984

R.J. Oosterbaan: Natural and social constraints to polder development in Guin-Bissau. Paper of the Int. Symp. Polders of the World, ILRI, 1982

target variables

INTERVENTION: Storm surge / saltwater dam in estuary EFFECT - CHAINS	natural values	sponta-neous functions	intensive exploi-tation	exten-sive ex-ploitation	health
a) <u>location</u> - barrier for fish, shrimps, manatees etc.	x^0	x^0	-	$x^{0,1}$	-
b) <u>water quantity</u>					
- change of streampatterns along the coast can lead to ersion	-	x^3	-	-	-
- tidal influence behind the dam is lost ⟶ intertidal flats become permanently exposed or inundated ⟶ foraging grounds for waders and other waterfowl are lost	x^0	x^0	-	-	-
c) <u>water quality</u>					
- typical estuary environment (salt - fresh water gradient) lost ⟶ mangroves upstream disappear. High primary production will decrease in the new fresh environment	$x^{0,2}$	$x^{0,2}$	-	$x^{0,2}$	-
- reservoir increases pressure on groundwater ⟶ salination soils	-	-	x^4	x^4	-
- exchange of silt and org. matter decreases ⟶ fishery affected	-	-	-	x^2	-
d) <u>disposition of natural resources</u>					
e) <u>secondary impacts</u>					
- upstream more possibilities for irrigation		see 'arid land irrigation'			

Alternatives and mitigating measures for storm surges/saltwater barriers in estuaria

0. <u>Inventory of the pre-project situation</u>. Take notice of the nursery-function of estuaries for shrimp, several fish species, wildlife (manatees, turtles, crocodiles, Hippos, birds) and rare wetland ecotypes such as mangroves and seagrasses.
   <u>Alternatives</u>: * Semi-open dams
   * Raise of embankment
   * Flowregulation upstream

1. Fishladders and sluices for migrating fish and shrimp species.

2. Barriers should be situated, as possible, upstream of mangroves and estuaries.

3. One should take into account the extra costs for coastal protection, after construction of the dam.

4. The maximum waterlevel in the created reservoir should be kept low to preserve as much as possible of the original environment.

INTERVENTION: Storage dam in main river system. EFFECT - CHAINS	target variables: natural values	spontaneous functions	intensive exploitation	extensive exploitation	health
a) location reservoir creation implies:					
- loss of agriculture-, fish- and herding grounds	$x^{0,1}$	$x^{0,1}$	$x^{0,1,2,3}$	$x^{0,1,2,3}$	-
- loss of valuable ecosystems	$x^{0,1}$	$x^{0,1}$	-	-	-
- blocking of migration routes of fish, cattle and wildlife	x^{5}	-	-	x^{5}	-
- resettlement problems ⟶ see 'arid land irrigation'					
b) water quantity					
- regulation of river discharges: decreased peak discharges, delay in flooding and increased low water discharges	x^{6}	x^{6}	x^{6}	x^{6}	-
- new settlements on slopes of reservoir lead to deforestation ⟶ erosion and increased water folw in rainy season	-	-	x^{4}	-	-
c) water quality					
- decreased peak discharges ⟶ salt intrusion in delta	x^{6}	x^{6}	-	x^{6}	-
- aquatic weeds development in reservoir	-	-	x^{9}	x^{9}	x^{9}
- reservoir acts as silt trap ⟶ loss of fertility of soils	-	$x^{4,8}$	$x^{4,8}$	$x^{4,8}$	-
- reservoir stratification ⟶ downstreams O_2 shortage and toxic matter	x^{7}	x^{7}	-	x^{7}	x^{7}
d) disposition of natural resources					
- resettlement leads to use of marginal lands ⟶ erosion	$x^{1,3,4}$	$x^{1,3,4}$	$x^{1,3,4}$	$x^{1,3,4}$	$x^{1,3,4}$
- competition between export oriented agriculture and subsistence agriculture for scarce grounds	-	-	$x^{2,3}$	$x^{2,3}$	$x^{2,3}$
e) secondary impacts					
- development of reservoir fishery	-	-	x^{7}	-	-
- electricity generation leads to industrialization					

Alternatives and mitigating measures for
a storage dam in the main river channel.

0. Inventory of the pre-project situation. Take notice of the migration patterns of cattle and wildlife.

1. Cost-benefit analysis which also takes into account the costs, caused by the loss of original agricultural lands and important ecosystems. The enormous social costs of resettlement projects must be given due consideration.

2. The resettlement planning program should be available before the start of the project. Settlers should have the possibility to participate in the planning program. The planning program must give guarantees that sufficient resources are available in the new created environment. Men and women should have equal access to these resources.

3. Farmers, who stay behind near reservoir, must be held back from clearing marginal and erosion-susceptible lands. Small agro-industry and adequate homegardens could provide an income.

4. The remaining farmers could also play an important role in the watershed-management program, eg. reafforestation-activities. Within such a watershed-management program, soil conservation measures like reafforestation, contourploughing, mulching etc are very important.

5. The choice for the location of the reservoir should also take into account the migration patterns of cattle and wildlife. Fishladders could service the fish-routes.

6. A management program for a storage dam should not only take into account irrigation and electricity needs but also nature values, spontaneous functions and exploitation values of floodplains and estuaries downstream. The preservation of these latter areas must be secured with legally enforced waterdischarges during the wet season.

7. The construction of deep reservoirs should be avoided. Deep storage reservoirs are poor with fish and often stratified.

8. Mechanical weeding of aquatic weeds is prefered to chemical weeding.

INTERVENTION: Upstream marsh drainage

EFFECT - CHAINS	natural values	spontaneous functions	intensive exploitation	extensive exploitation	health
	target variables				
a) <u>location</u> peat soils → oxidation and compaction of soils; erosion via canals } reduction of soil fertility	-	$x^{0,1}$	$x^{0,1}$	-	-
- loss of wetland habitat	x^2	x^2	-	x^3	-
b) <u>water quantity</u> - reduction of 'sponge' function of marshes → increased peak discharges in rainy period and decreased discharges in dry period	-	x^2	x^4	x^3	x^4
c) <u>water quality</u> - leaching of agricultural chemicals	x^5	x^5	-	x^5	x^5
d) <u>disposition of natural resources</u>					
e) <u>secondary impacts</u>					

Alternatives and mitigating measures for <u>upstream marsh drainage.</u>

0. <u>Inventory of pre-project situation</u>. Take particularly notice of the soil characteristics.
   <u>Alternatives:</u>
   * Drainage of for instance marshy peats causes an irreversible process, by which an intensive, but not sustainable land-use is made possible. Development of these areas should be executed with the greatest reservedness as possible.
   * Development of land utilization types which need only partial drainage (rice-agriculture) should be taken into consideration.

1. Canalbottom drops could prevent a rapid decline of the groundwater level, as to slow down oxidation- and compaction processes. These drops also prevent high stream velocities, which cause canalbank erosion.

3. Valuable parts of the marshes, particularly depressions in the wetlands, which are difficult to drain, should be protected and developed as nature reserves.

3. New kinds of landuse should be developed as a compensation for people who used to exploit the marshes.

4. Downstream structures should be build to prevent undesirable flooding. Water could possibly be stored for dry seasons.

5. Within an integrated weed control program, bio-degradable pesticides should be used.

INTERVENTION: Impoldering (reclamation)

EFFECT - CHAINS	natural values	spontaneous functions	intensive exploitation	extensive exploitation	health
	target variables				
a) <u>location</u>					
- loss of fish- and grazing grounds of wildlife/cattle	-	-	-	X^1	-
- loss of habitat for wildlife/birds	X^1	X^1	-	X^1	-
- loss of valuable ecosystems	X^1	X^1	-	-	-
- risk of acid sulphate soil development (in coastal areas)	-	-	X^2	-	-
- loss of natural fertilization	-	X^8	X^8	-	-
- blocking of migration routes of people/cattle/wildlife	X^7	X^7	-	X^7	-
b) <u>water quantity</u>					
- loss of buffer capacity and sponge function of lakes/wetlands ⟶ increased peak discharges and risk of downstream flooding	-	X^4	-	-	X^4
c) <u>water quality</u>					
- water purification capacity of marshes is lost	$X^{5,6}$	$X^{5,6}$	-	$X^{5,6}$	$X^{5,6}$
- drainagewater of polder is contaminated with agro-chemicals	$X^{5,6}$	$X^{5,6}$	-	$X^{5,6}$	$X^{5,6}$
d) <u>disposition of natural resources</u>					
- the community loses collective control over natural resources ⟶ social changes, marginalisation, increased pressure on remaining resources (fuelwood, poaching etc.)	$X^{1,3}$	-	-	$X^{1,3}$	
e) <u>secondary impacts</u>					
- improved infrastructure means better access to previously isolated areas ⟶ population increase ⟶ pressure on resources, need for sanitary facilities	X^9	X^9	-	X^9	X^9

Alternatives and mitigating measures for impoldering (reclamation).

0. <u>Inventory of the pre-project situation</u>. Take special notice of the soil-characteristics (acid-sulphate soils, peat), sedimentation processes, fish habitats, grazing grounds for cattle, presence of semi-nomadic farmers and fishermen.
   <u>Alternatives:</u>
   * increase of production on existing agricultural areas
   * more efficient storage and processing of the products (decreasing losses)
   * horse-shoe dikes and other structures to cope with the floods (low-cost solution, as compared with total reclamation)

1. Reclamation projects should be developed, as much as possible, downstream of valuable nature areas and important fishing and grazing grounds. Around these projects nature reserves and bufferzones should be assigned.
   The tradional inhabitants of the project areas should get compensation for their lost farming system.
   A cost-benefit analysis should take into account the loss of fish production and cattle grounds.

2. Before the start of the project, soil research is quite necessary. After reclamation, acid-sulphate soils could develop. The choice for a certain culture should be based on this potential acidity. If leaching of the acids out of the soil cannot effectively be accomplished, reclamation is strongly discouraged.

3. A bottom-up strategy (planning), carried by participating local communities should be implemented. The polder should be developed step by step (in space as well as in time) in order to let the changes pass away gradually and to introduce flexibility.

4. Remaining wetlands should be preserved in order to store an extra amount of water.

5. At the outlets of the polder, reed fields and/or sewage purification installations should be constructed to replace the purification function of wetlands.

6. Bio-degradable pesticides should be used. Fertilizers should be supplied in a limited way.

7. In the project design, corridors should be planned to facilitate migration of cattle and wildlife.

8. Within the new polder, the sustainability of the agricultural activities is the main objective. Fertilizers have to be used, even as other external inputs.
   The feasibility study should compare the new farming system with the original one and should predict the consequences of a growing dependence on external inputs. A study of the carrying capacity of the ecosystem is also necessary in the feasibility-study.

