1990 TDRI Year-End Conference on
Industrializing Thailand and Its Impact on the Environment

Integrated Information for Natural Resources Management

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Supplementary Report

Integrated Information for Natural Resources Management

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Disclaimer

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Chapter 1
Introduction

THE INFORMATION AGE

The *Information Age* is upon us, and to such an extent that information has recently been called the *currency of the future.*[1] We are swimming in a sea of data—from the morning newspaper to the nightly television news, from minute-by-minute stock prices to the latest figures on deforestation, information floods our senses and at times threatens to overwhelm us. The human race seems obsessed with information: we are constantly developing new information sources (surveys, maps, satellite images), as well as novel ways of gathering and organizing it (computers, satellites, laser disks). We have even begun calling those dealing with it information workers rather than the more pedestrian clerical workers. Why is this so? Why we gather such immense quantities of data?

Information gathering seems to be a fundamental human activity that stems from two basically human traits—our ability to make decisions and our innate curiosity. Placed in a strange environment, we will immediately start to explore it; this is readily apparent to anyone who has ever watched a small child. Perhaps more importantly, humans make decisions—from mundane choices such as *what shall I wear today*? or *what shall I have for lunch*? to the more profound *where should I locate my new factory*?; *what should I do about deforestation*?; *what might happen if the sea level really does rise*?; *what is an acceptable industrial pollution load that does not compromise the quality of life or deflate a booming economy*? This need to make decisions has helped fuel this enormous collection and dissemination of data. Paralleling this, perhaps even leading it, has been a technological revolution allowing us to harness the power of computers to process and to help gather our information.[2] Computing power once restricted to major government agencies and large corporations is now being delivered to

[1] 28th Annual URISA Conference Theme, Edmonton Alberta, Canada, August 1991.

our desktops. Real computer power can now be had at a modest price, making it affordable to an increasingly wider audience.

THE NEED FOR INFORMATION

All fields of human endeavor require information. Real estate agents must know the state of a piece of property as well as the current market conditions in order to turn a profit. A civil engineer laying out a road needs to know the slopes, soil and geological conditions over the proposed route; other required information might include the location of sites with suitable building materials close to the proposed route. A governor allocating budget might need to know which of the villages in his province are short of water, in order to establish how much of his limited budget is necessary for building weirs and irrigation canals. In arriving at a policy to protect a country's remaining forest, a government minister responsible for natural resources, would need to know the status quo of the forest as well as the historical rate of its encroachment—is it slowing down or accelerating? This type of political decision might be further complicated by the involvement of landless farmers—how many and how poor are they? Each of these various activities and the decisions associated with them requires information in order to be successfully carried out.

Natural resources management is a field where information is crucial, and where information has been acknowledged as the first requirement to successful management of natural resources and the environment.[3] Recognition of changes in the status of the earth's environment or resource base is underlaid with a thorough grasp of the facts about that change—the past, the status quo and the potential futures. Monitoring threats to biodiversity, reckoning real environmental costs in national accounts, and creating viable pollution control policies all need accurate and timely information. But what kind of information? And where do we get it?

Characteristic of natural resources and environmental concerns are questions regarding *where*—what is the quality of water **here**? Is there any forest left **there**? Can bananas be profitably grown **here**? Questions of geography are involved. In fact,

[2] One may argue the chicken or the egg here—which came first, the information explosion, which drove the need for computer or computer themselves, which created the information explosion by virtue of making it easier to collect and tore data.

[3] Clark, W.C., 1990, *Managing Planet Earth*, Scientific American Special Issue: Managing Planet Earth, Vol: 261 #3, pp 18-28.

geography and the data describing it are a part of our everyday world.[4] Almost every decision taken by humans is constrained, influenced or motivated by geography. For example, fire trucks are sent to fires by the fastest route; local governments receive their budget share on the basis of population; and diseases are investigated by identifying areas of prevalence and rate of spread. Some of today's most pressing problems intrinsically involve geography—tropical deforestation, acid rain, rampant urbanization, overpopulation, global climate change, even hunger.

GEOGRAPHIC INFORMATION SYSTEMS

Thus, a real need for geographic information has paralleled this computer revolution and the coming of the Information Age. This need and the opportunity afforded by increasingly cheaper computing power have together resulted in the creation of a computer-based technology specifically designed to handle geographic data—**Geographic Information Systems**. A Geographic Information System (GIS) is, in its broadest sense, a collection of computer-based procedures used to store and manipulate geographic data. Geographic data are inherently a form of **spatial information**. What is spatial information, and what role does it in play in the management of natural resources? What is a GIS, and how can using a GIS help in the decision-making process? The following sections will attempt to answer these questions.

[4] ESRI, *Understanding GIS*, 1991.

Chapter 2

Spatial Information In Natural Resources Management

WHAT IS SPATIAL INFORMATION?

From earliest times, people have been making maps of the earth's surface and of the environment around them. Some cave drawings indicated routes to hunting areas, others showed where water might be found. Land surveying and map making played an integral role in the Roman Empire. Military strategists have long made and used maps—*The Art of War*, published during China's period of the Warring States (476-221 BC), emphasized the creation and use of maps as one of its five principles of warfare. The first recorded evidence of maps in Thailand was a military map compiled in 1350 AD, during the reign of King Rama I.[1]

Fundamental Components

Traditionally, geographic data have been shown to users in the form of maps. Paper maps and the accompanying documentation have been what customarily constitutes a geographic database. Geographic data are commonly characterized as having three fundamental components:[2]

- **the phenomena being reported** (physical dimensions such as size or some type of class)
- **the spatial location of this phenomena**
- **the time when this phenomena were active**

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[1] Tongsawang, T. et al, Chan 1987, *Map and Photo Reading* (in Thai), Sang Chan Publishing, Bangkok.

[2] Aronoff, S., 1990, *Geographic Information System: A Management Perspective*. WDL Publication, Ottawa, Canada.

Spatial information describes phenomena existing at a certain location, at a specific point in time. It is information relating to a discrete place on the earth's surface or **georeferenced** data.

Physical dimensions might include population, width of a road, depth of a lake, or the elevation of a mountain peak. The class of a phenomena might be the type of rock, a soil, a category of forest, or even the name of a city. The location—pointing out exactly where something can be found—is usually specified with reference to some kind of coordinate system, such as latitude and longitude, or UTM[3] meters, which are commonly found on here base maps or even street addresses.

While usually not stated explicitly, the element of time is often a critical component of spatial information. Some types of spatial data such as soils and mountains, are fairly static, in theory changing little over time.[4] On the other hand, some spatial information, such as land use, is exceptionally dynamic. If an area is undergoing rapid change (as will be demonstrated for Samut Prakan Province later on), information can go out-of-date quickly, making it unsuitable for decision making requiring the most current data. However, if one were interested in historical trends, as input into predictive models, this type of dated information becomes an extremely valuable asset.

Aspects of Spatial Data

In using of spatial information, we must always keep in mind that this data is only an *abstraction of reality*, because in collecting spatial data, it is not feasible to assemble every bit of information available over an area. It is not wanted nor is it needed—we want only data we think would be useful. The most important aspects of spatial data to consider are accuracy, precision, time, currency and completeness. **Accuracy** measures how often, by how much, and how predictably the data will be right. **Precision** measures the fineness of the scale used to describe the data and at which it was collected. Scaling is an important concept that is very often misunderstood by those not familiar with cartographic principles. The scale at which data are collected will determine future

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[3] The UTM or Universal Transverse Mercator method of projecting the earth's surface onto a grid was developed by the United States Army in 1947. Its main advantage over other type of map projection is that it uses rectangular coordinatea and can be used the world over. For a more detailed description see John Synder, 1982, *Map Projection Used by the United States Geological Survey*, Geological Survey Bulletin 1532.

[4] This is commonly called the shelf life of data.

usage. A soil map sampled at a scale of 1:50,000 will **never** have the precision or accuracy of a 1:10,000 scale map regardless of the scale to which the map graphic is enlarged.

Very often, people will try to mix drastically different map scales—resulting in the creation of unscientific garbage. Thus, a map may have an apparent precision that does not match its true precision—a situation that will lead to incorrect decisions based on an *apparently* accurate map. A general rule-of-thumb in combining map scales is to always progress towards coarser map scales (for example combining 1:50,000 and 1:25,000 scale maps the resulting product would normally be used at 1:50,000). **Time** indicates at what point or over what period of time were the data collected. **Currency** designates how recently the data were collected. **Completeness** refers to how much of the area of interest is covered by the available data.

Guidelines for Collecting Spatial Information

There are several principles or guidelines generally applied to the collection and use of spatial information:[5]

- **You can't use data that you don't have.** The pieces of information that are collected will have an impact on the type and the level of analysis that can be accomplished. Who holds spatial information and what policies govern its availability also play an important role.
- **The most cost-effective data collection method is to collect only data that you really need.** It is costly to collect, store and analyze data. Excess data can hinder analysis by making access to the really needed data that much harder.
- **The ideal data quality is only as good as you need it** (the minimum level that will get the job done).
- **It costs more and more to get less and less data quality.** The law of diminishing returns also applies to spatial data collection. Each gain in data quality usually costs more effort (money, time, etc.) to acquire.
- **Data is of no value unless it is the right data, in the right place at the right time.** The way that we organize spatial data plays a major role in its successful use. Geographical databases are usually so large that when computerized the form and organization will have a major impact on the productiveness of the system.

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[5] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publication, Ottawa, Canada.

- **The best data model is the simplest one that does the most with the least data.** Modelling always involves costs. These costs may be budget, time or wrong answers. The more complex the model, the more costly it is to use.
- **A too high or too low performance level is expensive.** A level of data collection or modelling above that which is required can sometimes be costly because it produces results that do not contribute much to success; while under performing will add costs by producing incorrect results, by being late, or by losing opportunities due to better solutions.

Points, Arcs, and Polygons

Spatial information itself is usually represented on maps as one of three types of spatial primitive: point, arc, or polygon feature (see *Figure 1*). Points are used to represent the location of geographic phenomena at a point or when a line or area feature is too small to represent at the map scale. Examples of point data include groundwater wells, point pollution sources, mountain peaks, or cities (on a small scale map). An arc is an ordered set or string of points. Arcs are used to represent features that are too small to be shown as a polygon (such as roads or streams) or which have no real width (such as political boundaries or contour lines on a topographic map). A polygon feature is an area or region enclosed by arcs. Forests, soils, or a lake are examples of polygon features.

Discrete and Continuous Data

Some geographic information can be decomposed into one of the three spatial primitives mentioned above—these types of information can be thought of as **discrete** spatial data. Another type of spatial data that does not readily fall into such neat categories is called **continuous** data. Continuous features are not spatially discrete; there are no well-defined breaks between possible data values.

Elevation data (which in reality is a surface) is an example of continuous data.[6] An elevation surface can be thought of as having an infinite number of points. As mentioned above, it is not practical or possible to record every point on the surface—we can only hope to gather the most significant points. Normally, samples are taken across the surface at regularly spaced points such as in a grid or as a series of contour intervals.

[6] Elevation refers to an absolute height above some datum plane, usually sea level.

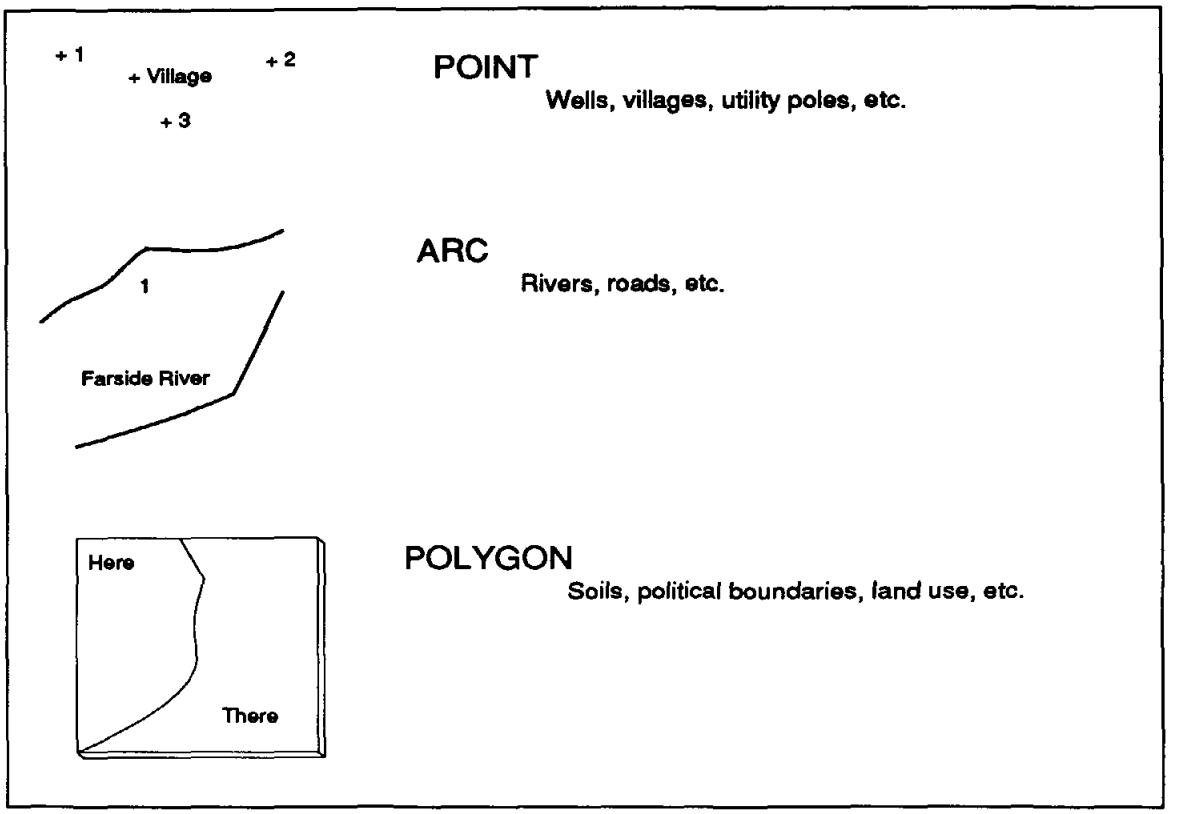

Figure 1: Spatial Information Primitives

The triangulated irregular network or TIN is another method, that is being widely adopted for storing and manipulating continuous data, especially elevation data. The surface in question is approximated by a series of irregularly spaced points in space, each having high information content.[7] These points should approximate features found on the earth's surface such as ridges, stream channels, mountain peaks, valleys, passes or even man-made features such as dams or roads. Thus, it is not necessary to sample areas of little or no change in elevation (and therefore of little interest) such as flat river plains, instead, efforts can be concentrated on areas of high relief such as mountains, valleys, and so on. The points are developed into a series of connected triangles, where each of the triangle's nodes corresponds to one of the irregularly spaced points on the surface. Besides the raw elevation data, two other important pieces of information are derived

[7] ESRI, 1987, *TIN Users' Guide*. For further information concerning TIN, also see T.K. Puecker et al, 1976, *Digital Representation of Triangulated Irregular Network (TIN)*, Office of Naval Research, Geography Program, Tech. Report #10, H. Akima, 1978, *A Method of Bivariate Interpolation and Smooth Surface Fitting for Irregularly Distributed Data Point*, ACM Transactions on Mathematical Software, 4(2), or M.J. McCullagh and C.G. Ross, 1980, *Delauney Triangulation of a Random Data Set for Isarthmic Mapping*, Cartographic Journal,

from elevation surfaces—slope and aspect. Slope is a measure of the rate of elevation change, while aspect is the direction that a surface faces. Slope is an extremely crucial piece of spatial information, as will be shown later.

WHO HAS SPATIAL INFORMATION?

In Thailand, various branches of the Royal Thai Government (RTG) holds a monopoly on spatial information. While some private companies or universities may from occasionally carry out ad hoc surveys, all systematic spatial data collection is carried out under the auspices of one RTG agency or another. *Table 2.1* provides a brief overview of the various spatial data collection tasks and inventories of the RTG.[8] As with any other type of information, there are two groups concerned with spatial data—those who create it and those who consume it.

Royal Thai Survey Department

By far, the military is the largest source of spatial information in the Kingdom. This is not surprising given the interest the military has traditionally shown in maps and geographic data throughout history. This is also due to Thailand's recent history of communist insurgency and the existence of unfriendly neighbors on two of its four international borders.

The Royal Thai Survey Department (RTSD) is the section of the Royal Thai Army (RTA) charged with creating base maps of the Kingdom, and thus is a producer of spatial information. RTSD functions include ground and air survey for map production, staff education, geodesy, and geophysical research. It will also carry out ad hoc mapping projects at the request of other RTG agencies. Since its products are ordinarily used within the military, data security is a main concern of the RTSD, especially in border areas. Consequently, its map products are not widely distributed. In terms of data updating, RTSD will normally update about 50 base maps a year, with emphasis given to sensitive areas or special projects. While it is striving to accelerate this process with the aid of computerized mapping systems (CAM) and satellite imagery (especially SPOT), it

#17(2). The pioneering work on TIN was done at the Department of Geography, University of Zurich by Martin Heller and colleague.

is hampered by a lack of recognition for the importance of its work. This has resulted in a relatively limited budget compared to the size of its task. While exact budget figures for mapping and map updating are unavailable, it was reported several years ago that the RTSD's normal mapping budget amounted to only 3 million baht.[9] (*Table 2.2* provides some of the available budgetary details for those RTG agencies concerned with spatial information).

The Base Map

RTSD's main products is a map used as a basis for other maps—a base map. It depicts essential geographic features such as elevation, infrastructure, major political boundaries, and surface water features like rivers and lakes. It is used as a foundation for other maps that are devoted to a single theme such as soil or land use maps.[10]

An accurate base map is essential to our ability to make use of spatial data. It provides the basic coordinate system or geo-coding for these thematic maps.[11] Thus, all thematic maps constructed from the same base map will have a common coordinate system. A common and accurate coordinate system is a critical factor to consider in geographic data analysis. For example, if we are overlaying two maps, it is essential that the features which should overlap do indeed overlap—for instance, if the coordinate systems differed by an offset of 100 meters, the road features on one map may well fall into the ocean on another map, making a hash of any analysis attempted with this data.

Thailand is extremely fortunate to have the entire Kingdom covered by base maps at a scale of 1:50,000.[12] The cities, villages, mountains, beaches, plains, rivers, canals, and infrastructure are mapped over the whole country. Thus, a solid foundation exists upon which other thematic data, such as soils, land use or geology, can build. Because of

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[8] For a more detailed description of the various spatial information gatherers see TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resources Management of Songkhla Lake Basin.*

[9] TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resources Management of Songkhla Lake Basin.*

[10] Maps devoted to a single subject or theme are commonly referred to as **thematic** maps.

[11] Geo-coding is the process of aligning referenced X,Y coordinate location to geographic features.

[12] A scale of 1:50,000 means that for every one distance unit, say centimeter, on the map there exist 50,000 in the real world. One centimeter on a map represents 500 meters on the earth's surface. The larger the scale (that is the smaller the scale number) the more accurate the data.

the RTSD base map scale, the majority of natural resource and environmental information, is therefore most widely available at a scale of 1:50,000 or 1:100,000.[13]

Department of Land Development

The next largest holders of spatial information in the RTG are those agencies charged with managing the Kingdom's natural resources—its soil, water, minerals and forests. In terms of data volume, the largest is the Department of Land Development (DLD) within the Ministry of Agriculture and Cooperatives (MAAC). By law, DLD is responsible for mapping soils, present land use, and geomorphology,[14] as well as formulating agricultural land use plans for the entire Kingdom. Another primary responsibility includes soil and water conservation. DLD also produces geomorphology maps at scales ranging from 1:100,000 to 1:1,000,000, on an ad hoc basis.

DLD has completed an inventory of soil over the whole of the Kingdom at a scale of 1:50,000. It also has a large, comprehensive database with detailed information concerning the physical and chemical characteristics for each of the soils found in Thailand. Although land use maps for much of the country also exist, they are usually not current, due to the exceptionally dynamic nature of this data. On average, land use maps are about five to seven years old; however, as indicated previously, they are excellent information sources concerning past conditions and can thus be vital in understanding and predicting land use changes.

The DLD is both an information consumer (RTSD base maps) and an information producer (soil and land use maps). It is perhaps its own best customer, in that the soil maps it produces are fundamental to the formulation of provincial land use plans. Several other RTG agencies, including Royal Irrigation Department, Department of Mineral Resources, Office of Agricultural Economics, Office of Agricultural Extension, Agricultural Land Reform Office, Office of Accelerated Rural Development, also use its soil maps and land use data.

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[13] Data reproduced at a scale of 1:100,000 are usually a reduction of data at 1:50,000. While it may be done for purposes of data accuracy, data is most often printed at this scale simply to save production costs. It takes fewer 1:100,000 scale maps to cover a given area than 1:50,000 scale map.

[14] Briefly, geomorphology is the science dealing with the form of the earth's surface. It seek to quantify the shape and origin of the earth's mountains, foothills, river valleys and plains.

Table 2.1 Main Spatial Information Producers

Ministry/ Agency	Main Products
Royal Thai Army	
RTSD	Topographic maps (1:50,000, 1:250,000)
Ministry of Agriculture and Cooperatives	
DLD	Soil, land use (1:50,000)
RFD	Forest, forest reserve (1:50,000, 1:250,000)
RID	Irrigation infrastructure, climatic, hydrology, statistics
Ministry of Interior	
DOL	Cadastre (1:1,000, 1:5,000, 1:10,000)
DTCP	City plans (1:8,000, 1:16,000, 1:20,000)
DCD	NRD2C database
Ministry of Industry	
DMR	Geology (1:50,000, 1:250,000) Hydrogeology (1:50,000) Groundwater wells
Ministry of Science, Technology and Energy	
NRCT	Satellite imagery (various scales)
Office of the Prime Minister	
NSO	Political boundary (1:50,000, & 1:5,000)

Overall, the DLD's information policy is more liberal than that of most RTG agencies. It sells provincial soil maps and reports at a nominal cost,[15] and it will

[15] For example, DLD will sell a provincial soil map for as little as 250 *baht*. For a province like Samut Prakan with an area of almost 600,000 *rai*, it costs approximately 900,000 *baht* to

sometimes provide its land use maps and plans upon official request. It is also willing to provide physical and chemical soil information in a digital form, although no policy has been established concerning costs, distribution restrictions, or liabilities. The DLD is presently improving its information by automating its soil map database and introducing image analysis facilities to accelerate its land use mapping.

The DLD's allotment for geographic data gathering purposes amounted to about 21 million baht for the budget year 1991, a significant decrease over 1990's budget of 27 million baht. The proportion of total budget expended for spatial data gathering also declined, from 3% to 1%, while its budget as a whole grew by some 24%. This may be attributed to the declining importance of agriculture to the Kingdom's economy as well as to the fact that the country's soils are now almost 100% mapped. This decline is worrisome since land use data will play an increasingly important role in allocating the Kingdom's diminishing land resources which are severely threatened by the current rapid urban expansion. Moreover soil information—particularly engineering characteristics—will continue to play a meaningful role in construction, especially during the present construction boom. Soil information use also assists rural poor in improving their crop production and resulting income.

Over the last two years, the DLD has allocated an average of about 2% of its total budget for the gathering of spatial information. This represents merely 0.08 baht per rai when the whole Kingdom is considered. The budget that the DLD expends on assembling spatial information is insignificant when compared to the value of what is being mapped. For instance, soil erosion alone accounts for around 3 billion baht per year, while the value of agricultural land has been estimated at 5 billion baht per year.[16]

Department of Mineral Resources

The next largest spatial information holder within the natural resources group is the Department of Mineral Resources (DMR) in the Ministry of Industry. The DMR is charged with mapping and evaluating all of Thailand's mineral resources—the groundwater, tin, lignite, antimony, construction materials, etc. It acts as a geoscience

gather the soil data (using 1.5 *baht* per *rai* mapping cost). DLD would have to sell 3,600 sets of maps to recover its data gathering cost.

[16] Theodore Panayotou, personal communication, 1990, Harvard Intitute for International Development (HIID).

technical center, on a national and regional basis, to disseminate the information it has compiled to the public.

Table 2.2 Spatial Information Producers Budget Allocations

Ministry Agency	1990 Mapping	1990 Total	1991 Mapping	1991 Total
Ministry of Agriculture and Cooperatives				
DLD	27 (3%)	1,023	21 (1%)	1,268
RFD	77 (3%)	2,791	101 (3%)	3,692
RID	355 (2%)	14,732	420 (2%)	16,818
Ministry of Interior				
DOL	91 (8%)	1,096	135 (9%)	1,456
DCD	14 (1%)	947		
DTCP	14 (7%)	188	20 (5%)	410
Ministry of Industry				
DMR	27 (3%)	916	26 (2%)	1,093
Ministry of Science, Technology and Energy				
NRCT	83 (55%)	150	127 (57%)	221

Notes: Figures in millions of baht. NRD2 Survey is biannual, thus no budget requests until 1992.

Source: Budget Bureau

DMR's 1:50,000 scale series of geologic maps covers about 50% of the country with the remainder being mapped at a rapidly accelerating pace. The whole Kingdom is covered by 1:250,000 scale maps. Hydrogeologic (groundwater) maps cover a portion of the country, usually where groundwater usage is critical or where groundwater resources are plentiful. Major groundwater areas that are mapped include the BMR, Chiang Mai, and Hat Yai areas. Groundwater well data, however, covers most of the wells under the DMR's permit obligation. This information has been developed into a comprehensive database made available to the general public. The DMR has recently completed a nationwide magnetic survey with the aid of the Canadian government, this is being made available at a scale of 1:50,000 as an aid to mineral exploration and evaluation.

In general, the DMR's information policy regarding its geological maps is fairly restricted. It normally limits distribution of its geological maps to other RTG agencies but will occasionally furnish maps to mineral exploration or mining companies cooperating with it. The DMR supplies its spatial information to the Office of National Energy Authority, the Royal Irrigation Department, the Royal Forestry Department, and the Department of Land Development, among others. On the positive side, the DMR is in the process of establishing its own integrated information system. This is unique among RTG agencies, since the DMR has had a clear policy regarding information for several years and has carried out its own feasibility study for this information system.[17] DMR's total 1991 budget was 1.093 billion baht of which some 2% was earmarked for mapping purposes. This is a decrease compared to its 1990 budget of 916 million baht, which allocated about 3% for mapping. Again, the expenditures on spatial data gathering pale in comparison to the value of the theme being mapped. Mineral exploitation accounts for about 20 billion baht per year, while groundwater extraction amounts to about 10 billion baht per year.

Royal Forestry Department

The Royal Forest Department (RFD), MAAC, is responsible for information concerning the country's forests, forest reserve,[18] and national parks. Since the implementation of the logging ban, its main task has been the management of the Kingdom's forests. It accomplishes this task through ground survey and satellite image interpretation and is perhaps the foremost institute in the country in terms of production remote sensing work. RFD's forest reserve maps are an important information source for land ownership, at least as far as public versus private land is concerned. For example, the Agriculture Land Reform Office relies heavily on these maps in determining potential land reform areas.[19] While these are normally stored as log books[20] or in the form of

[17] TDRI, 1988, *Feasibility Study on the Establishment of an Information Sytem for Natural and Environmental Resource Management of Songkhla Lake Bain.*

[18] The term forest reserve is misleading, as it may or may not have anything to do with forested land. Technically it refers to land not forest, that is nominally under the jurisdiction of the RFD. It may have had forest cover at one time in the past, but this may not be true at the present.

[19] Hasting, P., Chaiyacupt, C.,Boonraksa, C., Chaiwara, T., 1989, *Identification of Potential Land Reform Areas in Chanthaburi Province*, In Proceedings TDRI organized seminar GIS Applications in Thailand, November 8, 1989, Bangkok.

[20] Log books record the field traverse (direction, angle, distance, etc.) of the RFD party that surveyed a forest reserve boundary.

1:250,000 maps, they can be transferred to the more widely available scale of 1:50,000.[21] The RFD will usually provide maps of forest reserve and forested land on official request.

The RFD's geographical data gathering budget for 1991 is 3% of its total budget of 3.69 billion baht. This represents virtually no change from 1990's budget share of 3% against a total budget of 2.79 billion baht. Forested land has been estimated to be worth around 5 billion baht per year[22]; the cost of mapping it represents a meager 2% of its total value.

Royal Irrigation Department

The Royal Irrigation Department (RID) also in the MAAC, records large amounts of data concerning water—irrigation infrastructure, river flow, river levels, and daily rainfall. Its main task is water resource development for agriculture, and it is also responsible for drainage systems, hydrology control, water resource development for industrial and public consumption, and implementing any large-scale irrigation system. The RID is responsible for maintaining irrigated area maps, as well as maps detailing its irrigation infrastructure.

With the support of the Japanese government, the RID has had a large and well-run integrated information center for several years. Its information policy has been very forward looking and is among the most liberal in the RTG. RID has been willing to provide data (climatic, daily rainfall, water flow, river levels, and so on) in **digital form** to most requesting agencies. RID's budget expenditures for assembling spatial information have been limited—only 2% of its total budget (1.618 billion baht).

National Rural Database 2

The National Rural Database II (NRD2C), maintained by Thammasat University for the Department of Community Development (DCD), is another major source of geographic information. This biannual, village-level database encompasses nearly every

[21] Being aware that the precision of the map product is still at the scale of 1:250,000, despite the map graphic being at 1:50,000.

[22] Theodore Panayotou, personal communication, 1990, HIID.

village in rural Thailand.[23] It began as an ad hoc survey funded by USAID in 1984 to identify poor rural villages. It has since expanded to include all rural villages, becoming a permanent socioeconomic survey by order of the Cabinet in 1987. The RTG assumed full financial responsibility for the survey in 1990. Socioeconomic data covering 1984, 1986, and 1988 is available.