INTERVENTION: Arid-land irrigation with riverwater

EFFECT - CHAINS	target variables: natural values	spontaneous functions	intensive exploitation	extensive exploitation	health
a) <u>location</u> - loss of existing landuse in project area	-	-	-	x^{0}	-
- impact on ecosystem	$x^{1,3}$	$x^{1,3}$	-	-	-
- risk of soil salination	-	-	$x^{2,5}$	-	$x^{2,5}$
- climatic changes through increased evapotranspiration (local thunderstorms)	-	X	X	-	-
b) <u>water quantity</u>					
- regulation of river discharges: reduction of peak discharges and change in timing of the floods	x^{3}	x^{3}	$x^{3,6}$	x^{3}	-
- reduction of peak discharges can lead to a reduction of or complete eradication of wetland acreage downstream (floodplains, estuaries, mangroves and other wetlands)	x^{3}	x^{3}	-	x^{3}	-
c) <u>water quality</u>					
- drainagewater is contaminated with agro-chemicals	$x^{5,8}$	$x^{5,8}$	$x^{5,8}$	$x^{5,8}$	$x^{5,8}$
- stagnant surface water —— salination, waterrelated diseases, aquatic weeds	-	-	$x^{5,7}$		$x^{5,7}$
d) <u>disposition of natural resources</u>					
- commercialization of agriculture and natural resources —— change in disposition of resources —— socio-econ. differentiation / social conflicts —— reduced incentives to safeguard their own environment	-	-	$x^{0,1,2}$	$x^{0,1,2}$	$x^{0,1,2}$
e) <u>secondary impacts</u>					
- improvement infrastructure	x^{2}	-	x^{2}	x^{2}	-
- stimulus to urban and industrial development	x^{2}	-	x^{2}	-	x^{2}
- development aquaculture in canals and reservoirs					

Alternatives and mitigating measures for arid land irrigation with riverwater.

0. <u>Inventory of the pre-projectsituation</u>: take notice of the importance of dry-land agriculture (rainfed) in the tradional mode of production and take notice of womens' role in traditional farming systems.
   <u>Alternatives</u>:
   * development of smaal-scale irrigation
   * development of dry farming systems
   * in case of large-scale projects: use a decentralized management model with optimal participation of farmers' associations instead of a central bureaucratic management

1. Guarantees should be built as to provide every household equal access to safe domestic water, land, credit and living resources, such as cattle, homegardens, fuelwood, timber etc.

2. A diversification of different sources of income should be created: dry farming, cattle-breeding, non-agricultural labour etc, by which more safeguards for a subsistence level are built in and a second generation also can generate an income.

3. Irrigation always causes a decrease of river flows downstream (losses by evapotranspiration). Damage to downstream wetlands should be mitigated by an optimalisation of riverbasin watermanagement or by the construction of flowcontrol structures.

4. An adequate drainage of irrigation water should be ensured, to prevent stagnation and hence salination, waterborne diseases and aquatic weeds.

5. All allotments should get an equal and ensured amount of water, to prevent social conflicts.

6. An environmental management program should be elaborated to fight waterborne and waterrelated diseases.

INTERVENTION: Aquaculture development

EFFECT - CHAINS	natural values	sponta-neous functions	intensive exploi-tation	exten-sive ex-ploitation	health
a) <u>location</u>					
- loss of natural habitat for fish, birds and wildlife	x^0	x^0	-	x^0	-
- in coastal areas risk of acidification due to acid sulphate soils (under mangroves!) and stagnant water	-	-	x^1	-	-
b) <u>water quantity</u>					
c) <u>water quality</u>					
- stagnant water ---> waterrelated diseases	-	-	-	-	x^2
d) <u>disposition of natural resources</u>					
e) <u>secondary impacts</u>					

Alternatives and mitigating measures for
the development of fishculture/aquaculture.

0. <u>Alternatives</u>: * improvement of existing traditional fishing techniques and fish processing

1. The fishponds should be flushed with sufficient brackish water to prevent acidification.

2. Snail control (to prevent bilharsia) and a sound health program should be set up.

World Bank policy on environmental impacts of dams (source: Waterlines Vol 8, no.4

LAND LOSSES Large tracts of agricultural lands, forests or other wildlands may be inundated. Careful siting can minimize such losses (e.g. by selecting reservoirs with high Kwh-generated/ha land area inundated). The value of lost timber and other resources, and foregone use of inundated land should be estimated in the economic analysis.

HEALTH Some water-related diseases (e.g. schistosomiasis, malaria, onchocerciasis and Japanese B encephalitis) may increase unless precautions or mitigatory measures are implemented. Vector control, environmental modifications, and education of residents may need to be incorporated into the project.

PLANT AND ANIMAL LIFE Biotic surveys are normally essential; plant and animal extinction can be prevented or minimized by careful project siting. Loss of wildlife may be mitigated by including elsewhere in the country a wildlands management area equivalent to the inundated tract, as provided for by the Bank's Wildlands policy. Animal rescue, replenishment and relocation can be useful. Canal and other crossing facilities are often essential.

FISH AND OTHER AQUATIC LIFE Fish migrations (if any) will be impaired even with passage facilities. Fish propagation may mitigate losses and produce more fish protein than before the project. Spawning areas, aquaculture, improved fishing methods and marketing may need special attention. A reduced supply of nutrients downstream and to estuaries can impair fishery productivity. Interbasin transfers may threaten aquatic species by introducing new predators or competitors. A socio-economic survey can determine the importance of fish to the society.

WATER WEEDS Proliferation of floating weeds (e.g. water hyacinth [*Eichornia*] and water lettuce [*Pistia*], can impair water quality and increase disease vectors and water loss (through evapo-transpiration). Clogging impairs navigation, recreation, fisheries and irrigation. The potential to use weeds for compost, biogas or fodder should be investigated.

WATER QUALITY Suitability of water quality for drinking, irrigation, fisheries or other uses, both within reservoirs and downstream, should be addressed. Issues include saline intrusions, water retention time (i.e. flow/volume), loss of flushing, increased nutrients in reservoir, pollution (e.g. agricultural leachates, pathogens, industrial effluents), raising or contamination of water table, and salinization.

ANAEROBIC DECOMPOSITION Inundated vegetation on the bottom of reservoirs decomposes, consuming large amounts of oxygen. If thermal stratification occurs, mixing of surface and bottom water is impeded, and the bottom water may become anaerobic. Anaerobic decomposition of organic material produces noxious gases toxic to aquatic life and harmful to machinery. If discharged by the dam, downstream fish could be killed. Multiple-level outlets in the dam can avoid the discharge of anaerobic water. Inexpensive models are available to predict thermal stratification. Conversion of forest to timber before reservoir filling reduces project contribution to greenhouse gases.

EROSION Erosion upstream in the catchment area leads to sedimentation or land slides which can impair storage; catchment area management should be encouraged where appropriate. Increased erosivity of the water (the so-called 'hungry waters' effect), on the river-bed and structures below the dam, including deltaic and coastal changes, should be considered during preparation. Trap efficiency, the capacity of the reservoir to store sediments should be estimated. Many dams have low trap efficiency and do not store much sediment, hence do not increase erosivity downstream.

DOWNSTREAM HYDROLOGY Changes in downstream hydrology can impair ecosystems dependent on seasonal flooding, including areas that may be important for fisheries (e.g. floodplains, lagoons, marshes, mangroves) or for traditional flood-recession agriculture. Sometimes management of downstream water-releases can minimize such damage by partially replicating natural flooding regimes.

INTACT RIVERS Hydroelectric and other developments should preferably be concentrated on the same rivers if hydrological risks and other circumstances permit, in order to preserve elsewhere a representative sample of rivers in the natural state. This should be considered part of the trade-off.

MULTIPLE USE Multiple use should be addressed through tourism, irrigation, fisheries, bird and other biotic sanctuaries, and recreation. Water-flow regulation can convert seasonal rivers into perennial waterways, reduce flooding, and improve drinking-water and irrigation. Communal access should be perpetuated.

[Note that involuntary resettlement, tribal people, cultural property and dam safety are not discussed here as they are covered by other Bank policies.]

Checklist of issues influencing sound irrigation development
(source: Vincent L (1990) Environmentally sound irrigation projects; in Waterlines: Vol 8. No 4)

Table 1. Issues influencing environmentally sound irrigation development

1. The local production environment

- water control
- pesticide and fertilizer pollution
- crop choices
- cropping practices
- water - and/or rodent-based diseases
- livestock and fuelwood management

2. Sustainability of local irrigation practices

- technology choice (delivery and application)
- infrastructure maintenance
- energy availability
- water availability
- adequate drainage
- soil fertility maintenance

3. Interrelationships of irrigated areas with their surroundings

- upstream vegetation change affecting silt loads and flood risks
- impact of irrigation schemes on neighbouring agricultural systems
- water quality and quantity consequences for other uses
- mining of water reserves
- drainage and development of wetlands
- upstream pollution reducing water quality for irrigation

4. The world economic system

- debt and structural adjustment reducing government funding
- global market oportunities and limitations
- aid criteria for irrigation development

5. Adequate intellectual tools

- technical understanding
- farmer participation
- flexible design methodologies
- environmental economic techniques
- cost allocation techniques
- understanding interrelationships between irrigation practice and social change

6. Adequate political tools

- means to co-ordinate private and state development
- forums to debate resource allocation problems
- involvement of farmers in management
- appropriate personnel and policies for technical assistance and management
- appropriate personnel and policies for financial assistance and management

ANNEX III GUIDELINES FOR THE DESCRIPTION OF LAND UTILIZATION TYPES, FARMING SYSTEMS AND LAND QUALITIES

(source: Vink A.P.A. (1975) Land Use in advancing agriculture, Springer Verlag)

Land evaluation is the evaluation of land resources in relation to crop requirements and possible land utilization types within the socio-economical and political context in order to predict the (potential) application of the land resources.
The purpose of land evaluation is
- the prediction of the land utilization types which can be established on certain lands, with or without improvements;
- prediction of the crops which can be grown
- prediction of the land management which has to be practised
- prediction of the required land improvements, which are technically, socially and economically feasible

Land evaluation should give an answer on the questions: what can be done.
Land development plans should select the preferred final land use and define how to proceed from the present conditions towards the predicted possibilities.

Basically all land utilization types can be characterized by the following variables:
1. Purpose of the land use
2. Social characteristics:
   - land tenure
   - related social and administrative systems
   - size of farms
   - cultural aspects
   - level of know how
   - level of management
3. infrastructural characteristics: (access, dikes, polders, water management etc)
4. Produce (output)
5. Initial inputs; capital invested for long term purposes
6. Annual production inputs for maintenance and production, including labour
7. Labour intensity
8. Source, kind and intensity of farm power
9. Social, economic, cultural and institutional contexts within which the land use takes place

Land utilization types (after Kostrowicky)

I. Primitive agriculture
  1. Shifting (long fallow) agriculture.
  2. Nomadic herding.

II. Traditional agriculture
  3. Current fallow agriculture.
  4. Continuing, extensive, mixed agriculture.
  5. Labor intensive, non-irrigated, crop agriculture,
  6. Labor intensive, irrigated, crop agriculture,
  7. Labor intensive, irrigated, semi-commercial crop agriculture,
  8. Labor intensive, non-irrigated, semi-commercial crop agriculture,
  9. Low intensive, semi-commercial crop agriculture
  10. Large-scale, low intensive, semi-commercial agriculture, latifundia.