NRD2C records most of the important socioeconomic variables—including demographics, occupation and livelihood indicators, education, health, quality of life, income, and land tenure—for rural Thailand. In its original form, NRD2C is not strictly spatial data, as it does not contain coordinate locations for each village in the database. It is, however, a relatively simple matter to add a coordinate location to each of the villages recorded in this database.[24] Once this data become true spatial information, it unlocks a window into the socioeconomic and physical conditions existing in rural Thailand through which planners and policy makers can peer to develop objectives and agendas and assess their success or failure in human terms—Were people's lives really improved by what was done? Beyond its actual content, this database is especially useful because it is in digital form, making it potentially one of the most exciting databases in Thailand today.

The NRD2 database has been made widely available to most organizations requesting it, even to the extent of allowing the private sector to purchase copies at a nominal cost.[25] The budget allocated for the collection of the NRD2 was around 14 million baht—an information bargain for the amount and type of data it provides.

National Statistics Office

The National Statistics Office (NSO) is an additional source of spatial data. Besides taking the census, NSO is also responsible for maintaining political boundary maps. *Tambon, amphoe* and *changwat*[26] boundaries as well as *tesaban* and *sukapiban* are demarcated by NSO under the direction of the Local Administration Department, Ministry of Interior. This makes it an ideal source for demographic data from the

[23] In 1988, over 56,000 villages were surveyed.

[24] The Royal Thai Army is reported to hold a database with just such information.

[25] The entire database can be had for about 3,000 *baht.* This come to approximately 19 villages per baht!

[26] These Thai terms are equivalent to sub-district, district and province, respectively, while municipalities and sanitary districts are equal to *teasban* and *sukapiban* in urban settings.

tambon-level up when used in conjunction with registration data available from the National Registration Department, Ministry of Interior or its own census.

National Research Council of Thailand

An additional source of spatial information other than maps is data gathered by remote sensing. **Remote sensing** is a technique of collecting information from a distance—in this case a satellite in orbit around the earth. Remotely sensed data, although spatial data when properly geocoded, is **raw data**—it needs to be **interpreted** before it can become spatial information. The interpretation process can be long and involved, requiring practiced researchers and proper facilities to achieve a high level of accuracy.

The RTG agency responsible for remote sensing is the National Research Council of Thailand (NRCT).[27] Its satellite signal ground receiving station, supported at first by the American and later the Canadian governments, is among the most advanced in the world. Through it, NRCT receives LANDSAT, SPOT, and MOS-1 satellite imageries that are relevant to natural resources and environmental management. The following is a brief discussion of two of the more commonly used satellite imageries, LANDSAT and SPOT.

LANDSAT

The LANDSAT program had its start in 1972 with the launch of LANDSAT-1.[28] LANDSAT-1 was the first non-military satellite designed to provide systematic global coverage of the earth's resources. LANDSAT-1 was followed by LANDSAT-2 through LANDSAT-5, with NASA launching the TM (Thematic Mapper) sensor aboard the LANDSAT-5 satellite in 1984. In addition to the TM sensor, it also carries an MSS (Multispectral Scanner), which provides an 80 meter resolution over four bands (green and red in the visible range and two near infrared bands). The TM sensor has a resolution of 30 meters and covers seven spectral bands—a dramatic improvement in both spatial and spectral resolution over previous sensors. TM images normally cover a

[27] Specifically the NRCT's Remote Sensing Division.

[28] The LANDSAT program was originally called the Earth Resource Technology Satellite or ERTS.

swath 185 km wide, but subscenes corresponding to 1:50,000 scale maps can be produced.

The LANDSAT program was originally developed under the ideal of the *Open Skies Policy*, where data that was collected from space was to be freely available to anyone, regardless of national interests. In 1984 it was commercialized and turned over to the Department of Commerce's National Oceanographic and Atmospheric Administration (NOAA) as the Earth Observation Satellite Corporation (**EOSAT**), under a plan backed by the U.S. Congress and the Reagan administration. LANDSAT images are distributed under the auspices of EOSAT, which licenses the right to receive LANDSAT data to various ground stations around the world. NOAA's administration of the LANDSAT program has recently come under fire from the U.S. Congress, citing increasing data costs and overly long turnaround times on data requests. The undersecretary of oceans and atmosphere at NOAA, John Knauss, said in testimony before a Congressional hearing: *Our experience with the LANDSAT program has led us to believe that commercialization is not possible.* It has been suggested that LANDSAT be brought back under government control within the Interior Department.[29]

SPOT

SPOT (Systeme Pour l'Observation de la Terre) is a satellite program begun by France in 1978, with its first satellite, SPOT-1 being launched in February, 1986. In contrast to LANDSAT, **was designed from the start to be commercial**. Its pricing and copyright policy reflect this concept. It carries two identical HRV (High Resolution Visible) sensors which can operate in one of two modes. In **panchromatic** mode, visible light is detected and an image with a resolution of 10 meters is produced. In **multispectral** mode, three images (green, red, and near-infrared) are produced with a resolution of 20 meters. SPOT images usually cover a swath 60 km wide, but as with the LANDSAT, subscenes equivalent to 1:50,000 scale maps can be produced. SPOT-2, with the same sensor configuration as SPOT-1 was launched in January 1990.

Remote Sensing in Thailand

Within Thailand, TM and SPOT are most widely used for land use mapping, especially forested land—and as an aid in the assessment of natural disasters such as the

[29] Porter, E, 1990, *United States Federal Agencies* Column in GIS World, Vol. 3 #4, pp 22-27.

landslides in southern Thailand in 1988 and the devastation caused by Typhoon Gay in 1989. From the 1991 RTG budget, mineral resource assessment will become another major application of satellite imagery during the coming budget year.

In 1990 NRCT's LANDSAT license cost about 16 million baht, while it's SPOT fee was about 9 million baht. LANDSAT's fee remained relatively constant at 16 million baht; SPOT's costs, however, increased considerably to 21 million baht for the 1991 budget year. NRCT's total remote sensing budget for 1990 was 83 million baht. This will be increased by 53% in 1991 to 127 million baht, making NRCT the largest RTG agency gathering spatial data in terms of budget percentage.

An analysis of RTG budgets dealing with remote sensing (see *Table 2.3*, this is not an exhaustive list as some agencies receive funding for spatial data gathering from outside sources are not recorded by the Budget Bureau) indicates that NRCT can expect about 9 million baht of income from RTG sources in 1991. While NRCT's 53% budget increase is reflected by an expected 57% increase in imagery sales, it is apparent that its increased operating costs are not being met by an equivalent increase in sales of imagery within the RTG.

It is evident that the few RTG purchasers of satellite imagery contribute little to the fixed operating costs, let alone to the necessary system upgrades and thus are being **subsidized** by the NRCT. Part of the reason may be found in the pricing scheme established by the NRCT (*Table 2.4*), which reflects the fact that its main satellite imagery products are commercial products. Another reason is the lack of adequate image processing facilities in RTG line agencies, which limits the utility of the images it does sell and restricts its potential customers.[30]

While exact details of the imageries being purchased by RTG agencies are not known, if one assumes that it was all 3 band, color SPOT (@31,200 baht, the most expensive), the budget expended could be used to produce about 280 1:50,000 land use maps which would cover approximately one-third of the Kingdom. Thus, it would take DLD three years or a tripling of the entire current RTG remote sensing budget (the line agency responsible for land use mapping) to acquire data completely covering the

[30] Atwell, B., 1987, *Government Policy Issues for Satellite Remote Sensing in Natural Resources Development: Thailand.* In Proceedings of Remote Sensing '87: Remote Sensing and Information System for Planning and Development, Songkhla Thailand.

Kingdom. This hardly seems likely in view of the overall decline in DLD's spatial data gathering budget.

Table 2.3 RTG Remote Sensing Budgets

Agency	1990 (baht)	1991 (baht)
RFD	3,710,000	3,157,000
DMR	300,000	5,000,000
DTCP	1,465,400	0
OAE	300,000	500,000
DLD	0	512,000
NEB	63,000	55,000

Source: Budget Bureau

Recommendations

If data from satellite remote sensing is important to the management of the Kingdom's natural resources, there are two possible courses of action for NRCT: (1) to fully subsidize its satellite imagery making it freely available to all users within the country (the ideal of the original *Open Skies Policy* of the LANDSAT program) or (2) to dramatically increase the remote sensing budgets (and consequently their spatial data gathering costs) for all RTG line agencies. Obviously, because RTG agencies are reluctant to spend money on gathering geographic information, it is unlikely that the latter course would be feasible. The relatively meager amounts that the NRCT normally receives for this spatial data might be better spent on upgrading each individual RTG agency's image analysis capabilities in terms of equipment and staff training.[31] This would tend to help develop a future market for satellite imagery as well as a market for NRCT's own skills in image analysis.

[31] For example, DMR's 5 million *baht* remote sensing budget for 1991 should be able to purchase 3 to 5, state-of-the-art image analysis worktations.

Cadastral and Urban Spatial Information

The above spatial information can usually be found at the RTSD base map scale of 1:50,000. Apart from this scale, there exists, another larger scale of data normally found in urban surroundings. Two RTG agencies customarily gather spatial information in this environment: the Department of Land (DOL) and the Department of Town and Country Planning (DTCP), both within the Ministry of Interior.

The Department of Land

The DOL is legally responsible for gathering detailed cadastral information and recording it on large scale maps (scales ranging from 1:1,000 to 1:10,000). The DOL is responsible for maintaining the cadastre for all public and private non-forest reserve land in the Kingdom.[32] Specifically, its responsibilities include public land surveying, protecting public land, utilizing public land to benefit the RTG, land allocation, land parcel adjustment, issuance of land titles, land registrations, control of real estate business, as well land and property tax evaluation. Thus the DOL is the country's primary land management agency, except for land defined as forest reserve. The importance of spatial data to the DOL is reflected in the relatively large portion of its total budget that it sets aside for such purposes: 8% of its 1990 budget of 1.096 billion baht, further increasing to 9% of 1.456 billion baht for the 1991 budget year. Other than NRCT, it is the only RTG agency that actually increased its spatial data collection budget in 1991.

Updating Cadastral Information

The DOL's cognizance of the importance of spatial information is driven by several factors. First, the cadastral information in Thailand is presently in a state of flux. Accurate land deeds (*chanote*) exists for a relatively small area of the country only. They are restricted mainly to the larger urban centers and their surrounding suburbs, and it is estimated that only one landholder in six possesses a land title.[33] Less accurately recorded land certificates (*Naw Saw 3 Kaw* or NS3K) cover a slightly larger part of the Kingdom, mainly the newer urban centers' surroundings. The remaining land area, mainly rural or encroached reserve forest land, is covered by even less legally binding

[32] The term cadastre refers to the legally recognized register of quantity, ownership and value of land parcel.

land documents (*Bai jong*, STK, etc.) Financial institutions usually recognize only chanote and NS3 as collateral. DOL is currently embarking on an ambitious project to reform its land record system and to upgrade all present land titles by issuing chanote for the whole Kingdom. This massive undertaking is scheduled to take 20 years, with initial support coming from the World Bank and the Australian International Development Assistance Bureau.

Table 2.4 NRCT Satellite Remote Sensing Data Pricing

Product	Price
TM subscene (1:50,000)	13,750
TM Computer Compatible Tape (CCT)	55,000
SPOT panchromatic (1:50,000)	26,000
SPOT panchromatic CCT	59,800
SPOT 1 band, black & white (1:50,000)	11,700
SPOT 3 bands,black & white (1:50,000)	23,400
SPOT color (1:50,000)	31,200
SPOT color CCT	46,800

Note: All prices in baht for geocoded product. NRCT adds a 50% surcharge for rush service.

Source: Thailand Remote Sensing Center, NRCT

Second, the Thai Cabinet established a Central Valuation Authority (CVA) as an impartial body to evaluate property values. The CVA will value land as a basis for DOL's transfer fees and taxes, as a basis for local taxes, and as a source of information when compensating land owners in cases of government land acquisition. Thus, the CVA has need of an accurate land record system to which it could link its property valuations.

Finally, concurrent with the enhancement of existing land titles is the changing nature of Thailand's land use. More and more suburban and rural land is becoming **urbanized**—creating a need for more accurate and legally acceptable cadastral information. Credible cadastral maps are required if urban managers are to keep pace with rapid development and subdivision. In Bangkok, the cadastral maps have been

[33] Angus-Leppan, P. 1989, *The Thailand Land Titling Project: First Step in a parcel-based LIS*, Int. J. Geographical Information Systems, Vol 3, #1, pp 59-68.

described as *unsatisfactory, old, and dilapidated.*[34] In most urban centers in Thailand, the cadastral maps have not been updated for decades.

Drawbacks and Advantages

Cadastral information would form an excellent basis for managing other thematic data were it not for the large scale at which it is recorded.[35] Almost no other spatial information concerning natural resources or the environment exists at this scale. As we have seen previously, the majority of Thailand's natural resources and environmental information is found at the RTSD base map scale of 1:50,000 and thus cannot be accurately integrated with cadastral data. Land Information System (LIS) proposals based on the premise of integrating cadastral and environmental information are therefore untenable and bound to fail.[36]

In orthodox urban situations, however, cadastral data can and do form the base maps for other spatial information. This spatial data deals with all of the urban area's intricacies, from individual land tenure to the location of a city's infrastructure—its water mains, electric poles, fire hydrants, and so on. In the Bangkok Metropolis, DOL, the Bangkok Metropolitan Authority, Metropolitan Electrical Authority, Metropolitan Water Works Authority, and the Telephone Organization of Thailand have begun a joint pilot project in Phra Khanong district to establish a multi-theme Land Information System (LIS). This project will cover an area of about 25 km^2.

Urban or cadastral based information is generally of considerable size. Consider for example, land tenure or cadastral data, where on a day-by-day basis, the land ownership, land use or the actual shape of a land parcel, is changing.[37] Add to this the other information that a complex urban entity generates and you have a truly staggering amount of information. Because of the size and complexities involved in urban or cadastral situations, the cost-benefits of an LIS would be expected to be high.

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[34] Angus-Leppan, P. 1989, *The Thailand Land Titling Project: First Step in a parcel-based LIS*, Int. J. Geographical Information Systems, Vol 3, #1, pp 59-68.

[35] In fact in the United States and Europe it does. For example, it forms the basis of county-level LIS or Land Information Sytem in many state in the USA, San Diego County, California, being a good example.

[36] For example see the proposed LIS in TDRI, 1990, *A Land Policy Study* edited by T. Onchan. *TDRI Foundation Research Monograph #3.*

[37] Hunter, G.J. and Williamson, I.P., 1990, *The Development of a Historical Cadastral Database*, Int. J. Geographical Information Systems, Vol 4, #2, pp 169-179.

Department of Town and Country Planning

City and town planning for the Kingdom is the responsibility of the DTCP. While technically the DTCP is responsible for formulating regional, provincial, municipal, and rural plans, it customarily limits its planning activities to the municipal level and has only recently forayed into the provincial level (Samut Prakan province, see chapter 4). The principal spatial information that DTCP creates is a map, zoning a municipality into areas of approved activities—areas reserved for agriculture, parks, nature areas, industry, housing estates, etc. The DTCP prepares these master plans for municipalities, but implementation and zoning enforcement resides with the local authorities. The DTCP, with the aid of JICA, is acting to improve and expedite its planning practices, which to date have not kept pace with the rapid changes in Thailand.

The DTCP's total budget increased 118% from 1990 to 1991, from 188 up to 410 million baht. The budget portion expended on spatial data gathering, however, fell as a result, from 7% (14 million baht) to 5% (20 million baht).

WHAT GOOD IS SPATIAL INFORMATION TO MANAGERS?

The well-being of human societies has always been dependent upon their surroundings. From Thailand's early irrigation-based city-states to its present day urbanization and approaching NIC status, the geography of human communities has been important. It is becoming increasingly more important now that the world is becoming more crowded and its resource base is diminishing. Past laissez-faire attitudes that resulted in environmental degradation are no longer being tolerated, from grass-roots to international levels. Converting farm land to a new urban area, granting of mining concessions, constructing a dam, or building a hazardous waste disposal site are activities that are now being scrutinized by different regulatory agencies and are frequently the subject of public opposition. Globally, acid rain, climatic changes, the specter of rising sea levels and tropical deforestation have been recognized by many as problems that affect the economic and social well-being of the entire human race. Indeed, geography and the very fabric of human societies are inextricably interwoven.

Today's managers are faced with solving complicated problems—problems that are no longer single-faceted or exclusive to one discipline. In addition to the complexities of the problems themselves, further complexity is introduced by diverse and

sometimes contradictory government regulations and jurisdictions. Even the lack of regulations and jurisdictions can sometimes create an additional layer of difficulty. Complex interrelationships exist between the various components that comprise today's environmental and natural resources issues—geography, ecosystems, economics, and public opinion are all important factors. Success or failure in dealing with these issues will be determined by how well managers are able to integrate multidisciplinary knowledge and expertise.

Decision Making Under Uncertainty

Thus, decision makers require detailed knowledge about the real, complicated world. As indicated previously, it is not possible to collect complete knowledge of our world. Realistically, we must accept some sort of contrivance that allows us to make judgments without complete information. We term this mechanism a **model** of the real world. The conceptual model we adopt will subsequently affect any decisions that are based on it.

Decision makers are thus forced to **operate under uncertainty**, while at the same time having to **avoid taking risks**. One way of reducing risks is to assess the problem in conjunction with other information that may only appear to be peripheral to it. Lord Chorley, president of the British Royal Geographic Society, has pointed out that, *the usefulness of one data set may be greatly enhanced by merging or linking it with other data sets*[38] and thus will result in better decisions. With each piece of information integrated into the decision making process, the uncertainty and thus risk is reduced. The confidence that the decision is correct increases as a consequence.

Diverse phenomena are sometimes best understood in terms of their geography. For instance, take the question of whether a proposed *Greenbelt* policy is feasible. The location and extent of the remaining suitable agricultural land would first have to be determined by examining land use and soil information. Its proximity to urban or urbanizing areas would also have to be taken into account, as would present land prices—is it really practical to acquire this land? The brief review of the spatial information gathered by various RTG agencies presented above also bears witness to the

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[38] Lord Roger Chorley, 1988, *Some reflections on the handling of geographical information,* Int. J. Geographic Information Systems, Vol. 2 #1, pp 3-9.

realization by many RTG agencies that spatial information is pertinent to the proper management of natural resources.

Spatial Information as a Social Commodity

Within the public sector, geographic information has been described as *a social commodity*. Its collection is legally mandated by political organizations for social needs, legal description of land ownership, assessment of forest and mineral resources, the determination of land capability, and so on. The *Land Development Act of 1983* illustrates this point. The Act transferred authority concerning land development from the Department of Land to the Department of Land Development, thus effecting a change in spatial information collection duties. It further stipulated that the Department of Land Development would be the responsible agency for mapping land suitability, current land use, planning land development and for the conservation of land and water resources.

There is also a trend for government agencies to collect more detailed, more precise and more current geographic information. This trend is being motivated in part by increased awareness of environmental concerns and by the simple fact that in order for organizations to function effectively, they require accurate and timely information. For example, the forest inventories now being collected by the Royal Forest Department have been driven by a need to more reliably and more promptly estimate forest reserves since the governments decision to close the nation's forests in 1989. Other RTG agencies are also a part of this trend: the Department of Land is in the process of upgrading and issuing precise land deeds for the entire country; the NRD2C village survey has grown progressively to include more detailed socioeconomic data and has now become a permanent feature of RTG data gathering practices.

SPATIAL INFORMATION TECHNOLOGY

Traditionally, paper maps have been used to hold spatial information, with the map acting like a *snapshot*, usually of a single set of geographic data at a single point in time. Spatial information on paper maps is customarily organized by sets of themes, such as villages, infrastructure, rivers, and political boundaries which are represented by various colors, shade patterns, and point and line symbols. The physical map can be relatively easy to produce. It stores a considerable amount of geographic data in a readily

accessible and somewhat compact form. Several limitations, however, restrict the usefulness of spatial information retained on paper maps.

The level of detail represented on a paper is usually a trade-off between information requirements and the physical limitations of the paper map. The information is said to **generalized**, that it is presented in less detail to make the map more readable.[39] This is because a paper map is **both the storage medium for the spatial information as well as its form of presentation**. The form of presentation actually serves to limit the information content of the map. Consider for instance, an RTSD base map. It normally contains villages, topography, infrastructure, rivers as well as amphoe-level and higher political boundaries. A one-for-one comparison of the villages in the NRD2 database and those found on the base map will usually show that there are several villages in the database that cannot be found on the map.[40] Enquiries made at the RTSD, indicated that these missing villages were not placed on the map for esthetic and legibility reasons. If all the villages, particularly in a densely populated area, were to be placed on the map, it would quickly become unreadable and therefore useless.

Keeping a paper map current can be an expensive proposition. The process of updating a physical map involves changes to the map's film masters and reprinting the entire map, no matter how small the changes. The expense and time involved generally restrict the time between updates. Paper maps are thus relatively static. For example, most of Thailand's topographic maps date from the late 1960's, while the average age of a *present* land use map is about 5-7 years.

Another drawback of using paper maps is in analysis. Geographic analysis usually requires determining the relationships between several sets of data or map layers. For example, in rationalizing land use in mountainous terrain, several factors must be considered: slope, elevation, water availability, forested land, population, cultural practices, crop requirements, and transportation. Each of these pieces of spatial information would normally be plotted on different maps. In analyzing this data, all nine of these map layers would need to be overlaid, resulting in 512 possible combinations.[41] The map graphic resulting from so many layers of overlays would be nearly incomprehensible, while the 512 possible combinations would very likely overload any

[39] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective*. WDL Publication, Ottawa, Canada.

[40] It has been TDRI's experience that, in some cases, there is up to a 45% discrepancy between thee two data sets.

[41] This is 2^9 possible combinations.

attempts to manually analyze them. It is relatively easy to retrieve small amounts of spatial data or analyze the relationship among a few data sets using manual methods. These methods begin to break down when large volumes of data are considered. The physical maps themselves impose a very finite limit to the number of layers that can be analyzed.

Analytical products derived from paper maps are customarily used for a single purpose—it is usually difficult or impossible to adapt one product to another application. The potential benefit-cost ratio is thus limited because of the limitation of the analysis to a single application. If, however, multiple products could be derived from the same data sets, the benefit-cost ratio should be increased.

The pace of change—socially, environmentally and technologically—is accelerating. The demand for accurate spatial data presented quickly in map form is increasing as well. Given the shortcomings of physical maps, how can we improve our ability to deal with spatial information and thus the world around us? Increasingly many are finding the answer to this question in Geographic Information Systems technology. The following will attempt to answer some of the more important questions about GIS as well as its status in Thailand.

Chapter 3

GIS: New Solutions to Old Problems

BACKGROUND

Physical maps have been used to integrate spatial information for several years. *Light table gymnastics*[1] can be accomplished with paper maps, as pointed out in 1969 by the American landscape architect, Ian McHarg, in his work, *Design with Nature.*[2] But as noted previously, physical maps have practical limits that are quickly reached in complex analytical situations. Ways have been sought to apply computer-based techniques to the problems of handling and analyzing geographic information since the mid-1960s.

The first two GISes began about the same time in North America, in the United States and Canada . The Land Use and Natural Resources Inventory of New York State (LUNR) and the Canadian Geographic Information System (CGIS), both made heavy use of aerial photography, as well as existing maps, to develop an inventory of existing resources. The spatial information encoded into computer form in these systems included, agriculture, soils, forestry, wildlife and geology. These systems were also important in an institutional context. They had both recognized from the outset that a clear, well-defined **sponsor** would be a prime requirement for a successful system—the state of New York sponsored LUNR, while the Canadian Federal Government sponsored CGIS.

While these systems began in the 1960s it wasn't until the early 1970s that they became operational. The computer hardware of the 1960s was the main drawbacks, it simply wasn't powerful or inexpensive enough for this type of system to become operational.[3] While not entirely successful, these systems, served as a spur to stimulate

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[1] Berry, J.K., 1987, *Fundamental operations in computer assisted map analysis.* Int. J. Geographical Information Systems, Vol 1, #2.

[2] McHarg, I.L., 1969, *Design with Nature.* Doubleday & Company, New York.

[3] Tomlinson, R.F. Calkins, H.W., and Marble, D.F., 1976, *Computer Handling of Geographical Data.* Natural Resource Research Series XIII. The UNESCO Press, Paris, France.

technical creativity that later improved the viability of computer based geographic information systems.

From the 1960s on, the Harvard Graphics Laboratory, was one of the most active research groups in developing computer-assisted map analysis programs. It was staffed by an enthusiastic, internationally reputed and able staff. The early programs they created—SYMAP, GRID and IMGRID—performed overlay operations in a manner that was faster and more flexible than manual methods. These systems, with a little more effort, also allowed spatial information to be stored and organized in computers, allowing planners for the first time to make use of them.

In 1977, experiences using computer-based cartography had advanced to such a point that David Rhind, a British geographer, was able to compile a list of reasons for using a computer:[4]

- **To make existing maps more quickly**
- **To make existing maps more cheaply**
- **To make maps for specific user needs**
- **To make map production possible in situations where skilled staff is unavailable**
- **To allow experimentation with different graphic representations of the same data**
- **To facilitate map making and updating when the data are already in digital form**
- **To facilitate analyses of data that demand interaction between statistical analyses and mapping**
- **To minimize the use of printed maps as a data store and thereby minimize the effects of classification and generalization on the quality of the data**
- **To create maps that are difficult to make by hand, e.g., 3-D maps or stereoscopic maps**
- **To create maps in which selection and generalization procedures are explicitly defined and consistently executed**
- **Introduction of automation can lead to a review of the whole map-making process, which can also lead to savings and improvement**

[4] Rhind, D. 1977, *Computer-aided Cartography*, Tran. Int. British Geographer, 2, pp 71-96.

Over the last decade or so, the rapid development of computer technology has enabled computer-based geographic information systems to flourish into what we now term GIS.[5] GIS technology has developed to such a point that current estimates indicate GIS expenditures total **billions of US dollars** in the United States alone.[6] It is being applied to tax planning, emergency vehicle routing, demographic research, environmental impact assessment, and more. Why is GIS such a fast-growing field? Why does GIS promise to be one of the largest and fastest growing computer applications ever to emerge?

WHY GIS?

The answer to the question *Why GIS*? has much to do with the importance of spatial information in helping to solve problems. As we have seen, geography and the data describing it are a common part of the workaday world, each decision taken by human beings being governed by some aspect of geography. GIS technology helps to organize information about problems and allows humans to try to understand their spatial relationships. Sensitive and intelligent decision making stem from such an understanding.

Using a computer can profoundly accelerate the speed at which geographical analysis can be accomplished. Much as the printing press transformed the way information flowed through society by making the production of printed material faster and less expensive, a GIS will significantly change the rate at which geographic information is produced, updated, and distributed. GIS will change the way geographical analysis can be approached by changing the way we perceive and make use of spatial information. Geographic data is more malleable, more easily shaped to best fit a user's application by using GIS technology. Geographic information can thus be custom-made, to an extent that was never possible before.

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[5] This brief extract of GIS development is by no means a full history. For a fuller history see: Burrough, P.A. 1986, *Principles of Geographic Information Systems for Land Reource Assesment*, Clarendon Press, Oxford; *American Cartographer* July, 1988 issue; Marble, D.F., Calkin, H., Peuquet, D.J., Brael, K. and Wailenko, M., 1981, *Computer Software for Spatial Data Handling* (Three Vols.). Prepared by the International Geographical Union, Commission on Geographical Data Sensing and Processing for the United States Dept. of Interior, UG. IGU, Ottawa, Canada.

[6] Dr. David Rhind's address at the 1990 ERIS's Users Conference, held in Palm Spring, CA., USA.

Perhaps the two most important advantages of GIS compared with physical maps is its ability to keep spatial information current and to efficiently synthesize multiple data sets into a single integrated database. The capacity to quickly update the geographic database and produce a physical map allows the production of *snapshots* of a continuously changing geographic database. Analyzing and re-analyzing the data is therefore relatively inexpensive and rapidly accomplished. Decision makers can progressively refine a planning scenario by re-analyzing the plan to assess any proposed changes. Several alternate proposals can be appraised by simply re-running the analysis and comparing the results offered by the different plans. Manual methods are generally prohibitively expensive for this **iterative** approach to planning. Planners can now easily play *what-if* games to assess impacts before a plan gets to the implementation phase—helping to reduce risks.

Today, the natural resources and environment field is on the frontier of a new, potentially revolutionary event—a technological and political development consisting of the convergence of a social and political need for rapid and complex analysis of the environment and resources, the swift evolution of GIS technology, and the dramatic advances in computer hardware and storage technology. GIS technology has come to be recognized by many as an important **tool** for managing the environment and resource base for sustainability—it is not just another passing fad. It is a **tool** that can be used to support timely and accountable decision making in an ever-changing world.

WHAT IS A GIS?

Background

A GIS has been variously described as:

- An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information[7]

[7] ESRI, 1990, *Undertanding GIS*.

- A data base system in which most of the data are spatially indexed, and upon which a set of procedures operates in order to answer queries about spatial entities in the data base[8]
- An internally referenced, automated, spatial information system[9]
- A set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes[10]
- Is a tool for storing and manipulating geographic information in a computer[11]

From the above it is clear that a GIS is both a **tool** and a **database**. It is essentially a **data driven process**—that data being geographic data.

Vector and Raster Formats

Two distinct, basic types of GIS are recognized. The first type makes use of map-based data in a **vector** format.[12] The second type of GIS uses image-based data in a **raster** format.[13] The vector type of GIS can be summarized very simply: **the map is a database and the database is a map.** The physical storage of the data is independent of its graphical representation. The raster type of GIS views the **map as a picture.** The vector based GIS approach of *map-as-database* will usually have more functions devoted to database management than the raster *map-as-picture* style.[14]

Building a Spatial Database

The first step in building a GIS is designing and creating a digital spatial database. For spatial information or maps to be automated, there must be explicit definitions of the information to be stored, the database's form or structure must be

[8] Smith and others, 1987, *Requirements and principle for the implementation and contruction of large-cale geographic information system.* International Journal of Geographical Information Systems, Vol. 1, #1, pp 13-31.