III. Market-oriented agriculture
  11. Mixed agriculture,
  12. Intensive agriculture with fruit growing and/or market gardening dominant,
  13. Large-scale, specialized agriculture with livestock breeding dominant,
  14. Plantation agriculture.
  15. Specialized irrigated agriculture.
  16. Specialized, large-scale grain crop agriculture.
  17. Specialized large-scale grazing (ranching).

Table 95. Major land qualities and their symbols to be used in the subclasses of the new international land suitability classification (mainly after Beek and Bennema, 1972)

1. Major land qualities related to plant growth (symbol)
- — availability of water (w)
- — availability of nutrients (n)
- — availability of oxygen for root growth (o)
- — availability of foothold for roots (Fh)
- — conditions for germination (seed bed c.a.)
- — salinization and/or alkalinization (Sa)
- — soil toxicity or extreme acidity (To)
- — pests and diseases related to the land (d)
- — flooding hazard (In)
- — temperature regime (including incidence of frosts) (t)
- — radiation energy and photoperiod (r)
- — wind and storm as affecting plant growth (Cw)
- — hail and snow as affecting plant growth (h)
- — air humidity as affecting plant growth (Ah)
- — drying periods for ripening of crops and at harvest time (Hs)

2. Major land qualities specifically related to animal growth
- — hardships due to climate (Ch)
- — endemic pests and diseases (De)
- — nutritive value of grazing land (Ng)
- — toxicity of grazing land (Pt)
- — resistance to degradation of vegetation (Vd)
- — resistance to soil erosion under grazing conditions (Eg)
- — availability of drinking water (Wd)
- — accessibility of the terrain (Ta)

3. Major land qualities related to natural product extraction
- — presence of valuable wood species (Tf)
- — presence of medicinal plants and/or vegetation extraction products (Pm)
- — presence of fruits (f)
- — presence of game for meat and/or hides (g)
- — accessibility of the terrain (Tb)

4. Major land qualities related to practices in plant production, in animal production or in extractions
- — possibilities of mechanization (m)
- — resistance towards erosion (e)
- — freedom in the layout of a farm plan or a developed scheme, including the freedom to select the shape and the size of fields (Lo)
- — trafficability from farm to land (Tr)
- — vegetation cover in terms of favorable or unfavorable effects for cropping (Ve)

Criteria Checklist for assessing farming techniques (ILEIA may 1991)

Productivity

1 Does the technique meet farmer/household needs for kind?
- does it improve food availability, quality and security?
- does it sustain or improve the availability of secondary products (fuelwood, building material, medicines, gifts etc)?

2 Does it meet farmer/household needs for exchangeable products/cash?
- is there a market for the products?
- are prices high enough?

3 Is enough land available to produce farmer/household needs?
- quantity
- quality

4 Do labour requirements fit farmers' labour resources and needs for labour productivity?
- by gender
- by season

5 Do farmers have access to the necessary inputs?
- available
- affordable

6 Do financial requirements fit farmers' monetary resources and needs for cost efficiency?
- by different costs (nutrients, pesticides, hired labour, transport, provisions, bribes, etc)
- by season

Security

7 Does the technique minimise the risk of
- crop failure (pests, diseases, climate)
- financial failure
- health hazards
- non-availability of external input
- inappropriateness of exotic species

8 Does it leave sufficient management flexibility?

9 Is it based on the use of local resources (e.g. land, water, genetic resources, knowledge, experience, skill) and locally produced inputs?
- are these resources under the control of the farmers?

10 Does it reduce dependency on information, inputs, subsidies, credit and markets?

11 Does it avoid conflicts of interest?

Continuity

12 Does it maintain/enhance soil quality?
- soil life
- soil fertility (macro-, micro-nutrients)
- nutrient balance (macro-, micro-nutrients)
- structure
- water-holding capacity

13 Does it recycle nutrients?

14 Does it prevent/reduce soil/nutrient loss?
- soil cover
- complementary root structure
- water conservation

15 Does it enhance/maintain perennial biomass (grasses, shrubs, trees, animals)?

16 Does it use water in a safe and efficient way?
- water-use efficiency of crops
- overpumping
- drainage

17 Does it enhance diversity (genetic diversity and mixed farming)?

18 Does it reduce toxic effects on people and resources?

19 Does it enhance human health?

20 Are maintenance costs of ecological and economic infrastructure affordable?

21 Does it recycle capital?

22 Does it have neutral or positive effects on systems beyond the farm (watershed, village, downstream areas, nation etc)?
- use of nonrenewable resources
- pollution of air, water, soil
- production of "greenhouse gases"

Identity

23 Does the technique integrate well within the existing farming system?
- agroecological
- socioeconomic
- household conditions
- gender
- evolution

24 Is it feasible to introduce the technique given the existing infrastructure (credit, roads, transportation, support by extension service etc)?

25 Does it fit/strengthen the culture of the farming population?
- social organisation
- religion or values
- preferences
- perceptions of social justice

26 Can it be easily understood by farmers?

27 Is it consistent with government policy?
- does it generate employment opportunities with adequate returns (on-farm, off-farm)?
- does it contribute to regional/national food security
- does it enhance the foreign currency balance?

28 Does it benefit poorer/powerless farmers (men, women)?

Adaptability

29 Has it been practised already by small farmers or has it spread spontaneously?

30 Does it bring rapid, recognisable success?

31 Does it stimulate or allow experimentation/adaptation by farmers?

32 Can it easily be communicated to other farmers?

33 Can knowledge, skill easily be transferred to farmers by training?

Guidelines for use

This is a checklist and not a should-list. People working with this list should feel free to give high or low value to the different criteria, modify and/or skip or add new criteria.

ANNEX III GUIDELINES FOR THE DESCRIPTION OF LAND UTILIZATION TYPES, FARMING SYSTEMS AND LAND QUALITIES

(source: Vink A.P.A. (1975) Land Use in advancing agriculture, Springer Verlag)

Land evaluation is the evaluation of land resources in relation to crop requirements and possible land utilization types within the socio-economical and political context in order to predict the (potential) application of the land resources.
The purpose of land evaluation is

- the prediction of the land utilization types which can be established on certain lands, with or without improvements;
- prediction of the crops which can be grown
- prediction of the land management which has to be practised
- prediction of the required land improvements, which are technically, socially and economically feasible

Land evaluation should give an answer on the questions: what can be done.
Land development plans should select the preferred final land use and define how to proceed from the present conditions towards the predicted possibilities.

Basically all land utilization types can be characterized by the following variables:

1. Purpose of the land use
2. Social characteristics:
   - land tenure
   - related social and administrative systems
   - size of farms
   - cultural aspects
   - level of know how
   - level of management
3. infrastructural characteristics: (access, dikes, polders, water management etc)
4. Produce (output)
5. Initial inputs; capital invested for long term purposes
6. Annual production inputs for maintenance and production, including labour
7. Labour intensity
8. Source, kind and intensity of farm power
9. Social, economic, cultural and institutional contexts within which the land use takes place

Land utilization types (after Kostrowicky)

I. Primitive agriculture
1. Shifting (long fallow) agriculture.
2. Nomadic herding.

II. Traditional agriculture
3. Current fallow agriculture.
4. Continuing, extensive, mixed agriculture,
5. Labor intensive, non-irrigated, crop agriculture,
6. Labor intensive, irrigated, crop agriculture,
7. Labor intensive, irrigated, semi-commercial crop agriculture,
8. Labor intensive, non-irrigated, semi-commercial crop agriculture,
9. Low intensive, semi-commercial crop agriculture
10. Large-scale, low intensive, semi-commercial agriculture, latifundia.

III. Market-oriented agriculture
11. Mixed agriculture,
12. Intensive agriculture with fruit growing and/or market gardening dominant,
13. Large-scale, specialized agriculture with livestock breeding dominant,
14. Plantation agriculture,
15. Specialized irrigated agriculture,
16. Specialized, large-scale grain crop agriculture,
17. Specialized large-scale grazing (ranching).

Table 95. Major land qualities and their symbols to be used in the subclasses of the new international land suitability classification (mainly after BEEK and BENNEMA, 1972)

1. *Major land qualities related to plant growth (symbol)*
   — availability of water (w)
   — availability of nutrients (n)
   — availability of oxygen for root growth (o)
   — availability of foothold for roots (Fh)
   — conditions for germination (seed bed c.a.)
   — salinization and/or alkalinization (Sa)
   — soil toxicity or extreme acidity (To)
   — pests and diseases related to the land (d)
   — flooding hazard (In)
   — temperature regime (including incidence of frosts) (t)
   — radiation energy and photoperiod (r)
   — wind and storm as affecting plant growth (Cw)
   — hail and snow as affecting plant growth (h)
   — air humidity as affecting plant growth (Ah)
   — drying periods for ripening of crops and at harvest time (Hs)

2. *Major land qualities specifically related to animal growth*
   — hardships due to climate (Ch)
   — endemic pests and diseases (De)
   — nutritive value of grazing land (Ng)
   — toxicity of grazing land (Pt)
   — resistance to degradation of vegetation (Vd)
   — resistance to soil erosion under grazing conditions (Eg)
   — availability of drinking water (Wd)
   — accessibility of the terrain (Ta)

3. *Major land qualities related to natural product extraction*
   — presence of valuable wood species (Tf)
   — presence of medicinal plants and/or vegetation extraction products (Pm)
   — presence of fruits (f)
   — presence of game for meat and/or hides (g)
   — accessibility of the terrain (Tb)

4. *Major land qualities related to practices in plant production, in animal production or in extractions*
   — possibilities of mechanization (m)
   — resistance towards erosion (e)
   — freedom in the layout of a farm plan or a developed scheme, including the freedom to select the shape and the size of fields (Lo)
   — trafficability from farm to land (Tr)
   — vegetation cover in terms of favorable or unfavorable effects for cropping (Ve)

Criteria Checklist for assessing farming techniques (ILEIA may 1991)

Productivity

1 Does the technique meet farmer/household needs for kind?
- does it improve food availability, quality and security?
- does it sustain or improve the availability of secondary products (fuelwood, building material, medicines, gifts etc)?

2 Does it meet farmer/household needs for exchangeable products/cash?
- is there a market for the products?
- are prices high enough?

3 Is enough land available to produce farmer/household needs?
- quantity
- quality

4 Do labour requirements fit farmers' labour resources and needs for labour productivity?
- by gender
- by season

5 Do farmers have access to the necessary inputs?
- available
- affordable

6 Do financial requirements fit farmers' monetary resources and needs for cost efficiency?
- by different costs (nutrients, pesticides, hired labour, transport, provisions, bribes, etc)
- by season

Security

7 Does the technique minimise the risk of
- crop failure (pests, diseases, climate)
- financial failure
- health hazards
- non-availability of external input
- inappropriateness of exotic species

8 Does it leave sufficient management flexibility?

9 Is it based on the use of local resources (e.g. land, water, genetic resources, knowledge, experience, skill) and locally produced inputs?
- are these resources under the control of the farmers?