[9] Berry, J.K., 1986, *Learning computer-assisted map analysis*, Journal of Forestry, Oct. pp 39-43.

[10] Burrough, 1987, *Principles of Geographical Information Systems for Land Resource Assesment.* (Clarendon Press Oxford).

[11] ESRI, 1988, ARC/INFO Training Manual.

[12] Vector data is a phyical quantity having magnitude and scale or the directed line segment representing such a quantity. More simply put a vector is a bit of information going someplace. It has a direction and a length, it is not fixed.

[13] Raster data can be considered as matrix of discrete, fixed sized cells covering a certain area.

[14] For a fuller description of the various types of GIS see Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective* or Burrough, 1987, *Principles of Geographical Information Systems for Land Resource Assesment.* (Clarendon Press Oxford).

precisely defined, and the general applications or uses of the database must also be determined.

As stated before, there are three types of spatial primitives or entities on any given map: points, lines, and polygons. These entities can also be hierarchically related; that is points form lines which in turn form polygons. Wells, houses, and villages (at certain map scales) are point data. Streams, roads, and utility lines are line or arc data, while soils, land use and forest stands are polygon type entities. In order to take advantage of digital GIS, we must reduce our map data to terms that a computer can understand or *we must raise our own levels of definition and precision to that which the computer can accept.*[15]

The process of automating these spatial entities from map manuscripts or analog data to computer compatible form (digits) is called *digitization.* These is usually done by simply tracing the entities form on a digitizing tablet, which converts this tracing into a string or set of X,Y points of map-based coordinates. This is also perhaps the most critical part of the implementation of any GIS—what you input into the computer will subsequently effect any analysis made later.

Once we have reduced map spatial data to point, arc and/or polygon entities, and rendered these into computer-compatible format, three things must be further specified:

- **where each feature is geographically** (UTM, latitude and longitude, etc.). This can usually be accomplished during the digitization process but may be done at a later stage by transforming the raw digitizer coordinates to map coordinates using standard algorithms.
- **what each feature is** (roads, streams, soils, etc.). This is known as the feature's **attribute data**, including information that describes the major characteristics of the feature in question, such as depth of stream, stream name, annual flow, water quality, etc., etc. These attributes may also be used to manipulate the spatial features and vice versa.
- **what each entities relationship is to the other features on the map** (to-from, left-right, etc.). This is known as **topology**. While humans can intuitively grasp that a certain village is north of a particular stream, a computer has no such built-in recognition system—it must be taught these things from the spatial relationships encoded into the **spatial** database's structure. This is usually accomplished by computer edits, as experience has shown that manually assembling topology is usually a failure in terms of processing speed and time as well as error levels.

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[15] Parker, H.D., 1987 *What is a Geographic Information Systems*?, In Proceedings GIS'87-San Franscico, 2nd Annual International Conference on Geographic Information Systems.

GIS Analysis Function

The data analysis needed by most users of GIS include: reclassification and/or aggregation of attribute data; overlaying operations including union and intersection, measurement of area; perimeter, distance, connectivity, neighborhood statistics and directions; and statistical analyses.

The first and in many ways the most rudimentary class of analytical operations involves the **reclassification** of map attribute data. A new map is created by assigning thematic values to categories of an existing digital map (or coverage). Reclassification merely repackages existing information on a single coverage and results in no new boundaries. It generally involves boolean querying of spatial and/or attribute data. An example of this is the creation of a crop suitability map from a soil map. Various levels of suitability would be assigned to soil polygons based on a particular crop's soil requirements.

Overlay processes, on the other hand, involve two or more maps and result in new boundaries. This class of operations has been aptly characterized as *light table gymnastics.*[16] Intersecting a soil and land use map to create a coverage containing both soil and land use, is an example of this class of techniques. The soil types and properties could be derived for each land use from the new coverage.

Reclassification and overlay processes address most GIS analysis requirements. However, in order to more fully integrate spatial data into the decision making process, other types of analysis are needed. Simple information (such as perimeter, area and distance between points) is frequently needed during resource allocation. Moreover, distance data often needs to be expressed in terms more relevant to the problem at hand—time or money. Delineation of paths or connectivity on a coverage is another distance-related operation useful in many GIS applications (such as delivery truck routing or police car dispatching). Another form of connectivity deals with the intervisibility among locations or **viewsheds**. The ability to determine whether a particular point is visible from another point is useful for example, in siting facilities in natural areas or in military applications such as locating *dead ground* in defense zones. These classes of GIS operations can be best characterized as *rubber rulers*. Operations

[16] Berry, J.K., 1987, *Fundamental operations in computer assisted map analysis.* Int. J. Geographical Information Systems, Vol 1, #2.

which characterized neighborhoods can be thought of as *roving windows* and are often used in deriving slope, aspect, and profile from elevation data.

Statistical analysis, usually in the form of tabular summaries or listings, is a GIS operation whose concept is perhaps the most easily understood. Calculations of frequencies, averages, distributions, etc., of spatial entities or their attributes are regularly required by many GIS users. The frequency of particular soil polygons, the distribution of pH along a stream, and the average width of paved roads in a particular area are some examples of this class operations.

The GIS functions mentioned above are described in terms of map analysis. If one takes the computer science point of view, the answers provided by a GIS will usually fall into one of three categories:[17]

- **a presentation of the current data**, for example what is the land use like now, (storage and retrieval).
- **a pattern within the current data**, such as all abandoned land over 20 rai (constrained query).
- **predicting what the data could be** at a different time or place or given different present conditions, for example forecasting erosion after the conversion of forested to agriculture (modelling functions).

Components of a GIS

Many people getting their first taste of GIS, have a tendency to become infatuated with its hardware and software. The seemingly expensive price tags and the colorful displays and maps tend to lead people into assuming that these two components are the most important or that they are **all** it takes to implement a GIS. More GISes have failed because of this **misconception** than for any other reason. An improperly staffed, poorly managed, or underfunded GIS will surely fail, in spite of huge budgets expended on hardware and software. **A GIS without geographic information is useless**, the true value of a GIS is measured by the geographic data it contains. A *real* GIS must consist of five components:

- **hardware**—used to treat, store and display digital spatial data.

[17] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective*. WDL Publication, Ottawa, Canada.

- **software**—performs GIS operations.
- **digital geographic data**—which the GIS manipulates and displays.
- **procedures**—are followed to accomplish various operations.
- **expertise**—the people who provide the underlying intelligence to develop, use and maintain the system. Of the five parts of a GIS, people who know how to use the system are the most important and the hardest to find

Users of the GIS, in fact, become a part of the GIS. They provide the intellect, the genius behind the system. This is especially true when complicated spatial analysis and modelling must be carried out. Expertise is required to select and to use the appropriate GIS tools as well as to understand the data being used. Advertising claims to the contrary, there is **no** off-the-shelf, general purpose GIS available today that is simply push-button—the users must know what they are doing.

Institutional Aspects of a GIS

To be effective, a GIS, must reside in an appropriate institutional framework. It is often pointed out that a GIS does not exist in a vacuum. The GIS must be properly staffed, managed, and funded; above all it must be given some type of **mandate** or goal. The GIS's management is mandated to service some **user community** within a government agency, a business, or some academic institute. Stan Arnoff summed up the institutional issue as follows, *ultimately, the purpose for the GIS facility is to assist the users in accomplishing the goals of their respective organizations.*[18] Thus, **a GIS is not an end in itself.**

Users of a GIS (and most other information systems) fall into two categories: internal and external users. **Internal** users are those users responsible to the same management as the GIS, while **external** users report to a management other that controlling and/or funding the GIS. Each must be treated in different ways. For example, consider a GIS built by a military organization, users with the proper clearances (generally military users) would have much freer access to the database than would some outside organization such as a university—access to the GIS would be rigorously controlled and restricted.

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[18] Aronoff, S., 1990, *Geographic Information System: A Management Perspective.* WDL Publication, Ottawa, Canada.

All GISes begin life performing old tasks in the old manner (organizations would like to continue doing what they do best or are most comfortable with because organizations do not readily adapt to change). Over time, however, the principal use of an information system will always tend to evolve. As users become familiar with the system's capabilities, new ways taking full advantage of the new technology will be developed to provide the same functions. Finally, new functions will appear and new technology will be used for new tasks. GISes normally develop from inventory systems, where emphasis is placed on building databases, to analytical systems, and finally to meeting management needs.

Implementing a GIS

The design and implementation of a GIS is a considerable undertaking, which may take a year or more. The issues having the most influence on the success or failure of a GIS are almost always related to **people**. The technology itself is concrete and therefore rational. Thus, its performance in a given situation can usually be predicted. Humans are, however, not as easily predictable as the technology they employ. Humans react not only to facts but to their context as well. Personality clashes and power struggles can result in seemingly irrational decisions. In arriving at a decision, people bring their own emotional and institutional baggage with them. Differing agendas are thus sometimes reconciled according to institutional or personal power.

The reason humans complicate the implementation process so much is that a GIS is where humans and technology meet (or sometimes, clash). The implementation of GIS technology within any organization is also a political process. The influence a GIS has on an organization has been described as *pervasive*.[19] In adopting this technology the organization itself must change because **information is power**. A GIS will cause a shift in the flow of information within an organization, with a different set of people now exerting control over the disposal of information. Power will be shifted into the hands of the organization that controls and generates information. Computer information systems are always political because control over centralized information almost always ends in the hands of the system administrators or technical experts who dominate the system at the expense of those without their technical know-how.

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[19] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective*. WDL Publication, Ottawa, Canada.

Decisions based on data generated by a GIS can made into impressive political weapons. Policy makers and the general public usually consider computer-derived information to be more accurate and credible simply because it was generated by a computer. Technical language used to describe the data and the decision generated from it usually sounds politically neutral and thus more objective. A technical expert can use a computer to conceal political choices beneath a veil of seemingly unbiased technology.[20] On the positive side, most GISes can usually keep a log, similar to the transactions in one's bank account, that is a faithful recording of the data and the analytical procedures applied to it. While this log may or may not be publicly revealed, it can still be audited or *played back* by a technically capable person, thus maintaining some measure of **accountability** within the system.

Generally there are six steps or phases to implementing a GIS:

- **Knowledge of the GIS**: This is when an organization first becomes aware of the technology and its potential benefits to the agency. This may be suggested by someone or group within the organization itself, another GIS-experienced institution, or a third party such as a GIS vendor. Problems within the current system are identified and a GIS-based solution is proposed. Perceived problems may include poor data maintenance, non-standardized data, isolated data, or the assignment of new responsibilities to the organization.
- **System requirements**: After an agency becomes aware of and formally accepts the GIS idea, its own functional requirements in terms of the GIS technology must be appraised. Potential users and applications must be identified. This will usually require what is termed a *user survey*[21]. This process has political overtones to it because it will effect the specifications of the system—who has first priority, who has what equipment, who has access rights to what data, etc. The system sponsor is usually identified during this phase. The user survey is also a process fraught with pitfalls. If improperly done a user survey may arrive at system specifications too broad to be of use to the narrower institutional environment within some subgroup of the agency. On the other hand, too narrow a functional definition concentrating on one subgroup, may not serve the broader interests of the organization as a whole. It is important that the functional requirements reflect the needs of those who will actually use the system and that all interest groups within the organization have their needs equitably represented.
- **System evaluation**: Once an organization defines its functional requirements, it should evaluate several, competing solutions to these requirements. Benchmarks of required functions should be run, as well as evaluations of training, documentation, technical support, data entry, back-up and recovery systems, and

[20] Kloterman, R.E., 1987, *Guidelines for Computer-Aided Planning Models*, In Proceedings of the URISA '87 Conference. Urban and Regional Information System Association, Washington D.C., Vol. 4, pp 1-14.

[21] For an example of a user survey carried out in Thailand see TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resource Management of Songkhla Lake Basin.*

overall system flexibility. **Data entry** functions are especially important in Thailand, where most GISes must begin from scratch. A system with slow or awkward data capture facilities may well doom a GIS to failure in Thailand, simply because it cannot keep up a steady supply of spatial data for analytical purposes. It will also prove more expensive in the long run, as the database development costs will usually account for 75% of the total implementation budget. This step will determine the go/no-go of the GIS.[22] If no system evaluates out to the required specifications within the available budget, then the system will not be feasible.

- **Implementation plan**: Following a go decision on establishing the GIS, a more or less formalized plan should be developed to implement it. This plan should address system acquisition, staffing and above all, the needed organizational changes and budgeting to implement the GIS. Technology, information and people will be molded into a single system following the scheme laid out in the implementation plan. Justification for the system, including cost-benefits, may be worked out during this phase. The plan should consider database development priorities in order to bring the GIS into operation as soon as possible. The plan should also thoroughly cover staffing requirements, as people will ultimately determine the success or failure of the GIS. It is critical that expertise, enthusiasm, and commitment should be built within the group chosen to implement the GIS.
- System purchase: After developing the implementation plan and **gaining the support of the organization**, the next step is to contract for equipment and services. The functional requirements considered critical to the organization should be unambiguously specified in the vendor's contract as specific guarantees of system performance . While pricing is important, **service, staff training, support, and delivery schedules** may prove critical to the overall success of the GIS, especially as the first products produced by the GIS will have an impact on how the GIS is perceived within the organization.
- Operations: The operational phase of a GIS implementation is defined as the point when users of the system begin to make satisfactory use of it. Although a GIS may have reached this stage, it may still fail if the system is not performing acceptably as intended by the organization. It must meet the information needs of the agency, even as the GIS itself effects changes in them. Operational issues include procedures to keep data and services up-to-date, procedures to keep staff up-to-date on new GIS developments, and guidelines to deal with the responsibilities arising from the effects of using the information provided by the system. Procedures that publicizes the GIS, should also be established, such as making known the successes of the system, tours of the facility, project highlights, proven benefits emphasized, etc.

Issues of Responsibility

Once a GIS begins to function in an operational sense, certain issues will begin to make themselves felt. These questions revolve around responsibility for the

[22] TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resource Management of Songkhla Lake Basin.*

repercussions of providing spatial information. This is especially true of GISes within publicly funded organizations (such as the GIS within the Department of Land) or GISes operating within independent third party NGOs ostensibly acting for the public good (TDRI as a policy research institute, for example). Responsibility and liability may be one of the more serious issues facing GIS operators, planners and managers as these systems become operational.

While computer systems have well-developed security techniques, the voluntary distribution of information carries responsibilities that are more often than not vague or undefined. **Information is power.** Society often assigns to some professions, **legal** accountability for the quality of information these professions provides. Medical doctors for example, are held responsible for the diagnoses (information) they dispense to their patients. Recently in Bangkok several buildings under construction collapsed. One of the first persons usually sought by police in connection with these cases is the site or quality control engineer. An accident involving a ten-wheeled truck, will usually see the driver fleeing to avoid being held accountable. Thai society holds these occupations responsible for the information they provide or the tasks they perform. Thai society does not, however, hold producers of spatial information or analyses accountable. A researcher can often shirk responsibility by simply producing spatial information without any coordinate system, scale or attributable markings—it can thus be easily denied. In many cases, responsibility is disowned by the simple expedient of denying access to the information in the first place.

Within an operational GIS, critical information policy is often left by default to the discretion of the GIS operator or researcher, without any clear-cut responsibility being designated. Decisions involving the generation, distribution, and validity of data is often not explicitly assigned to any individual within the organization. Stan Aronoff has suggested the creation of a position entitled *GIS Information Officer*,[23] who would be ultimately responsible for the ways the GIS was used. It would be incumbent on this officer to seek advice on the technical, legal, economic, and political aspects of the data generated or released from the GIS. A good example of a system for responsibility is the engineering profession. The output from a design process is an engineering plan. While this plan may have been drawn by some draftsman, an engineer somewhere along the line will have assumed responsibility for this product by stamping and signing it. The

[23] Aronoff .S, 1990, *Geographic Information Systems: A Management Perspective*. WDL Publication, Ottawa, Canada.

engineer's signature on this document indicates that he/she assumes responsibility for its correctness, at least as far as its intended purpose.

Basically, there are four areas of responsibility that should be addressed in the context of an operational GIS:[24]

- **Content**: The reliability of spatial location or map attributes recorded in a GIS is important. The management of a GIS must therefore ensure that the data within the GIS accurately represents the **real conditions** that it is supposed to describe. The producer of spatial information should be held liable for its content. The U.S. federal government was held accountable for the **inaccurate** placement of a broadcasting tower on an aeronautical chart that resulted in a fatal plane crash.[25] Once accepted into a GIS, spatial information would then become the responsibility of the GIS organization. Responsibility for its original accuracy should therefore be assigned to the **original** producer of the information prior to being incorporated into the database—however, verification for this must be the task of the GIS management. Data standards are an attempt to ensure accuracy of content, with most efforts to date concentrating on the supply side of information. The consumers of spatial information should also be held responsible for knowingly using data beyond its level of accuracy. The concept of risk assessment may be used to determine and minimize potentially dangerous consequences of using maps. Stan Aronoff describes a system based on a **minimum accuracy value**, whereby the worst case map accuracies can be estimated and their consequences diminished.[26]
- **Context**: Users of spatial data can be mislead by the context of the information displayed on a map. Information from different sources depicted together on a map makes a statement about the spatial relationships among all the elements on that map. Elements that look adjacent to one another are assumed to be adjacent from the context of the map. Erroneous inferences can thus be drawn from information intentionally or inadvertently taken out of context.
- **Data Format**: Once spatial information is transferred from physical maps into digital format in a GIS, querying or searching it becomes relatively quick and easy. While this change of data format may be a blessing to many, in some cases it actually lowers the protection of some types of information. For example, consider cadastral information in Bangkok. It is held in paper form scattered throughout the city in local offices of the Department of Land. If someone wanted to search for owners holding titles valued at 10 million *baht* and above, one would have to gain access to several **different offices** past several different officials, and search through perhaps hundreds or thousands of paper records—combined together, an almost impossible task. Once this information is stored in computer form and centralized, searching for these properties becomes almost child's play. In this case, the format of the information is a

[24] Aronoff .S, 1990, *Geographic Information Systems: A Management Perspective*. WDL Publication, Ottawa, Canada.

[25] Epstein, E.F., 1987, *Litigation over Information: The Use and Misuse of Maps*, In Proceeding of the International Geographic Information System Symposium: The Research Agenda. Association of American Geographers, Washington, D.C.

[26] Aronoff, S.,1985, *The Minimum Accuracy Value as an Index of Classification Accuracy*. Photogrammetric Engineering and Remote Sensing 51(1), pp 99-111.

practical and effective form of protection. Steps must be taken to ensure that information that should **rationally** be protected is indeed secure once it becomes part of the GIS database.

- **Data Set Combination:** One of the main benefits of a GIS is its ability to combine different spatial data sets together to facilitate analysis. The users and operators of a GIS should, however, be aware that inaccuracies may be created or increased when synthesizing data sets. The accuracy of any product of combination functions (for example, intersection or union) is not more than that of the least accurate input data. Many times users of GIS will combine information of different scales, and make use of the product at the larger (better) scale. No assessment of the accuracy of the combined product is ever made. Data set combination can also take information out of context. One theme of data plotted on another map implies that the accuracy of both is the same. For example, plotting 1:50,000 scale geology map on a large scale cadastral map (1:10,000) implies that the geological information is as accurately represented as the cadastral data—something which is simply not true. In another example, a government agency uses forest, public land, soil, and political maps, to locate potential areas for its activities. This reconnaissance work uses information at a scale of 1:50,000. Once these areas have been located, it proceeds to intensively survey the terrain and cadastral information for these areas at a scale of 1:10,000 in order to plan and implement its assigned work. In creating its 1:10,000 scale plans, it uses the same scale soil information (1:50,000) used during its search for potential areas on the assumption that this information is accurate because it comes from a different government agency.

The above are only a few of the more important issues confronting those responsible for operational GISes. These questions will become troublesome later, if left unanswered now. GIS managers in Thailand can avoid any future problems if these issues are calmly and rationally addressed from the outset.

Errors in GIS

Errors of some kind are inherent to all geographic information. Every step in using geographic data introduces error. In managing error levels in a GIS, there is a trade-off between reducing levels of error in the database and the cost of creating and maintaining that database. Geographic errors can be grouped into six major types:[27]

- **Data collection errors** result from errors in the original map manuscripts, from field surveyed data, or from analysis of remotely sensed data.
- **Data input errors** ensue from inaccurate digitizing as a result of equipment or operator errors and the errors inherent in the map representation of certain natural

[27] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publication, Ottawa, Canada.

boundaries such as soil or forest—which are never as sharp as depicted on the map.

- **Data storage errors** result from the way the information is actually represented in the computer. Inadequate numerical precision for vector type databases or insufficient spatial precision for raster type databases are sources of error.
- **Data manipulation errors** are byproducts of the selection of ill-suited class intervals, boundary errors, the propagation of errors from multiple overlays, and mixing radically different map scales.
- **Data output errors** derive from flaws in scaling, inaccuracy of the output device, and the instability of the output medium.
- **Errors from use of results** follow from misunderstandings of the actual information product generated by the GIS, accuracy levels ignored or when results are inappropriately used.

The objective in dealing with errors in a GIS should not be to altogether remove them but to manage them. It is an important responsibility for GIS managers to see that errors which cannot be eliminated are plainly known to the end users of GIS generated products.

Cost-Benefit of GIS

Recently, there have been several efforts at preparing cost-benefit evaluations of GISes.[28] Generally these undertakings have been able to more or less precisely determine **costs**, but have not been as successful in estimating benefits. Several reasons have been cited for this:

- **it may be difficult or impossible to identify and describe the level of demand which the GIS is supposed to meet** (the very nature of the organization holding the GIS will change because of its presence)

- **the supply and demand of geographic information is not easily quantified** (a buyer-seller market may not exist, as some end users of spatial information are

[28] For example see, Dickinson, H.J. and Calkins, H.W., 1988, *The economic evaluation of implementing a GIS*, Int. J. Geographical Information Systems, Vol. 2 #4, pp 307-327; Wilcox, D.L., 1990, *Concerning 'The economic evaluation of implementing a GIS'*, Int. J. Geographical Information Systems, 1990, Vol. 4 #2, pp 203-210; Dickinson, H.J. and Calkins, H.W., 1990, *Comment on 'Concerning "The economic evaluation of implementing a GIS "*, Int. J. Geographical Information Systems, Vol. 4 #2, pp 211-212; Kevany, M.J., 1986, *Assessing Productivity Gains in Advance: Feasibility Studies.* In Proceeding of the URISA '86 Conference, Urban and Regional Information System Association, Washington, D.C., Vol.2 pp 40-46; Laroche, . and Hamilton, A.C., 1986, *Unit Costs for Topographic Mapping.* In Proceedings of the URISA '86 Conference, Urban and Regional Information System Association, Washington, D.C., Vol.1 pp 150-158.

many times the GIS agency itself or that much of the spatial data collected is looked upon as a social commodity)

- **a realistic economic evaluation of some products may not be available** (how much is more realistic data worth in policy analysis)
- **the objectives of the GIS cannot be described as a discrete product** (assisting policy-makers in policy analysis)

GIS implementation costs have been estimated to consist of the following:

- **feasibility studies, including user survey**
- **hardware and hardware maintenance**
- **software and software maintenance**
- **database entry or format transfer**
- **database maintenance**
- **training**
- **in-house software enhancement** (macros, interface, special data formats, etc.)
- **running applications** (salaries of system staff, applications specialists, etc.)
- **supplies** (paper pens, disks, tapes, etc.)
- **overhead** (air conditioning, building space, etc.)

These costs can be quantified with reasonable accuracy. Staffing costs are, however, harder to approximate because performance levels and training requirements can only be very grossly estimated. New staff may need to be hired, old staff will need re-training—some old staff may never *take* to the new system. Salary levels needed to attract new staff may cause salaries of existing staff to be raised. At present, the GIS personnel market is such that managers may earn considerably less than the more experienced GIS staff they manage—very few organizations could tolerate this situation for long.

The benefits derived from using a GIS are much more difficult to quantify. The Joint Nordic Project's survey of North American GISes concluded that there are two types of benefits, tangible and intangible.[29] The tangible benefits include:

- **saving time in map production and updating**
- **saving time in maintenance of facilities**

[29] Joint Nordic Project, 1987, *Digital Map Database, Economic and User Experiences in North America.* Publication Division, National Board of Survey, Helsinki, Finland.

- **better maintenance**
- **better planning/engineering**
- **saving of time in administration**
- **more effective administration**
- **more up-to-date information**
- **quicker access to information**

This survey summarized the intangible benefits as:

- **more information**
- **better analysis in less time**
- **increased analysis capability**
- **introduction of analysis not possible before**
- **better decisions**
- **better planning**
- **increased understanding and better analysis of highly complicated systems**

The tangible benefits are mostly related to cost savings. In many cases, the intangible benefits may be quite large—better analysis, planning and therefore decision making. *How much is a correct decision worth? How much is an incorrect decision worth*? Jonathan Raper of Birkbeck College, London, relates an incident from the Channel Tunnel project, Europe's largest infrastructure venture, where British Rail (BR) routed a high speed rail line, connecting London to the Tunnel, right through a recently completed housing project. This large and **public** mistake forced an admission from BR that *the relevant mapping had been done on grease-proof paper on a BR executive's kitchen table.*[30] If administrators focus solely on quantifiable benefits, they may significantly underestimate the potential total benefits of the GIS.

Stan Aronoff indicated that there are five types of benefits that need to be quantified:[31]

- **Increased efficiency**: An effective system will require less resources to accomplish any given assignment. The time saved is generally for an existing task. The time saved is assumed to be beneficial to the organization. Time-savings must, however, be looked at throughout a work day. If a savings in time

[30] Raper, J., 1990, *GIS's Impact on Society: A View from the U.K.* in GIS World, Vol. 3, #2, p 66.
[31] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publication, Ottawa, Canada.

can be affected on a series of **sequential** tasks, these savings will accumulate at the end of the day. The time saved in such circumstances can be usefully applied to other tasks. If these time savings are made on a more or less random basis throughout the work day, then this time saved will be of no benefit to the organization. No new work can possibly be scheduled into these time periods because they appear on a random basis.

- **New non-marketable services**: How valuable is it for an organization to be able to produce better graphics? A GIS can provide new, previously unavailable products. While some of these can be quantified, many more will appear unexpectedly.
- **New marketable services**: The GIS expertise that an organization develops is a marketable skill. If an organization charges for its products or services, the GIS will improve its efficiency leading to increased revenues.
- **Better decisions**: Predicting the value of improved decisions is a problematic task. The GIS will certainly provide more accurate information in a more timely manner and allow more flexible and iterative analyses, but how much is this worth?
- **Intangible benefits**: These differ significantly from the intangible benefits outlined by the Joint Nordic Project. These include better communications within an organization, improved morale, and a better public image. These benefits are hardly a concrete quantity, but will most certainly have a significant impact on an organization's proficiency.

In light of the above, applying strict cost-benefit analysis to GIS is plagued with problems. While its application to **directly** quantifiable costs and benefits must not be overlooked, it can give only a part of the picture, not the whole. In Thailand, with the lion's share of spatial information being collected by the government and thus a social commodity, the benefits of a GIS may largely be intangible ones and its justification requiring an *act of faith.*

GIS Databases

Lord Chorley, president of the British Royal Geographical Society, in his opening address at the first European GIS Conference (EGIS '90) stated that *GIS is not mapmaking, GIS is about spatial data analysis and adding value to spatial data.* This idea is not often understood by those considering GISes, especially those from agencies of the old and traditional mapping establishment. Their concept of GIS is closer to that of an automated drafting or mapping system—not a true GIS. In these types of systems, the map is a graphic and the information recorded in these systems is data about that graphic. For example, it might record that a certain line on a map is dashed and red, not that it represents a highway under construction. These systems simply cannot perform

any serious spatial data analysis—they were not designed for it.[32] Any organization wanting a true GIS but somehow acquiring a mapping system instead, will be disappointed and frustrated with its *GIS*. The concept of the **map as a database** and the **database as a map**, is basic to a true GIS, there is no real substitute for it.

The principle asset of any GIS is its database. It is also its *raison d'etre*—without spatial information, a GIS is useless. Database creation generally accounts for the largest chunk of implementation budget. It involves organizing existing physical maps and converting them to digital form. While many may count it as an expense, the database is a very real and very valuable asset. The conversion process, from paper to digital form, will in many cases bring about actual improvements in the quality of the spatial data. Unlabeled or unclosed polygons, slightly shifted map entities, non-standard legends, and other *fuzzy* errors that humans are comfortable with, will be corrected when converted to digital form and entered into the GIS database. There is value in the data itself, which is increased as the data becomes more readily available, and multipurpose. The database's value will increase with time, as a GIS will facilitate data updating. Contrast this with hardware and software, which will depreciate over time. Historical data maintained in the GIS will also become more valuable as time passes, actually becoming a rare commodity as paper manuscripts deteriorate with time. Entering historical maps into a GIS database may, in fact, be the only solution for preserving their information content. An organization's or country's heritage may thus be safeguarded.

Given that **information is power**, the larger and more comprehensive an organization's GIS database, the more powerful that organization becomes. Once this is realized by an organization's management, support can be expected to crystallize for database development. However, there may be dangers resulting from this awareness. An organization may become possessive of *its* database and not allow others access to it—an exercise of negative power. This attitude will very much hamper or even retard the development of digital spatial databases. It will result in isolated islands of data surrounded by an ocean of institutional and technological barriers. For example, many European government agencies actively restrict access to both physical and digital data. A similar dilemma exists in the United Kingdom, where while the data is less restricted, it is held under **Crown Copyright** and thus end users are not able to make free use of

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[32] Phantumvanit, D., Vearasilp,T., and Hastings, P. *GIS in Traditional Engineering Application.* Proceedings Computer Aided Engineering Conference, 11-12 February, 1988, Prince of Songkla University, Songkhla.

it—it also costs substantially more than comparable data in the U.S.[33] In contrast the United States has enacted **freedom of information** laws guaranteeing public access to government collected information. One result is that spatial data in the United States is widely available at a modest cost.[34] Because of this, GIS development has progressed further, the databases are more comprehensive, and the general contributions of GIS to the United States's economy and society are more widely felt. Because of the overwhelming importance of databases to a healthy and successful GIS, **freedom of information** is one of the more crucial policy issues facing GIS in Thailand today.