10 Does it reduce dependency on information, inputs, subsidies, credit and markets?

11 Does it avoid conflicts of interest?

Continuity

12 Does it maintain/enhance soil quality?
- soil life
- soil fertility (macro-, micro-nutrients)
- nutrient balance (macro-, micro-nutrients)
- structure
- water-holding capacity

13 Does it recycle nutrients?

14 Does it prevent/reduce soil/nutrient loss?
- soil cover
- complementary root structure
- water conservation

15 Does it enhance/maintain perennial biomass (grasses, shrubs, trees, animals)?

16 Does it use water in a safe and efficient way?
- water-use efficiency of crops
- overpumping
- drainage

17 Does it enhance diversity (genetic diversity and mixed farming)?

18 Does it reduce toxic effects on people and resources?

19 Does it enhance human health?

20 Are maintenance costs of ecological and economic infrastructure affordable?

21 Does it recycle capital?

22 Does it have neutral or positive effects on systems beyond the farm (watershed, village, downstream areas, nation etc)?
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Identity

23 Does the technique integrate well within the existing farming system?
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24 Is it feasible to introduce the technique given the existing infrastructure (credit, roads, transportation, support by extension service etc)?

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- social organisation
- religion or values
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26 Can it be easily understood by farmers?

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Adaptability

29 Has it been practised already by small farmers or has it spread spontaneously?

30 Does it bring rapid, recognisable success?

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Guidelines for use

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ANNEX IV: CONSTRAINTS FOR IRRIGATION DEVELOPMENT IN THE LOWER MEKONG BASIN

(source: Committee for the Coordination if Investigation of the Lower Mekong Basin (1978, draft) AGRICULTURE IN THE LOWER MEKONG BASIN)

(d) Problems with Irrigated Agriculture

Because irrigated agricultural systems require drastic changes in traditional farming methods, many problems have been experienced in attempting to establish irrigated farming in the lower basin. Several such problem areas have been clearly identified including (i) provision of adequate water and control of the water supply so that the farmer has it when he needs it, which means provision of an adequate distribution system, (ii) soil problems resulting from numerous sources including low fertility for crops other then rice, water logging, and subsoil exposure, (iii) drainage to remove excess water and to enable timely harvesting to clear the land for the next crop, (iv) ensuring adequate operation and maintenance of irrigation facilities, (v) land consolidation and field re-levelling to adapt the existing bunded field apatterns to irrigation, (vi) farm management (choice of crops, fertilizers, etc.), (vii) farm equipment, (viii) credit for financing farm improvements, equipment, and agricultural chemicals, and (ix) community public services as a basis for sustaining an acceptable quality of life in the new agricultural community (which may be characterized as "hectic" compared to the easy-going attitudes of traditional farming practices).

It is concluded that more intensive use of lowland areas through modern sustained-yield agriculture is the only alternative which will meet the basin's critical food needs over the next several decades. Such irrigation on a wide scale will also require large supplies of water to be made available by an adequate system of dams and reservoirs including development of the Mekong mainstream.

Problems with Irrigated Agricultural Systems

Whenever countries attempt to establish new irrigated agricult systems, as has been advocated by the Mekong Project, there are invariab some difficult problems involved. Before these problems can be solved they must first be clearly identified. Ten problem areas which have b identified relevant to irrigation in the lower basin as discussed bel

1. Inadequate Water Supply

The adequacy of the water supply is related to several factors, including the basic water supply and reservoir or river operation practices (see Chapter I). Even though the water supply may physically exist, it may be impossible to deliver it to the individual farm unit in the amount or at the time desired. The most common reason for this is the lack of adequate canal or lateral capacity. The limited capacity may be attributable to inaccurate determination of farm water requirements, differences of opinion regarding the irrigation methods to be used, or inadequate maintenance, as described below:

The farm water requirement is a function of consumptive use of plants, deep percolation, evaporation, and runoff. These in turn are affected by the number of crops grown per year, the evapotranspiration rate of the particular crops, the texture and slope of the fields (the drainage characteristics of the soil), the length of the runs, and the irrigation method selected.

In the lower Mekong basin, which has two basic land types (uplands and lowlands) soil differences can be very important. The flat heavy textured lands, which are commonly underlain by hardpan and characteristically used for rice production, have a different water requirement than the uplands which are usually lighter in texture, have pronounced variation in relief, and are open and freely drainable. One of the main problems in irrigating these upland soils is poor management leading to excessive deep percolation.

There is often a conflict between the economies of design of canals and laterals and the farmer's desire for water delivery. Generally speaking, the canal designer will assume that water will be delivered on a rotation basis which minimizes the canal capacity required and related costs, while the farmer would prefer to have water delivered on a demand basis (whenever he wants it). This increases the canal capacity requirements with attendant increases in costs, as well as presenting additional management problems. The manager has to increase or decrease the amount of water in the canal depending upon the collective farmers' orders. Otherwise, at certain times more water is diverted into the canal than is needed, and water is thus wasted.

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The matter of how the water is delivered to the farmer (demand or rotation) is extremely important to him. This is particularly true of the upland farmer because the upland soils have a low moisture-retain capacity and crops will become stressed very quickly. For this reason, farmers like to have a water supply available so they can irrigated immediately before the crop reaches the wilting point.

As a general rule, farmers the world over are reluctant to buy improved seeds, fertilizer, and pesticides unless they have considerable assurance of the required supply of water. Water is necessary to secure the expected responses from improved practices, particularly the application of commercial fertilizer. Farmers simply will not make the investment in additional or more expensive inputs if they do not have an assured supply of water when they need it.

Therefore, the design of the system and the method of delivery of water have much to do with whether farmers use water and, if so, the response they get from it. The plans for use of water supply should be worked out in close consultation with those who will actually use the water.

2. <u>Inclusion of Non-Irrigable Lands</u>

Many projects have failed or proved to be less successful than expected because of soil problems, including harmful accumulation of salts and alkali, water-logging because of poor drainage characteristics, excessive erosion or water requirements because of light texture of the soil or excessive slope, and limitations of productivity because of shallowness of the soil.

There are other kinds of soil problems that develop as a result of the manner in which the project was developed. One of the most common examples is the exposure of subsoil, hardpan, or gravel by excessive or improper levelling. This is a serious mistake, and somehow it continu to be made in the development of new irrigation projects; but it can often be avoided by selecting the sprinkler method of irrigation (though this is only economically justified for specialized crops).

3. Drainage

It is now generally recognized that successful irrigation requires the ability to remove water from the land at will as well as to apply it, so in most cases the service canals and laterals constitute only part of the total irrigation facilities requires. Perhaps partly due to the difficulty of anticipating where and when drainage problems will develop, there is often a temptation to ignore the potential drainage requirements; hence it is important that drainage facilities be included in the initial plans and estimates. If the drainage water is not polluted by harmful accumulations of salts or alkali, it can be reused, and project costs can often be minimized by making provision for the recycling of such drainage water.

Drainage and periodic flushing are particularly important in those lands that have or salts in the soil profile. In the process of irrigation, these substances are dissolved and brought to the surface of the soil by evaporation, leading to concentrations of the chemicals on the soil surface. This make it impossible to germinate certain seeds, i.e., many crops will not tolerate even moderate concentration of these chemicals. In those cases where the problem is not too serious it can be controlled by drainage and water management; however, badly affected areas should be excluded from the service area. Fortunately, with modern technology, it is now possible to identify such areas in the process of selecting the lands for service (land classification).

Another facet of the drainage problem in tropical areas, where double or triple cropping can be practiced, is the need to remove water so one crop can be harvested and the seed bed prepared for the next in as short a time as possible.

4. Operation and Maintenance of Irrigation Facilities

Many irrigation projects encounter difficulty in delivering adequate water, not because of inadequate supply, design, or canal capacity, but because of inadequate maintenance. The operation and maintenance of irrigation systems is not very glamorous; it does not attract the pbulic attention as does construction of a large dam and reservoir.

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But maintenance is equally as important as construction to the success of an irrigation project and must be provided for in the planning stage.

An improperly maintained irrigation system will quickly deteriorate to the point where it will be impossible to make adequate deliveries. Farmers adjust to this situation by reducing the irrigated area or limiting the crops to those that can be produced under natural rainfall, thus defeating the goals of the project. Common problems of maintenance include loss of capacity because of silt accumulation or weed growth, and inability to distribute water because of deterioration of diversion structures and head gates. Loss of water by seepage is another common problem; this not only affects the project water supply, but it often waterlogs the lands immediately below the canals and thus seriously limits their usefulness.

One solution to the maintenance problem is to employ a highly qualified staff, including ditch riders, who will deliver water to individual farm units under the method of water delivery being employed; but it generally takes a rather large and prosperous irrigation enterprise to afford this kind of staffing. An alternative that has worked particularly well on small irrigation enterprises is for the water users themselves to take over the operation. When this system is followed, it is generally the practice to elect a manager and a Board of Directors from among the water users. In some cases the Board employs a trained manager. The manager and Board are then responsible for managing and directing the activities of the enterprise. This system has been known to work very well particularly in those cases where the water users own the system; the farmers then have a proprietary interest in the irrigation system.

5. Water Control

Certain facets of this problem have already been discussed. It has been noted that a farmer should have control of his water supply so that he can put it on and take it off his fields at his will, especially where multiple cropping is expected. In order to facilitate such control, it is essential that a service outlet be provided for each individual farm unit. With small and irregularly shaped units, this often becomes diffic

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There are modern ways of delivery, for example by constructing concrete "canalettes" but this kind of a system is generally too costly to be practical. It is therefore deemed necessary to plan an open ditch gravity delivery system for the basin, requiring careful and detailed planning. Land consolidation may be an important part of this planning.

One of the problems in making such delivery, particularly in areas that are already farmed, is the acquisition of the right-of-way for the canal or lateral. Because of the lay of the land, such canals or laterals often dissect established farm units. The owners of such lands are obviously not pleased by the prospects of having a canal cut through their farm and generally oppose such construction. Because of this problem, most countries where irrigated agriculture constitutes an important part of the economy have enacted legislation which requires that any person must make available a right-of-way across his land if needed to serve adjacent lands (this, of course, is to be done with reasonable compensation). The possibility of isolating land from a source of water is thus eliminated.

6. Full Farm Development

For areas that are not currently used for agriculture,/it is necessary to clear and level the fields for irrigation so the water that is delivered to each farm unit can be effectively used. The levelling (slope of the fields) will depend upon the land type, texture of soils, and the type or irrigation to be practiced (rill, furrow, flood, border, or sprinkler). For instance, with flood irrigation it is desirable to prepare the lands as flat as possible, but with furrow irrigation it is generally desirable to level the lands so there is some fall in the field. The fall or slope of the field and the length of the run is related to the texture of the soil and the heads of water to be used.

In the lower Mekong basin much of the future irrigation is projected in lowlands that are now in use as bunded rainfed fields. The problem in this case is to adapt the field pattern to the irrigation/drainage system. In many cases, land consolidation and field re-levelling is necessary. The irrigation system, the land preparation, and the method of irrigation to be used should be properly integrated so they will be compatable. This will be much more of a problem on the uplands than in

./the flat

the flat soils which are generally used for rice production.

7. Farm Management Practices

After the irrigation system is developed and the farm unit has been prepared for irrigation, the farmer is then ready to engage in irrigated agriculture. At this point he is then faced with a multitude of decisions such as which crops to produce, varieties to use, the fertilizer to be used and how much, what plant diseases and insects can be expected and how should he control them, how often should he irrigate, how much water should he apply, etc.

If the farmer has had irrigated agriculture experience, he may very well know the answers to many or even all of these kinds of questions but if he has had little or no experience he will likely need much guidance. Thus provision of demonstration farms and farm extension services should be considered an integral part of the irrigation development programme.

8. Farm Supplies and Equipment

The development of a newly irrigated area often creates large demands for farm supplies, equipment, and machinery. In established areas such products can normally be procured, but in new large areas this may not be the case, so it is important that necessary trade centers be established and that the farm supplies that will be needed in the development of the newly irrigated lands will indeed be available.

9. Credit

It is evident from the foregoing that there is a large expense associated with the development and operation of a newly irrigated farm. If the farmer has to buy the land, clear it, level it, and build his home, he will likely need some sources of long-term credit to finance his operation. In some cases these may all be provided as part of the project cost and plan.

Intermediate-term credit may be needed for the purchase of livestock, farm equipment, and machinery; and short-term credit may be needed to finance the current production expenses. Moreover, all these types of credit should be available at reasonable interest rates; otherwise,

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there is little incentive for the farmer to borrow money and assume obligations to repay. If available at reasonable interest rates, credit can considerably accelerate the return from irrigation projects.

10. Public Services

Life in a newly irrigated area may sometimes be a discouraging experience, but with a little thought and attention to provision of essential public services some of the hardships can be removed and with modern technology and capital the process of farm unit development can be greatly accelerated. There are now examples of irrigated farms that have been completely developed within two or three years.

The difficulties of adjusting to the new environment can be reduced also by providing some of the public services or amenities that are usually associated with "the good life". These include such things as roads (closely related to the question of markets discussed earlier), potable water supply, schools, public meeting places, electric services, and medical and public health services. The availability of these kinds of services will provide a higher quality of life for the new farm family and thus accelerate the development of the irrigation enterprise.

The provision of these kinds of services can often be expedited by settling the farm families in cohesive villages; the farmers can then go into the fields each day to perform their farm tasks. The village method of settlement not only results in economies in the provision of public services but it also facilitates the development of a cohesiveness in the society and a spirit of cooperation.

From the standpoint of efficiency in the management and operation of the individual farms, there are certain disadvantages to the village type of settlement. Nevertheless, in a new development there are sufficient advantages to the community pattern of settlement to warrant its serious consideration.

ANNEX V: ENVIRONMENTAL PROJECTS IN THE PROGRAMME OF THE INTERIM MEKONG COMMITTEE

WORK PROGRAMME
1988

1.3 Environmental impact assessment and planning

1.3.01 Co-ordination of environmental planning (basin-wide)

– 1.3.02 Assessment of potential and application of reforestation and agro-forestry to soil management (Lao PDR and Thailand)

– 1.3.03 Control of soil erosion, sedimentation and flash flood hazards (basin-wide)

– 1.3.04 Establishment of a water quality monitoring network (basin-wide)

1.3.05 Ecologically sound development of water and land resources in Mekong delta (Viet Nam)

– 1.3.06 Study of water-borne diseases, Phase II (basin-wide)

1.3.08 Management of acid sulphate soils (Viet Nam)

– 1.3.10 Integration of environmental management aspects in Mekong resource development projects (basin-wide)

– 1.3.11 Assessment of impacts of water management on fishery resources in the basin (basin-wide)

1.3.12 Mekong watershed assessment for elaboration of a management programme (basin-wide)

– 1.3.13 Study to formulate plans for the management of the wetlands in the lower Mekong basin

– 1.3.14 Studies and pilot projects for the productive use of problem soils (basin-wide)

1.3.15 Environmental study of the Xeset hydropower project (Lao PDR)

1.3.16 Study for integrated development planning of the Quan Lo/Phung Hiep project (Viet Nam)

– 1.3.17 Water quality monitoring network in the lower Mekong basin, Phase II (basin-wide)

ECOLOGICALLY SOUND DEVELOPMENT OF WATER AND LAND RESOURCES IN MEKONG DELTA (Viet Nam) — 1.3.05/83

MKG/R.434

Objectives: To test/demonstrate management measures in order to achieve sustainable, productive use of acid sulphate soils in the Mekong delta by establishing two 1,000-ha pilot development areas, one each in freshwater and saline acid areas; and to assess the environmental impacts of development on acid soils.

Justification: Acid sulphate soils are present in nearly 45 per cent of the Mekong delta and their presence is an important constraint hindering the development of available land for agriculture to increase food production and improve water and land management. Such soils may become more acidic if unsuitable cultivation techniques are employed. Therefore management strategies are required which will be developed and demonstrated in the pilot projects.

Activities: Land evaluation and land use planning; assessment of impacts of agricultural development on acid sulphate soils; possible application of gross land management; delineation of areas having an important role in transporting and storing floodwater; optimum allocation of fresh water resources; water quality control; modernization of irrigation and drainage systems; and application of agronomic, aquacultural and sylvicultural techniques. A time-frame of two years is envisaged.

Requirements: Services of experts in various fields related to environment, soils, agronomy and aquaculture. Equipment and materials required for laboratory analyses, field investigations, construction, land development and transportation. Training of national technicians in appropriate disciplines. Background information/data, land for development, infrastructure facilities, staff for conducting field studies to be provided by the Government of Viet Nam.

		US$
Total project cost:		1,833,500
Government input (in-kind):		1,000,000
External funds required:		833,500
Funds secured from:	UNEP	833,500
Funds being sought:		Nil

INTEGRATION OF ENVIRONMENTAL MANAGEMENT ASPECTS IN MEKONG RESOURCE DEVELOPMENT PROJECTS (basin-wide) — 1.3.10/88

MKG/R.88004

Objectives: To incorporate environmental assessment and management aspects in resource development projects at an early stage of project conception and formulation to ensure optimum matching of resource capabilities and uses, minimize environmental costs and provide for the realization of all potential benefits on a sustainable basis.

Justification: Ecological effects of resource development projects may entail considerable environmental costs, and in some instances endanger the resource base to be developed. Such negative consequences of resource development can be minimized or avoided, through timely recognition of environmental hazards and incorporation of appropriate modifications into project plans. At present, environmental impact assessments (EIA's) are not carried out for all resource development projects of the Mekong Committee. Often an EIA is foreseen only after project plans have reached the level of feasibility study - a stage when many decisions have already been taken and the introduction of major modifications and management measures is often considered impracticable. Therefore, incorporating environmental aspects at the earliest possible stage in resource development project formulation is the only possible means of mitigating or avoiding adverse side effects.

Activities: Collection, compilation and evaluation of data and information on resource development projects under formulation from the inception stage in co-operation with the units concerned. Determination of requirements for additional surveys, investigations and expertise from an environmental point of view. Elaboration and supervision of corresponding survey/assessment programmes and, based on the results, formulation of recommendations and management plans.

Requirements: Services of a full-time project co-ordinator and support staff; services of consultants in various fields (6 man-months); funds for travel, field surveys, data processing, reporting and sub-contracting of investigations or analytical work.

	US$
Total project cost:	294,000
Government input (in-kind):	50,000
External funds required:	244,000
Funds secured from:	Nil
Funds being sought:	244,000

ANNEX V: ENVIRONMENTAL PROJECTS IN THE PROGRAMME OF THE INTERIM MEKONG COMMITTEE

WORK PROGRAMME 1988

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1.3.05/83

MKG/R.434

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Activities: Land evaluation and land use planning; assessment of impacts of agricultural development on acid sulphate soils; possible application of gross land management; delineation of areas having an important role in transporting and storing floodwater; optimum allocation of fresh water resources; water quality control; modernization of irrigation and drainage systems; and application of agronomic, aquacultural and sylvicultural techniques. A time-frame of two years is envisaged.

Requirements: Services of experts in various fields related to environment, soils, agronomy and aquaculture. Equipment and materials required for laboratory analyses, field investigations, construction, land development and transportation. Training of national technicians in appropriate disciplines. Background information/data, land for development, infrastructure facilities, staff for conducting field studies to be provided by the Government of Viet Nam.

		US$
Total project cost:		1,833,500
Government input (in-kind):		1,000,000
External funds required:		833,500
Funds secured from:	UNEP	833,500
Funds being sought:		Nil

INTEGRATION OF ENVIRONMENTAL MANAGEMENT ASPECTS IN MEKONG RESOURCE DEVELOPMENT PROJECTS (basin-wide)

1.3.10/88

MKG/R.88004

Objectives: To incorporate environmental assessment and management aspects in resource development projects at an early stage of project conception and formulation to ensure optimum matching of resource capabilities and uses, minimize environmental costs and provide for the realization of all potential benefits on a sustainable basis.

Justification: Ecological effects of resource development projects may entail considerable environmental costs, and in some instances endanger the resource base to be developed. Such negative consequences of resource development can be minimized or avoided, through timely recognition of environmental hazards and incorporation of appropriate modifications into project plans. At present, environmental impact assessments (EIA's) are not carried out for all resource development projects of the Mekong Committee. Often an EIA is foreseen only after project plans have reached the level of feasibility study - a stage when many decisions have already been taken and the introduction of major modifications and management measures is often considered impracticable. Therefore, incorporating environmental aspects at the earliest possible stage in resource development project formulation is the only possible means of mitigating or avoiding adverse side effects.

Activities: Collection, compilation and evaluation of data and information on resource development projects under formulation from the inception stage in co-operation with the units concerned. Determination of requirements for additional surveys, investigations and expertise from an environmental point of view. Elaboration and supervision of corresponding survey/assessment programmes and, based on the results, formulation of recommendations and management plans.

Requirements: Services of a full-time project co-ordinator and support staff; services of consultants in various fields (6 man-months); funds for travel, field surveys, data processing, reporting and sub-contracting of investigations or analytical work.