Heterogeneous Data Integration: The "I" in GIS

Despite the large and growing number of databases in Thailand, it is still fairly rare to see them used in an integrated manner. As one can see from the major spatial data collectors mentioned above, it is evident that Thailand now possesses most of the databases needed to continue development. These databases are however, isolated, and will continue to be isolated because each organization's political climate is not conducive to integration. Each RTG agency will usually only collect data that is strictly necessary to its main task. This is because the term **development** means different things to different RTG agencies. For example, development to the Department of Land Development usually means improvements of land conditions in order to increase production, while development to the Office of Accelerated Rural Development typically means improvements to rural infrastructure, roads, canals, dams, and so on. Thus, socioeconomic and physical data are collected without regard to one another. It is very rare to see integrated surveys carried out simply because no one RTG agency has such an integrated responsibility.

Development, true development, must be carried out in human terms. The ultimate measure of success or failure should not be purely physical—how many kilometers of road were constructed or how many new telephones were installed, but rather in terms of people—*were their lives really improved by what was done*? If one takes this idea as the philosophical basis for all development work then it becomes clear that socioeconomic and physical data must, in some way, be integrated. Given that Thailand recognizes that it is now in the Information Age, then the solution might

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[33] Parker, H.D., 1990, *I am not a cartographer, but...*, in From The Publisher column in GIS World, Vol.3, #3,pp 9-10.

[34] For example one can order digital elevation data for any part of the United States for US$90 from the USGS, and $7 for each additional one.

logically be found in some kind of information system—**an integrated information system.**

What, one might well ask, does socioeconomic and physical data have in common? **The answer is geography, these disparate types of information are united in space—they are spatial information.** The socioeconomic conditions that exist at some point on the earth's surface can, within a GIS, be readily matched to the physical conditions at that point. These data can be related at their intersection in space. Geography binds all data together, thus integration is not only possible but relatively simple within a system based on geography.

Thus, one of the strongest benefits of employing a GIS is its ability to integrate several different sets of data. In fact, the capacity to integrate socioeconomic and physical data is just now beginning to be recognized as an important and extremely powerful tool to planners with agencies such as the NESDB even now beginning to implement its own GIS.

WHAT A GIS IS NOT

Hopefully, the above has indicated *what a GIS is.* It is also important to define *what a GIS is not.* As Lord Chorley pointed out, a GIS is not simply an automated system for making maps. Although it can produce maps at different scales, in very colorful formats, it is not a system for merely making pictures. A GIS is a tool for analysis. Its main advantage over computer mapping systems is that it helps people to identify and understand spatial relationships between map features. It is a decision support system.

A GIS does not store a map in the conventional sense, nor does it store a particular image or view of any geographic area.[35] A GIS instead stores the **data** about that geographic area. From this data, a GIS user can produce any desired view of the information over that area, and it can be drawn to specifically suit a user's requirements.

A GIS has the ability to link geographic information with attributes or characteristics about each of the spatial features graphically represented on a map. An automated mapping or drafting system can not. A GIS can use the stored attributes to create new information about map features; for example, the length of a particular road,

[35] ESRI, 1990, *Understanding GIS.*

the time it takes to travel to a specific destination, the area of any soil type, or the area of a specific soil-land use combination. An automated mapping or drafting system can not. In short, a GIS does not hold maps or pictures—it holds a database. Despite advertising and salesmen's claims to the contrary, **without the spatial database you do not have a GIS.**

REMOTE SENSING AND GIS

As mentioned before, the remote sensing arm of the RTG, NRCT, is by far the largest assembler of spatial information in terms of budget share. Logically, one could assume that this would be the place to turn to for most spatial information needs. Reality (in the form of RTG budgets) has been somewhat less than this optimistic idea. This is true for several reasons.

Image analysis equipment—the hardware and software to take full advantage of the information potential of remotely sensed data—is still extremely rare where it is most needed—within **line** RTG agencies. Budgets allocated for the purchase of remotely sensed data is still too low to fully support the costs of operating and upgrading a ground station in Thailand. Remotely sensed data must be interpreted and analyzed to be useful, this analytical skill or *art* is still not very widespread within line RTG agencies, especially in relation to the enormous data collection tasks facing these agencies. The situation is improving, but is hampered by the lack of image analysis facilities within line RTG agencies. Remote sensing has many times been used as the sole source of data and has thus been incorrectly labeled a failure when the remote sensing-based analysis turned out to be incorrect.[36] Remote sensing technology is primarily a data-gathering technology and attempts to use it analytically are thus encumbered with fairly primitive spatial analysis technology. Satellite-based remote sensing has been applied to situations where information requirements could not be properly met by remote sensing and where it should never have been used in the first place.[37] Its failure in these types of situations

[36] For example, remotely sensed data may, at times, be able to pick out a road, but it would have a hard time determining the type of road or the amount of traffic flowing along it. This information **must** be gathered from another source.

[37] These types of situations are analogous to someone purchasing a Mercedes Benz to pull a plow—not the best use of automotive technology.

have led to feelings of disappointment, frustration and what Stan Aronoff has termed *myths*[38] about the failure and inappropriateness of remote sensing.

Nonetheless, remote sensing when properly used in the correct context can be an extremely valuable **adjunct** to GIS. **Remote sensing, like GIS, can not be an end in itself.** It must perform some useful function within the appropriate institutional context if it is ever to be considered successful. Despite the different technical view points of GIS and remote sensing users, GIS and remote sensing technologies are, in fact, complementary. Remote sensing analyses can be vastly improved by using data retrieved from a GIS for verification. For example, a 1987 land use map can greatly ease the analysis of an image from 1989 by helping to chose training classes, helping to evaluate hard-to-classify land covers (rice paddies versus fish ponds, for example), and so on. Similarly, GIS applications can benefit from remotely sensed information, which in most cases is the most up-to-date available.

The integrated use of GIS and remote sensing technology will improve the quality of the information produced, that in turn will enhance the decisions based on it. Thus reducing risks. It will also allow information not previously available to be economically incorporated into the decision-making process. Even now, GIS and remote sensing vendors are striving to further integrate these technologies. Their successful integration and use, however, remains in the hands of the users.

Global Positioning System Technology

There is another form of remote spatial data gathering technology that is now rapidly gaining wide usage—Global Positioning Systems or GPS. A GPS is a satellite-based navigation and positioning system that can accurately (from less than 1 meter to 12 meters) geo-reference any type of spatial information, almost any place on the face of the earth. Presently there are 13 active GPS satellites orbiting the earth, with another 11 more scheduled at 60 to 90 day intervals.[39] The orbital period of each satellite is about 12 hours, each orbiting at a height of approximately 20,000 km. Each satellite contains a very accurate cesium clock which is synchronized to a common clock by ground control stations operated by the U.S. Air Force. Precise timing information is important as each

[38] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publication, Ottawa, Canada.

[39] Lange, A.F., 1990, *GPS, A Revolutionary Tool for GIS*, In Proceedings Tenth Annual ESRI User Conference, Vol. 1, Palm Spring, Ca.

satellite transmits timing and ephemeris information which, when recieved by a receiver, can be used to calculate the satellite's spatial location. A receiver can then decode timing data from the GPS satellites in view, and knowing their respective locations from the ephemeris information, calculate latitude, longitude, and altitude for the GPS's user. This position fix is continuously update once a second and can thus be used on the move.

GPS technology has existed for several years now but has been hampered by the relatively few GPS satellites in operation and the relatively primitive receiver technology employed, some of which needed a rather large truck to transport and constant attention to keep precisely referenced. The new generation receivers are now rugged and compact, some the size of a small car stereo and thus exceptionally portable. This new portability now sees a GPS that can be mounted in a vehicle, even on the back of a motorcycle, and driven along newly constructed roads or around an encroached forest to update a GIS database. GPS information gathering potential is enormous.

To understand the potential power of such a system, an example is in order. The Thomas Brothers Map Company, one of the world's foremost producers of maps, attempted a pilot project using GPS to map about 2,000 miles of roads in Imperial County, California, USA. The entire project took only five weeks, of which only three weeks were spent on field observations.[40] The GPS was mounted on a car's roof and driven over the county's roads at an average speed of 20 miles per hour. A project of this size would normally take about five to six months to complete using manual survey and mapping methods. The GPS was capable of simply and easily producing **directly** usable spatial information which was fed directly into the Thomas Brothers's GIS database.

At this point in time, one can see several potential applications for GPS technology in Thailand:

- **adding and verifying horizontal control points and benchmarks throughout the Kingdom** (densifying geodetic control points)
- **determining the exact position of forest reserve and national park boundaries**
- **establishing accurate and verifiable land marks for forest reserves and national parks**
- **forest inventories and land marks around forested land boundaries**
- **tracking and mapping ranges or migration routes for endangered species**

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[40] Stutheit, J., 1990, *GIS/GPS Link Produces Map...Fast*, GIS World, Vol. 3, #2, pp 61-63.

- **cadastral surveying**
- **updating rural infrastructure including bridges, canals, dams, roads, etc.**
- **precisely locating rural villages, especially in mountainous areas**
- **providing *on-the-fly* spatial locations for socioeconomic survey**
- **locating and helping to efficiently route delivery vehicles**
- **locating and routing police patrol cars and emergency service vehicles**
- **exactly locating telephone poles, fire hydrants, street lamps, telephone booths, man holes, etc. in urban areas**
- **search and rescue operations**

This is only a small sampling of the more obvious potential applications of a GPS. Presently, there are three RTG agencies that have begun to use GPS technology:[41]

- **The Royal Thai Survey Department** is using GPS for ground survey in establishing horizontal control points and in work along the Kingdom's international boundaries,
- **The Royal Irrigation Department** is applying GPS to its horizontal control points for irrigation projects,
- **The Royal Forestry Department** is using GPS technology in establishing starting control points for forest boundaries as well as in field surveying existing forest inventories.

These applications are for the most part devoted to precision surveying, that is the establishment of control points where the needed accuracy is measured in centimeters. These control points, in turn, would be used as a basis for further survey efforts. The real potential for GPS technology may, however, be in less accurate (2-12 meter accuracy) but more urgently required spatial information such as forested land boundaries, one of the applications that RFD is beginning to apply GPS technology to.

The U.S. government charges no fees for using this service. However, permission for its use with Thailand must be obtained from the Thai Post and Telegraph Department which charges a small fee to inspect the receiver (about 100 baht) and must be renewed every six months. Today, there are little or no real obstacles to the spread of this important new technology.

[41] Personal communication, 1990, Digital Information Associates Limited.

BRIEF HISTORY & PRESENT STATUS OF GIS IN THAILAND

The history of GIS in Thailand is a brief one. The first known application of GIS to Thailand was the World Bank study published in 1985, *A Geographical Information System for Land Policy Analysis in Thailand.*[42] This study was carried out as a demonstration project to show the application of GIS to a land policy analysis. The project covered the whole of the Kingdom at a scale of 1:500,000. The analysis was however **not** carried out in Thailand, but in the U.S. by a consulting firm using a public-domain GIS package, AUTOGIS. Following this project, there were several feasibility and prefeasibility studies concerning GIS, but no actual GIS work was done until 1987. UNEP published a case study as part of its Global Resource Information Database (GRID) under the Global Environmental Monitoring System (GEMS) program, *An Analysis of Deforestation and Associated Environmental Hazards in Northern Thailand.*[43] Like the preceding World Bank study, it used fairly small scale data (1:250,000 and 1:500,000) with the actual work being done outside the country. The GRID unit, in Geneva, Switzerland, processed this data using a turnkey, professional GIS package.

It wasn't until 1988 that the first GIS work was actually carried out in Thailand, as part of the TDRI work *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resources Management of Songkhla Lake Basin.*[44] This work involved three GIS case studies covering land use planning and rubber plantation management (over an area equivalent to one RTSD 1:50,000 map sheet), as well as an urban planning exercise (over one city block at a scale of 1:1,000). These case studies conclusively demonstrated the applicability of GIS to natural resource and environmental planners in Thailand.

The pace of GIS growth in Thailand, while initially sluggish, has in recent years picked up pace considerably. Since 1988, the number of GIS users has grown dramatically—there are now about 25 known users of GIS technology in Thailand (see *Table 3.1*), with the number growing constantly. For the present, it is not possible to analyze RTG budgets for GIS technology applications because many RTG agencies do

[42] World Bank, 1985, *A Geographical Information System for Land Policy Analysis in Thailand,* Country Program Department, East Asia and Pacific Regional Office.

[43] UNEP,1987, *An Analysis of Deforestation and Associated Environmental Hazards in Northern Thailand,* GRID Case Study Series, #3, United Nations Environment Program.

[44] TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resource Management of Songkhla Lake Basin.*

not separate GIS acquisitions from other computer purchases. Additionally many agencies are acquiring GIS through aid packages and are therefore not included in RTG budgets. In fact, there are only three agencies with specific line items for GIS: Royal Forestry Department with a 1991 budget allocation of 812,000 baht, the Department of Land Development has allotted 440,000 baht from its 1991 budget, and the Ministry of Science, Technology and Energy has a substantial 13,300,000 baht appropriated in its 1991 budget.

It is particularly noteworthy that the private sector is now beginning to take an interest in applying GIS technology. Besides those listed, it has been reported that several banks are currently considering using GIS, initially in the management of their real estate assets. This is an extremely healthy sign and bodes well for the overall future of GIS applications in Thailand. It is also heartening to see that of the six major Thai universities, four are now active in the GIS field. While it will take some years to build up expertise in using and teaching GIS technology, it is a good beginning for long term staffing requirements. In the short term, however, problems are beginning to arise.

GIS Staffing

Interviews with RTG GIS managers indicate that staffing problems seem to be the major obstacle to successful use of GIS in most agencies. This stems from a shortage of computer-literate staff and inadequate salaries, specifically in relation to the private sector and other sections of the organization.[45] The root cause, however, would seem to be improper institutional planning for the GIS. Staffing levels and salaries were usually not considered, especially in relation to the rest of the organization and the booming private sector. GIS skills are highly marketable, and will become even more so as the private sector begins to use GIS more widely. It is problematic that any RTG GIS unit can possibly retain trained staff, especially personnel required for database creation.

Staffing problems have also been cited for the glacial pace of database development within the major RTG GIS agencies. Among RTG agencies responsible for natural resources, none have built any substantial GIS databases to date. While this may change with time, it seems rather improbable in light of the difficulty in keeping trained

[45] In most spatial data gathering organizations in Thailand, GIS staff will almost always receive less overall salary than equivalent position outside the GIS unit. The reason being that the GIS staff do not participate in field survey work and hence do not receive per diem. Per diem can substantially supplement monthly salaries.

GIS staff—which will only get worse with time. Capable personnel has been described as the greatest challenge to making GIS technology more widely available.[46] Thailand is not alone in facing a shortage of GIS staff, there is critical shortage of GIS personnel worldwide. Internationally, training institutes are not meeting the demand for GIS staff. If ignored, this problem may become critical in Thailand as well, as many teaching institutes have not developed GIS curricula and it is not yet clear what educational background is required.