	US$
Total project cost:	294,000
Government input (in-kind):	50,000
External funds required:	244,000
Funds secured from:	Nil
Funds being sought:	244,000

ANNEX VI: EXAMPLE OF AN INITIAL EXAMINATION AND IMPACT MATRICES APPLIED TO COASTAL ZONE DEVELOPMENT

source: Asian Development Bank (1991) Environmental evaluation of coastal zone projects, ADB. Environment paper 8

Note: Although the following checklist is designed for a marine coastal environment, many of the factor and variables are also applicable to a sweet lake environment with mangrove.

II. INITIAL ENVIRONMENTAL EXAMINATION AND IMPACT MATRICES APPLIED TO COASTAL ZONE DEVELOPMENT

A. Initial Environmental Examination

54. The purpose of environmental assessment in the Bank's work, i.e., to ensure that anticipated socioeconomic benefits of Bank-financed development projects are not compromised by adverse impacts, is by now well-understood as is the role of the initial environmental examination (IEE) as a preliminary screening procedure designed to help determine, early on in the life of a project, the significance of its potential negative impacts and assess the need for mitigating or remedial measures.

55. Systematic presentation of potential impacts, typically taking the form of impact matrices, is the common starting point in IEE. Normally, a short description of each impact will accompany the matrix to facilitate judgments regarding the impact's significance. In the environmentally more complex cases, IEE will normally also be the technical basis for drafting the terms of reference for a follow-up and more comprehensive environmental impact assessment (EIA).

B. Impact Matrices

56. This section (Table 1) contains impact matrices for projects in the coastal zone. The matrices cover three broad categories of projects: (i) managed ecosystems, (ii) infrastructure, and (iii) industry. The matrix for each of these categories is further divided into sections according to activities. Below, the potential impacts are briefly summarized for eight out of fifteen activities[1/] and given a code number matching the impact matrix. No code number indicates that an impact is considered unlikely for this activity. However, some projects may be subject to unexpected impacts and compilers should take this into consideration.

1. Managed Ecosystems

1.1 Agriculture

1.1.1 Land Clearance

Code number

A1 Is the land to be cleared of current or potential economic value, e.g., mangroves supporting nearshore fisheries and providing a timber reserve? Has the economic analysis of the project taken this value into account?

A2 Will large-scale removal of tree or ground cover lead to soil erosion? Could this be aggravated by the use of machinery on delicate soil structures?

A3 Could soil erosion lead to increased sediment in nearby watercourses?

1/ The choice of the eight activities in part reflects the limitations of space and in part is in keeping with the document's emphasis on wetland habitats.

A4 Will increased sedimentation result in adverse effects for downstream uses, e.g., blocking industrial filters, siltation of reservoirs or navigation channels, etc.?

A5 If land clearance is to take place adjacent to a beach, could coastal erosion result? If mangroves are cleared, will coastal erosion affect the development?

A6 Will land clearance change surface hydrology patterns? Could these lead to changes in water supply downstream?

A7 Will land clearance result in increased leaching of solid nutrients, increase in soil acidity, shrinkage due to drying, etc.?

A8 Will cleared cover be burnt? If so, could this lead to large-scale, if temporary, atmospheric pollution?

A9 Will cleared cover be dumped? If so, is a suitable site available? Could debris (e.g., bark, leaves) find its way into rivers causing downstream problems (see A4)?

A10 Will noise from machinery (e.g., chain saws/bulldozers) cause unacceptable disturbance to local communities?

A11 What are the dangers to the workers involved in land clearance? Will clearance of vegetation cover affect drainage and thus create permanent or temporary breeding sites for waterborne disease vectors?

A12 Will social patterns of local groups be adversely changed by land clearance (e.g, traditional forest-dwelling tribes)?

A13 Will land clearance have a significant detrimental effect on the landscape? Could this affect the tourist industry?

A14 Will conservation of wildlife species be impaired through land clearance?

A15 Apart from the cleared area itself, will habitat change to adjacent land take place because of the clearance, e.g., degradation of the surrounding mangrove forest?

A16 Will land clearance alter the migration or dispersion of wildlife, e.g, by fragmentation of forest areas?

1.1.2 Bunding

A17 Will sediment runoff from a bund reach adjacent watercourses?

A18 Could such runoff cause adverse siltation (see A4)?

A19 Will the bunding change coastal currents by altering the flow of freshwater into the sea or affecting tidal patterns?

A20 Could coastal erosion result from: (a) reduction in sediment loads below the bund; (b cutting off freshwater flow to mangroves leading to their destruction; (c) decrease in rive flows changing coastal currents?

A21 Will bunding significantly alter surface hydrology leading to effects in A19 and A20?

A22 Will reduction of tidal flow into the soil cause drying and oxidation leading to acidificatior of the soils? Could soils become more acid due to runoff from acid-soils used to construc the bund?

A23 Will the bund lead to reduced freshwater input outside it, therefore, raising the salinity o those soils? Will vegetation on these die as a result, e.g., mangroves?

A24 Will excessive noise and vibration from heavy machinery occur during construction of the bunds? Will this affect nearby communities?

A25 Will there be any hazard to workers during the construction phase of the bund? If the bund fails to stop flooding what will be the effects on the project settlers? Will bunding affect drainage and cause stagnant pools for breeding, etc.?

A26 Will bunding reduce the landscape value either directly or indirectly e.g., through causing mangrove death?

A27& A28 Will bunding of mangrove areas result in their destruction (27) or degradation (28) leading to loss of wildlife?

A29 Could bunding interrupt migration of fish fry/crustacean larvae into mangrove nursery areas? Will this affect nearshore fisheries or mariculture developments?

1.1.3 Irrigation

A30 Will irrigation lead to reduced river flow? Could this change coastal current patterns and affect marine habitats, e.g., sea-grass beds, or nearshore fisheries?

A31 Could changes in coastal currents increase coastal erosion?

A32 Could reduced river flows have effects on downstream usage, e.g., industrial cooling water, urban water supply, etc.?

A33 Will increased water flow through the soil increase nutrient leaching?

A34 In areas where evaporation rates are high, could irrigation lead to salinization of soils?

A35 Will irrigation introduce waterborne diseases such as aquatic parasites such as flukes or increase incidence of malaria by providing mosquito breeding areas?

A36 Irrigation intensifies agricultural systems. Will this lead to social changes, e.g., reduction in the rice/fishery system of cropping?

A37 Will irrigation canals disrupt migration of wildlife, e.g., fish species?

1.1.4 Groundwater Usage

A38 Use of groundwater for irrigation. How extensive is the practice?

A39 Will excessive use of groundwater lead to salt intrusion?

A40 Could groundwater contain relatively high concentrations of naturally occurring elements or compounds such as barium sulphate or heavy metals which could lead to water pollution in the immediate area?

A41 Will groundwater usage for the project affect quality of groundwater used by local residents for drinking water?

1.1.5 Herbicides/Pesticides

A42 Will herbicides and/or pesticides be used in large quantities or sprayed from the air? Such practices will cause runoff to be contaminated with these chemicals. Will pollution from this source affect riparian, estuarine, or nearshore fisheries?

A43 Use of certain herbicides/pesticides has been documented as having serious effects on human health. If such chemicals are to be used, has health and subsequent medical care been considered?

A44 Pesticide residue is known to be seriously detrimental to wildlife. Have the effects of this on tourism or other economic sectors been fully evaluated?

1.1.6 Fertilizer Usage

A45 Will fertilizer runoff cause eutrophication of watercourses and affect fisheries? Will it reduce water quality (through increased nitrates) and affect potable supplies?

A46 Inorganic fertilizers also pose a health risk (see A43).

A47 Will eutrophication from fertilizer runoff affect uncommon species of aquatic wildlife?

A48 Will fertilizer runoff affect habitat change of marine communities (e.g., stimulating algal growth on coral reefs thereby destroying them)?

1.1.7 Cultivation

A49 Will new techniques of cultivation lead to increased soil erosion, e.g., by leaving fields fallow during rainy or dry/windy periods of the year?

A50 Will eroded soil increase sediment load in adjacent watercourses?

A51 Will the crops introduced affect groundwater levels/supplies, e.g., tree crops, will draw much more on groundwater than arable crops?

A52 Will the crops/cultivation methods deplete soil nutrients or reduce humus levels in soil? Will ploughing cause deleterious changes to the soil structure such as bringing toxic soil components to the surface, e.g., with acid sulphate soils or iron-pans soils?

A53 Will the new crops induce groundwater to come to the surface bringing with it dissolved *salts thus increasing salinity of surface?*

A54 Will burning of crop residues cause air pollution?

A55 Will waste products from harvesting cause solid waste disposal problems?

A56 Will new agricultural technology cause associated human health and safety problems such as danger from improper use of mechanized equipment by poorly trained workers?

A57 Will new agricultural technology lead to significant social changes in the area such as migration of workers into or out of the area, loss of natural forest products important for traditional medicinal/social purposes? Will new social systems, e.g., water users associations, have to be established which may conflict with current social organizations? Will the new agricultural practices need a substantial retraining of the local people? Will there be any problems with claims of traditional land rights? Will the projects involve introduction of people from different ethnic groups?

1.1.8 Animal Husbandry

A58 What methods are proposed for disposal of animal wastes, will they lead to contamination of water supply? Will excess nutrients lead to eutrophication of water bodies? (If pig breeding is involved, wastes will cause very serious contamination – especially if religion sensitivities are involved).

A59 What human diseases, e.g., parasites, may be introduced with animals? Will flies associated with animals be vectors of human disease, will animals be dangerous to humans, e.g., water buffalo?

A60 Will introduction of livestock farming lead to significant social change in the community structure? Will livestock cause conflicts by, for example, grazing plantation or arable crops?

A61 Will free-ranging livestock displace or transfer diseases to natural animals populations? Will fear of animal diseases (rabies, bovine tuberculosis, "Newcastle disease", etc.) being transferred to introduced livestock promote the extermination of natural animal populations?

A62 Are the proposed cropping levels above the carrying capacity of the land? Will the grazing pressure lead to irreversible changes in vegetation type and structure?

A63 Will fences/ditches interfere with natural migrations of large mammal species such as elephants or deer?

1.1.9 Processing

A64 Will processing industries cause water pollution? Organic pollution from oil palm processing is a major pollutant in Asia but can be eliminated by proper treatment.

A65 Do processing plants have adequate air pollution control devices? Emissions can cause both human health problems and have negative effect on crop growth.

A66 Will debris and solid waste block drainage canals or lead to health and safety problems?

A67 Have proper precautions been taken to reduce hazards to factory workers from machinery and hazardous chemicals?

A68 Will factory construction and operation lead to significant social change in the area such as inducing migration of labor to the disadvantage of locals?

A69 Will factory buildings and emissions reduce the aesthetic value of the area for recreation and tourism industries? Will they reduce the quality of life for local residents?

1.2 Wetland Forestry

1.2.1 Clear-Felling

F1& F2 Will clear-felling of timber lead to increased soil erosion, and thus increase sediment load in waterways in the forest? Will soil erosion reduce the chances of regeneration of the forested area? (1) Will increased turbidity of adjacent waterways reduce productivity for fisheries? (2)

F3 Will increased sedimentation in adjacent waters result in decreased fisheries potential?

F4 Clear-felling of mangroves adjacent to the coast will make the area more susceptible to coastal erosion. Has an adequate (at least 100 m) buffer zone been designated?

F5 Will clear-felling lead to increased runoff of rainfall? If fresh or peat swamp forest is cleared then increased runoff may lead to downstream flooding.

F6 Exposure of wetland soils as a result of clear-felling may lead to irresistible changes in soil characteristics such as oxidation, acidification and drying (preventing seedling growth).

F7 Minor water pollution can result from fuel/chemicals used in log-cutting.

F8 If brash is burnt, will this cause atmospheric pollution? Will sawdust from cutting/processing cause pollution?

F9 If brashings are not burnt will they cause a debris and solid waste problem? If left on site, they will retard regrowth.

F10 Have proper precautions been taken to ensure safety of workers during logging operations?

F11 Are there adequate buffer zones to screen clear-felled areas from sites of scenic attraction?

F12 Clear-felling will naturally remove wildlife habitat. Have surveys been made to exclude waterbird breeding colonies from area to be clear-felled? Are there adequate surrounding areas for animals to move to? Do any endangered animal species occur in the area?

F13 Clear-felling will naturally lead to a change in habitat. Unless felling is linked to replanting program of the same/similar species, habitat change will be irreversible. Has effect of loss of breeding/nursery habitat for fish species been determined?

F14 Is clear-felling managed on a sustainable yield basis with adequate planting and management or is harvesting a one-off operation similar to mining?

F15 Will corridors of forest be left between remaining forest patches to permit movement of animals? Isolation of animals in remaining forest patches could lead to low species survival rates.

1.2.2 Selective Logging

F16 Selective logging can lead to extensive damage to other trees in the forest. Large amounts of brash and damaged trees can impede regrowth of trees in forest and can lead to a major fire hazard. (It is thought that the very large forest fires in Kalimantan in 1983 were exacerbated by large amounts of dry timber old brash left by selective logging operations.)

F17 Selective logging can reduce aesthetic and landscape value of forest land unless trees are properly cleared.

F18 Selective logging operations may remove tree species important for wildlife species, e.g., disturbance from logging operations may also rescue a number of wildlife species. Loggers may partake in hunting of wildlife.

F19 Selective logging will open canopy and change species composition of forest. Ring-barking of non-commercial tree species will lead to mass death of canopy species and increased chance of forest fires.

F20 If there is no control on extraction of prime timber species, there may later be shortages of timber and little chance of natural regeneration.

1.2.3 Extraction/Hauling

F21 Erosion from logging roads and log-storage areas can cause increased sedimentation into adjacent river systems.

F22 Leakage of fuel used by haulage equipment can cause water pollution.

F23 Debris from debarking/brashing should not be thrown into rivers.

F24 Logging tracks for extraction of timber open up forest areas for hunters.

1.2.4 Log Floating

F25 Log floating increases debris in rivers.

F26 Floating logs are a navigation hazard.

1.2.5 Processing

F27 Chemicals used in processing of timber especially for pulp and paper manufacture can lead to severe water pollution problems.

F28 Burning of waste material can cause atmospheric pollution.

F29 Large amounts of bark and wood fragments can cause severe disruption of coastal ecosystems and can reduce attractiveness of tourist beaches.

F30 Timber processing centers situated adjacent to residential areas can cause disturbance.

F31 Use of processing equipment by unskilled labor may lead to safety problems without adequate training and supervision.

F32 Introduction of wood processing industries to communities previously dependent on hunter-gatherer activities in forest will need considerable cultural adjustment. Willingness of locals to make such adaptation should be assessed before project developed.

1.2.6 Re-Afforestation

F33, F34& F35 Afforestation of cleared open lands will generally reduce soil erosion (33), sediment loading of watersources and thus sediment reaching coastal areas (34). Replanting of mangrove along the coast (35) may help increase natural rates of sedimentation to consolidate land growth.

F36 Afforestation will improve generally landscape value of area though may reduce access to coastal areas.

F37& F38 Afforestation with mixed species similar to original forest will generally improve wildlife habitat (37). Where mangroves are planted on previously open mudflats (38) then habitat for waterbirds may be reduced.

1.3 Nearshore Fisheries

1.3.1 Artisanal Fisheries

N1 Fish traps and nets across river mouths may be hazards to navigation.

N2 Is a minimum mesh size specified to reduce overexploitation? Is there any control on access to of fishermen to breeding/nursery areas?

N3 Will fish traps and nets disrupt migration of adult fish wanting to move upstream to spawn?

1.3.2 Trawling

N4 If trawling is permitted inshore, it will cause severe disruption to bottom sediments and increase turbidity of coastal waters thus decreasing productivity. Is there adequate legislation and enforcement to prevent trawling closer than 3 km to the coast?

N5 Will introduction of trawlers lead to competition with traditional fishermen? Will the trawlers exploit new fishing grounds? Will the people living adjacent to the fishery grounds benefit from the trawling or only those at the main trawling port?

N6 Are the fish resources sufficient to support heavy pressure from trawling? Will the net sizes conform to existing legislation or proposed guidelines?

1.3.3 Artificial Reefs

N7 Artificial reefs should provide new habitat for fish thus increasing fish stocks thus reducing overexploitation. They are frequently only required in situations where lack of enforcement of existing legislation banning "fish bombing" (dynamite fishing) or coral mining is not effective. In initial stages artificial reefs may act as fish attraction devices allowing dynamite fishing to continue and the resource further depleted.

1.4 Aquaculture/Mariculture

1.4.1 Open Systems

M1 If cage systems cover a very large area they may affect wave patterns.

M2 Floating cages may cause a hazard to navigation.

M3 Management of cage systems will involve retraining of existing fishermen or other people. Marketing and transportation needs to be organized if project depends on export prices.

M4 Floating cages may reduce suitability of area for tourist activities such as sailing/boating.

1.4.2 Pond Siting

M5 Siting of ponds in natural ecosystems or land currently being used for agriculture will necessarily involve displacement. Where possible ponds should not be sited in mangrove where poor soil conditions and disruptions effect on nearshore fisheries are major problems. Ponds are best sited on land which has already been cleared or on marginal agricultural land.

M6 If ponds are sited too near to the coast they may accelerate the rate of coastal erosion by disrupting protective mangrove buffers. If they are constructed on intertidal mudflats or too far from the coast they may be eroded themselves.

M7 Will the ponds restrict or disrupt the flow of fresh water into the sea or to the mangrove buffer zone?

M8 Creation of ponds in mangrove areas is likely to cause serious, non-reversible changes in the soil characteristics. Many mangrove soils contain high levels of sulphites. Exposure to the air (especially by bund construction) leads to oxidation to release acids. Acidification of the ponds can severely reduce yields. Very careful and extensive studies should be made to determine if soils are "potential acid sulphate soils". If soil is acid sulphate, sulphites must be oxidized and leached or flushed out before ponds operations. This may require daily flushing which needs pumps or a large tidal range. The process is also much easier if there is a prolonged dry season. When ponds can be drained down, dried narrowed and flushed. If ponds are planned in the coastal zone and no study to look at with potential acid sulphate soils has been made this box must be marked as a major impact. If studies have been made but there is a low tidal range, no dry season and no pumping planned, then impact will also be major.

M9 Are local people willing to adapt their lifestyles to operate extensive or intensive ponds? Are ponds to be owned by locals or absentee landlords? If locals feel they have traditional rights to use the land designated for the ponds, this may cause tension or violence if they are not fully consulted and in agreement with the project.

M10 Will pond aquaculture reduce the attractiveness/value of the area for tourism/recreation?

M11 Will pond construction destroy areas important for wildlife conservation? Pond construction in coastal mudflats will remove feeding areas for waterbirds and open up area for hunters.

M12 Pond construction may reduce the habitat suitable for breeding and nursery areas for coastal commercial fish and prawn species.

M13 Ponds may remove intertidal feeding ground of migratory waterbirds. Modification of watercourses may affect migratory fish and prawn species.

1.4.3 Pond Construction

M14, M15& M16 If extensive earthworks are planned, soil erosion (14), increased turbidity of watercourse (15) and downstream siltation (16) may result.

M17 Construction of pond banks with an oxidized/leached soil will exacerbate acidity problems. It is best to use material taken from the upper 60 cm of the soil profile for bund construction.

M18 Storage of fuels and lubricants for heavy machinery used in construction may cause water pollution which may affect future productivity of pond.

M19 What will be done with the cleared vegetation from the site?

M20 If construction is adjacent to a residential area, will noise/vibration from heavy machinery be a problem?

M21 Will proper precautions be taken to ensure safety of workers during construction? In mangrove areas, heavy equipment may sink into unconsolidated sediments and natural predators such as crocodiles may cause problems with worker safety.

1.4.4 Pond Operation (extensive)

M22 Extensive pond systems are very wasteful of resources. In some cases the short-term gains from extensive ponds mariculture do not justify the long-term losses of nearshore fisheries and sustainable forestry which result from the project. If due consideration to these costs has not been made, then identify this as a major impact.

M23 Extensive mariculture projects are likely to have major effects on soil characteristics. How capital input may preclude soil testing and treatment and encourage abandonment of ponds.

M24 Extensive pond systems will seriously reduce multiple use options for coastal areas and may lead to social conflicts and problems. Training in management techniques will be required.

M25 Large areas of extensive ponds dependent on natural production of fish and prawn fry may lead to overexploitation of fry and shortage for pond stocking. Clearance of mangrove for pond construction will reduce natural breeding/nursery grounds for fry and thus affect total resource available.

1.4.5 Pond Operation (intensive)

M26 Water used for repeated flushing of intensive pond systems may carry a high sediment load and also high acidity levels.

M27 Oxidation and acidification of sediments brought to surface in construction will continue during operation phase. Liming, breaking up of soil and flushing will improve production but will alter soil characteristics.

M28 If saline water is pumped to inland areas for operations of intensive ponds, brackish pondwater may contaminate groundwater. Furthermore, if groundwater is pumped up for flushing or other purposes, saltwater intrusion may be encouraged.

M29 Fertilizers and fish toxins used in pond operations may contaminate watercourses.

M30 Intensive ponds require a high degree of management skill in pond operation, procurement of fry, fertilizers, etc., and in marketing. If scheme operated on paid workers rather than nuclear estate basis, then there may be problems of theft of stock. If scheme involves immigration of workers resentment by locals may lead to act of sabotage.

M31 Unless prawn/fish hatcheries are included in the scheme or are found nearby, high demand for fry collected from adjacent natural ecosystems may either overexploit the resource or lead to sub-optimal operation. If no plans are made for fry to come from hatcheries, over-exploitation by extensive mariculture will be a major impact.

57. The following detail the most important among the cross-sectoral interactions and impacts:

X1 Land-take (i.e., loss of land to other uses) will have an obvious and severe impact on the original activities on the site.

X2 Soil erosion will remove fertile topsoil important for productive agriculture.

X3 Increased sediment load in watercourses will reduce the value of water for agriculture purposes. If water is used for irrigation sediments will rapidly clog sluices and fill ditches necessitating high O&M costs.

X4 Coastal erosion may lead to flooding or saltwater intrusion into agricultural areas.

X5 Changes in surface hydrology may affect water supply or increase flooding. Changes in groundwater level will change the types of crops which may be grown, the growing period and productivity.

X6 Change in soil characteristics may kill certain crops or reduce productivity.

X7 Increased salinity will severely restrict range of suitable crops.

X8 Water pollution will affect livestock and workers. Certain chemicals, e.g., herbicides may have toxic effect on the crops.

X9 Health and safety risks to workers may lead to emigration of work force.

X10 Loss of natural predators may lead to high levels of certain pest species.

X11 Habitat changes in adjacent areas may make them more suitable to harbor pests.

X12 See X1.

X13 Loss of topsoil will reduce potential for natural or man-assisted regeneration of forests.

X14 Coastal erosion may reduce forest area or endanger facilities such as site offices or logging camps.

X15 Hydrology changes may reduce freshwater available to trees or induce permanent flooding leading to death of trees, rotting of stored timber, and restricted access.

X16 Changes in soil characteristics can lead to mass death of wetland forest or prevent effective regeneration.

X17 Long-term changes in salinity will affect survival and productivity of mangrove species.

X18 Water pollution may have some direct toxic effect on wetland forest species especially on seedlings.

X19 Risks to safety of workers may reduce available work force.

X20 Change in species composition or forest structure may reduce economic value of area for timber extraction.

X21 See X1.

X22 High sediment loads will cause silting of feeder canals, high turbidity in ponds, low productivity and high O&M costs.

X23 Increased sedimentation rates at mouths of watercourses may reduce water flow to ponds and isolate them from the coast.

X24 Hydrography changes may affect the quality of the water which can be pumped into pond systems and may also adversely affect floating cages.

X25 Coastal erosion may lead to breaching of ponds.

X26 Hydrology changes may reduce freshwater available for flushing.

X27 Changes in soil characteristics may lead to acidification of ponds and productivity.

X28 Changes in salinity may affect productivity rates in both ponds and cages.

X29 Water pollution is major reason for poor mariculture productivity and can cause the loss of the entire crop. Unpolluted water is critical for fish and prawn hatcheries.

X30 See X19.

X31 Change in habitat (e.g., loss of mangroves) adjacent to open system mariculture projects could severely affect production.

X32 Disruption of natural migration of prawns and fish to breeding and nursery areas will reduce natural production and thus available fry for ponds/cages.

X33 Loss of mangroves will reduce the area available for fish and prawn nursery areas.

X34 Increased turbidity of coastal waters and rivers will reduce suitability for fish and make catching of them harder.

X35 Sedimentation of sea-grass beds and coral reefs destroys them and their function as breeding, shelter and feeding areas.

X36 Change in coastal currents and wave action can affect suitability of catching sites and fish-landing areas.

X37 Reductions in surface water flow will affect river fisheries.

X38 Acidification of mangrove soil may reduce importance of habitat for fish breeding and as a nursery area.

X39 Changes in salinity may make coastal waters unsuitable for growth of certain fish species. Salinity changes may affect fish migrations.

X40 Water pollutants may kill fish. Sublethal levels may lead to poisoning of human consumers.

X41 Habitat changes may reduce importance of areas for fish breeding/feeding.

X42 Overexploitation of fisheries or mangrove forest will reduce long-term yields.

X43 Disruption of migration routes of fish may lead to the extinction of certain migratory fish species.

X44 Increased sediment loads may contaminate water supply for heavy industry causing increased O&M costs.

X45 Change in current and wave patterns may affect intake and discharge areas.

X46 Coastal erosion may lead to flooding or physical damage to industries situated on the coast.

X47 Surface hydrology changes may affect water availability for industrial purposes or lead to increased flooding on site.

X48 Change in soil character may increase chances of subsidence.

X49 Debris and solid waste may clog intake pipes for water.

X50 Health and safety problems will affect work force efficiency.

X51 High silt levels in cooling water increases O&M and damaged plant.

X52 High sedimentation in coastal waters may block intake/outlet areas.

X53 See X45.

X54 See X46.

X55 If power plant draws water from river it could be affected by decreased flows especially in dry seasons.

X56 See X48.

X57 See X49.

X58 See X50.

X59 Coastal current changes will affect oil spill contingency planning and may affect pipelines.

X60 Coastal erosion may affect onshore activities.

X61 Land-take by other projects may restrict access to one body.

X62 High sedimentation rates may quickly cover offshore ore body and affect subsea mining.

X63 Changes in wave and current action may affect mining operations by moving sandbanks, etc.

X64 High sediment load causes high maintenance costs for pumping equipment and leads to siltation of ponds.

X65 Change in currents may affect water quality at pond intake area.

X66 Coastal erosion may breach/flood pond system.

X67 A fall in salinity in intake water could severely reduce salt production capacity and render project uneconomic.

X68 Soil erosion can undermine and destabilize road.

X69 Coastal erosion can wash out roads and bridges or cause flooding.

X70 High sediment loads increase turbidity and make underwater checking/maintenance of harbor facilities difficult.

X71 High sedimentation rates reduce water depths and necessitate dredging.

X72 Change in current and wave action affects protective value of harbor.

X73 Coastal erosion damages port facilities and may increase sedimentation rates.

X74 Coastal erosion may increase flooding of residential areas or affect associated recreational facilities.

X75 Water pollution affects water supply and increase treatment cost.

X76 Atmospheric pollution causes health problems and reduces quality of life and property values.

X77 See X76.

X78 Reduces quality of life and property values.

X79 See X78.

X80 See X78.

X81 Land-take removes potential water storage areas.

X82 High sediment load increases treatment costs.

X83 Changed surface water flow and groundwater levels affect water supply.

X84 Acidification of soils or release of toxic compounds may affect soil-water quality. Loss of humus decreases water holding capacity of soil and necessitates increased water input.

X85 Saltwater intrusion to ground or surface water supply points renders water unusable for agriculture/domestic consumption.

X86 Water pollution may increase treatment costs or render water unusable.

X87 Debris and solid waste can clog pumps used for water extraction.

X88 Introduction of disease and discharge of sewage can increase water treatment costs or decrease quality of supply.

X89 Change in currents and wave patterns can wash sewage from subsea outfalls onto beaches.

X90 Reduction in river flow will increase concentration of sewage wastes. If treatment plant is flood-prone, untreated waste could be washed into the river system.

X91 New sources of solid waste can overload current disposal systems.

X92 Land-take can displace recreation activities.

X93 Increased turbidity of coastal waters reduces value for recreation.

X94 Increased in amount of silt deposited on tourist beaches can make them unattractive. Sedimentation of coral reefs may kill them removing attraction for divers.

X95 Coastal current and wave-pattern changes can be a danger to swimmers.

X96 Erosion of key tourist beaches can be a major problem.

X97 Water pollution decreases attractiveness of lakes and beaches.

X98 Air pollution discourages visitors.

X99 Oil and litter on beaches decreases attractiveness.

X100 Noise and vibration interferes with recreation activities.

X101 Health and problems discourage visitors especially tourists.

X102 Unattractive landscapes discourages visitors.

X103 Loss of wildlife discourages visitors.

X104 Changes in habitat types may make area less interesting to tourists.

Table 1. COASTAL ZONE IMPACTS MATRIX

IMPACT/ ACTIVITY	Disruption of Migration	Over-exploitation	Habitat Changes	Wildlife Conservation	Aesthetics/ Landscape	Social Changes	Health & Safety	Noise & Vibration	Debris & Solid Waste	Atmosphere Pollution	Water Pollution	Salinity Changes	Changes in Soil Characteristics	Hydrology Changes	Coastal Erosion	Hydrography Changes	Sedimentation	Increase in Sediment Load	Soil Erosion	Land-take/ Displacement
AGRICULTURE																				
Land clearance	A1	A2	A3	A4		A5	A6	A7			A8	A9	A10	A11	A12	A13	A14	A15		A16
Bunding			A17	A18	A19	A20	A21	A22	A23				A24	A25		A26	A27	A28		A29
Irrigation					A30	A31	A32	A33	A34					A35	A36					A37
Groundwater usage							A38		A39	A40					A41					
Herbicides/ pesticides										A42				A43			A44			
Fertilizer usage										A45				A46			A47	A48		
Cultivation		A49	A50				A51	A52	A53		A54	A55		A56	A57					
Animal husbandry										A58				A59	A60		A61		A62	A63
Processing										A64	A65	A66		A67	A68	A69				
WETLAND FORESTRY																				
Clear-felling		P1	P2	P3		P4	P5	P6		P7	P8	P9		P10		P11	P12	P13	P14	P15
Selective logging												P16				P17	P18	P19	P20	
Extraction/hauling			P21							P22		P23						P24		
Log floating												P25		P26						
Processing										P27	P28	P29	P30	P31	P32					
Re-afforestation		P33	P34	P35												P36	P37	P38		
NEARSHORE FISHERIES																				
Artisanal fisheries														N1					N2	N3
Trawling			N4												N5				N6	
Artificial reefs																			N7	
AQUACULTURE/MARICULTURE																				
Open System Mariculture					M1									M2	M3	M4				
Closed ponds																				
Pond siting	M5					M6	M7	M8							M9	M10	M11	M12		M13
Pond construction		M14	M15	M16				M17		M18		M19	M20	M21						
Pond operation (ext)	M22							M23							M24				M25	
Pond operation (int)			M26					M27	M28	M29					M30				M31	

IMPACT/ ACTIVITY	Disruption of Migration	Over-exploitation	Habitat Changes	Wildlife Conservation	Aesthetics/ Landscape	Social Changes	Health & Safety	Noise & Vibration	Debris & Solid Waste	Atmosphere Pollution	Water Pollution	Salinity Changes	Changes in Soil Characteristics	Hydrology Changes	Coastal Erosion	Hydrography Changes	Sedimentation	Increase in Sediment Load	Soil Erosion	Land-take/ Displacement
Cross-Sectoral	X1	X2	X3			X4	X5	X6	X7	X8				X9			X10	X11		
Impacts	X12	X13				X14	X15	X16	X17	X18				X19				X20		
	X21		X22	X23	X24	X25	X26	X27	X28	X29				X30				X31		X32
	X33		X34	X35	X36		X37	X38	X39	X40								X41	X42	X43
			X44		X45	X46														
			X51	X52	X53	X54														
					X59	X60														
	X61			X62	X63															
			X64		X65	X66			X67											
		X68				X69														
			X70	X71	X72	X73								X74						
						X75				X76	X77	X78	X79	X80		X81				
	X82		X83				X84	X85	X86	X87		X88		X89						
					X90		X91					X92								
	X93		X94	X95	X96	X97				X98	X99	X100	X101	X102		X103	X104	X105		