The National Center for Geographic Information and Analysis (NCGIA) has a major educational initiative to develop a *Core Curriculum* for GIS.[47] NCGIA has developed a set of teaching materials to be used for a one-year introductory sequence in GIS at the undergraduate level. The curriculum covers 75 lecture topics, divided among three major sections, introduction to GIS, technical issues in GIS, and application issues in GIS. This curriculum, already available for $200 US, may serve as at least a starting point and perhaps a model for Thai educational institutes in GIS training.

The largest known (published) GIS databases are held by TDRI and Khon Kaen University. TDRI's database coverage, by far the largest and most extensive, is shown in *Figure 2* while Khon Kaen University's database is said to hold about 70 RTSD 1:50,000 map sheets in the Northeast part of the country.

GIS POLICY ISSUES IN THAILAND

The preceding discussions have raised several issues that may have consequences for the further development of GIS in Thailand. These issues include:

- **remote sensing** and its relationship to GIS,
- **responsibility issues** for spatial data and its analysis,
- **institutional issues**, including staffing, education and the political implications of a GIS,
- **freedom of information** and **databases**, perhaps the most important issue of all.

To these, the needs of the private sector and its potential role in further developing GIS, might also be added.

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[46] Aronoff ,S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publication, Ottawa, Canada.

[47] Kemp. K.K. and Goodchild, M.F., 1990, *GIS Testing Nearing Completion*, NCGIA Report, GIS World, Vol. 3, #2, pp 75-77.

Table 3.1 GIS Users in Thailand

User	System
URBAN/CADASTRAL/UTILITY	
BMA	Arc/Info
MEA	Arc/Info
MWWA	Arc/Info
PEA	Arc/Info
TOT	Arc/Info
DOL	Arc/Info
UNIVERSITIES	
AIT	Arc/Info
	PAMAP
Chiang Mai	Arc/Info
	ILWIS
	PAMAP
Chulalongkorn	Arc/Info
Khon Kaen	PAMAP
	Arc/Info
Prince of Songkla	Arc/Info
RTG AGENCIES	
ALRO	Arc/Info
DLD	Arc/Info
	ILWIS
DTCP	Arc/Info
NESDB	Arc/Info
NEB	Arc/Info
NRCT	SPANS
RID	Synercom
NGO	
TDRI	Arc/Info
INTERNATIONAL	
CCOP	Arc/Info
FAO	Arc/Info
Mekhong Secretariat	Arc/Info
PRIVATE SECTOR	
Louis Berger International Inc.	Arc/Info
Team Consultants LTD	Arc/Info

Sources: GIS vendors, interviews, newsletters, etc. This list is by no means exhaustive, for instance, some vendors refuse to disclose their customers, some users' systems are not yet functional, etc.

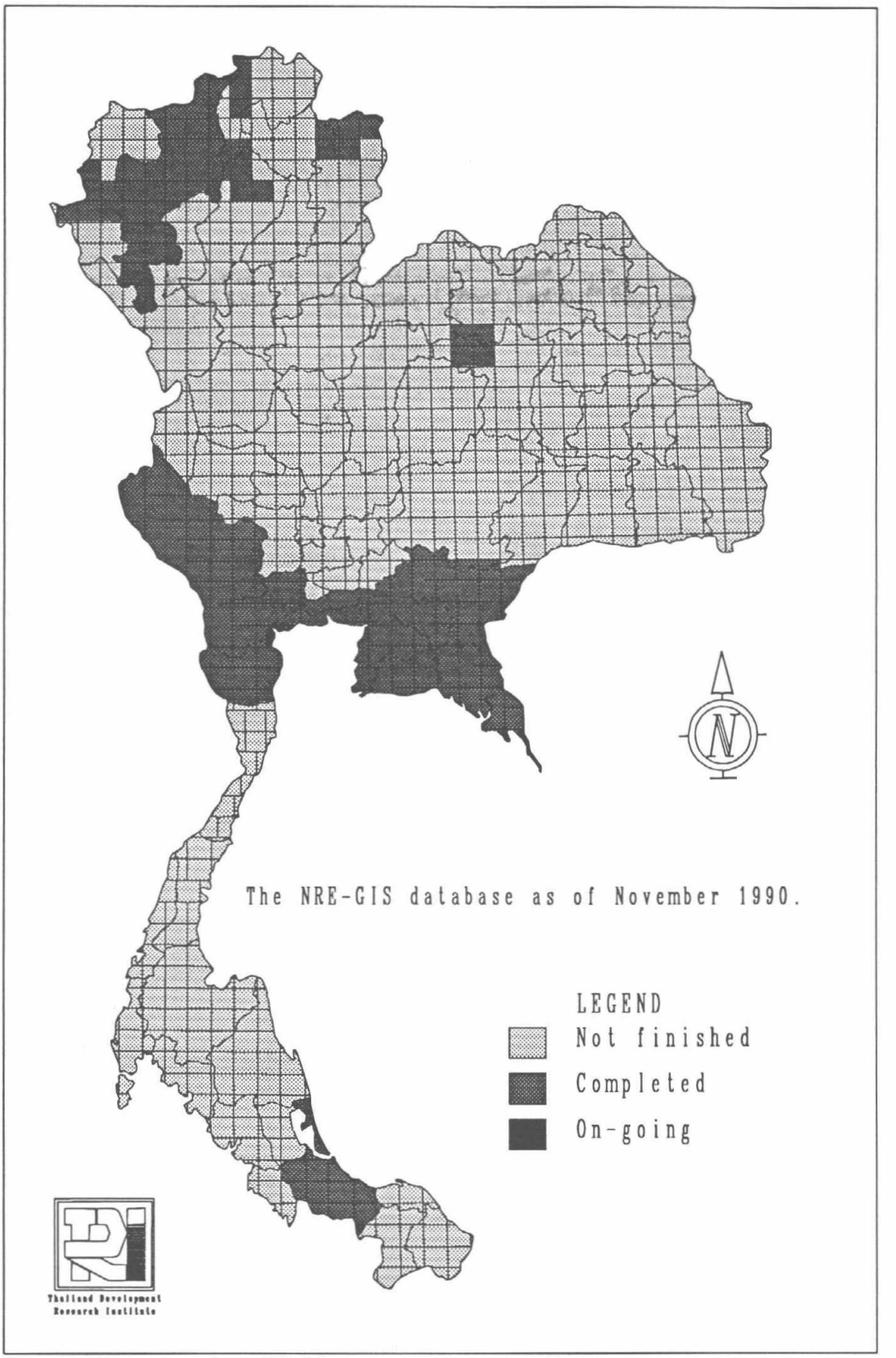

Figure 2: TDRI GIS Database

Remote Sensing

Remote sensing is, in terms of budget share, the single largest spatial data gathering activity in Thailand. Remote sensing's potential to provide up-to-date data for a GIS is very large and will become even more important with time. There are, however, institutional issues that limit its applicability, these being mainly RTG budget shortcomings that so far have restricted the purchasing power of line agencies wishing to procure remotely sensed data. Those RTG agencies that are able to allocate budget for the purchase of remotely sensed data in no way offset the costs of running the ground receiving station and are thus, to some extent, **underwritten** by NRCT. It is suggested here that, at least for the short term, remotely sensed data be fully subsidized and budgets previously allocated to purchasing it be turned instead to the acquisition of image analysis systems and staff training in their use.

Another aspect of the remote sensing issue is its integration with GIS. To date, there has been no large-scale, large-area work done that has successfully combined, in an operational sense, GIS and remote sensing. Both technical and institutional efforts must be made to ensure that this linkage is realized for **production** purposes.

Responsibility

Issues dealing with the responsibilities or liabilities involved with using GISes have never been addressed in Thailand, even though Thai society commonly establishes **legal** accountability in many other disciplines such as engineering, medicine, even truck driving. Four areas of responsibility have been identified: content of the GIS data and analysis, its context, its format, and finally its use when combined with other data sets. These issues are, at times, subtle and require input from both GIS technical practioners as well as social scientists and jurists. If addressed today—while GIS is in its nascent stage in Thailand—these issues can be resolved in a calm and rational manner. If left for a later stage, at a minimum, litigation will result, damaging to the organization and the GIS within it. A worst case may see serious injury or even deaths as the aftermath of irresponsible use of GIS technology. It has been suggested that each GIS have a *GIS*

Information Officer position to oversee the political, technical, legal, and economic aspects of using GIS generated data or analyses.[48]

Institutional Issues

Institutional issues begin with the start of the GIS. GISes do not exist in a vacuum, they must be placed in the proper institutional setting to be effective. Funding and staffing levels must be sufficient to ensure the healthy functioning of the GIS. Above all, a GIS must have some type of mandate or goal—a GIS is not an end in itself.

While an organization may have a specific task assigned to it by law, what role will the GIS play in meeting that task? Before a GIS is implemented this must be clearly defined within the environment of the institution that controls the GIS. Institutional issues also cover policies relating to data access by external users. How should access to an organization's data be organized? If it is completely prohibited, how can one socially justify creating the database in the first place?

Staffing

Staffing problems are looming as one of the more serious issues facing RTG GIS agencies. Presently, there is a serious shortage of GIS staff for the established RTG GIS agencies that reflects a shortage worldwide. As the private sector discovers the benefits of GIS for itself and incorporates it into its normal business practices, the present GIS staff shortage faced by most RTG line agencies will only get worse. Experienced GIS personnel will find themselves with very marketable skills, thus making their retention by the government even more difficult.

Educational institutes, internationally, are not keeping pace with the rising demand for GIS personnel. Within Thailand there is no set GIS curriculum or even agreement upon educational background—one is apt to find GIS training in engineering, geography, computer science, social science, and agriculture faculties. It is suggested that those institutes providing GIS training come to some agreement on the form and content of GIS curricula to ensure a thorough founding in GIS principles. This is a basic form of insurance for organizations using GIS—can it count on the staff it hires to

[48] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publication, Ottawa, Canada.

skillfully and responsibly run its GIS as much as it can count on engineering graduates to handle tasks within their field? The NCGIA has developed a *Core Curriculum* for GIS, that may serve as a starting point for Thai educational institutes.

Freedom of Information

It has been seen that GIS technology is most developed in the United States, a prime reason for this is the **public** access to government collected data provided by **freedom of information** laws in the United States Digital databases in the United States can be readily acquired at a nominal cost—there are virtually no restrictions on access to government data. This is in direct contrast to Europe and the U.K., where government control of data has been cited as actually retarding data distribution and hence the spread of GIS.[49]

Thailand is fortunate because most of the country and many of the important thematic data layers have already been mapped. Thus, there is a large, physical database already in existence. This is important because **databases** are at the very heart of any GIS; without a spatial database a GIS is nothing. Databases and the **free** flow of information are intimately linked. If information is restricted, its distribution will still proceed via informal channels, but at a very slow rate. This will in turn effect the development of GIS databases, as most RTG line agencies and those interested in using their data need to start from information contained on the existing stock of physical maps.

Spatial Databases

Another issue relevant to GIS databases is the **value** of such databases. In most cost-benefit analyses the database would be assessed as a **cost**, overlooking the very real value of the information contained in it. The principle asset of any GIS is its database, which should become more valuable as its information is becomes readily available because it is in digital form and as **historical** information becomes **rarer** with time. As of yet, there has been no successful attempts to establish the real **worth** of a GIS database in monetary terms. Some sort of fiscal yardstick is needed to measure, in well-accepted terms, the value of a GIS database.

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[49] Lord Chorley, Opening Address at First European GIS Conference, EGIS'90, The Netherlands.

Staffing and flow-of-information problems are seen as frustrating the development of GIS databases in Thailand. Among RTG natural resource and environmental line agencies possessing GISes, none have any serious databases on hand yet. The two largest and most comprehensive are held by an NGO (TDRI) and a university (Khon Kaen University). With the expected shortfall in GIS staff and the increasing allure of the private sector, is it reasonable to expect RTG line agencies to be able to realize these badly needed databases in a reasonable amount of time? It therefore seems prudent to offer that GIS database development be *farmed* out to the private sector. RTG line agencies excel in management, having educational backgrounds and experience not often found in the private sector. They also are legally mandated to manage human and natural resources to the benefit of society. If RTG agencies can relieve themselves of the difficult and thankless task of database building, they can devote their scarce resources to **using** GIS technology.

Initial costs for database creation by outside agencies may seem high, but long term per user costs, user labor costs, required user technical skills, and use of existing resources are quite low. Risks to the user organization are also reduced, because the database completeness and accuracy can be clearly guaranteed through contractual obligations.

Another possible solution to this dilemma might be found in a multidepartment co-operative GIS. In this environment equipment, staffing, expertise, database construction costs and the database itself would be shared among several different government agencies. The political implications of this sort of arrangement necessitates it being hosted by a third-party organization seen to be without a vested interest. The MOSTE has recently developed a proposal to create an action plan for establishing just such a center. The objective of the National GIS Center (NGIS) is to coordinate GIS activities in Thailand and aid in the establishment of national GIS databases.

One slight drawback of a multidepartment GIS is that users are at times united in an application in which they may find themselves diametrically opposed—friction is thus created. This suggests another form of GIS that is becoming increasingly popular in the United States, the **multiparticipant** GIS.[50] Users from both the public and private sectors, unite for a specific application that they tend to view in the same light. The private sector has the entrepreneurial drive and funding, while the government has the

[50] Montgomery, G.E., 1990, *Multiparticipant GIS Project*, GIS World, Vol. 3 #1, pp 79-81.

data and the legal mandate to manage this data. Both sectors bring their respective strengths together in such a project.

Chapter 4

GIS Application Examples

The following are two examples of work that TDRI was undertaken using GIS technology (a full list of TDRI GIS projects can be found in *Appendix 1*). The examples provided here are not case studies or pilot projects, rather, they are real tasks assigned to the GIS unit within TDRI, either from an outside agency (the Thai-Australia Highland Agricultural and Social Development Project) or within TDRI itself (Urban Working Group for the National Urban Development Policy Study). They are also concrete expressions of some of the ideas developed in the foregoing chapters.

MYTH PROPAGATION: THE MOUNTAINS OF NORTHERN THAILAND & LAND USE PLANNING

Introduction

The information used in decision making is taken for granted by many, it is typically assumed to be correct. There are times, however, when what is regarded by many as fact, is in fact an idea based upon some misconception—a myth. Anecdotes are often the starting point for many myths—an overly rushed visit or a casually expressed or uninformed opinion can be the seed of many misinterpretations. Likewise, an expert's opinion, taken out of context and applied to another area, can be responsible. Sometimes myths begin with a simple misunderstanding of terminology—*good* soil to a rubber plantation owner is a very different thing from the *good* soil of a rice farmer. With time, these distortions have a way of becoming imbued with an appearance that borders on fact. A myth, as it *ages*, comes to be presumed a truth—it need never be checked because its the *truth*. Once one person officially refers to it, a myth becomes even more firmly established. That reference is in turn referenced, which is again referenced, *ad infinitum*. **A myth is thus propagated.**

The highland areas of many countries are usually replete with myths and mysterious tales—the *big foot* legend of the North American wilderness, the *yeti* of the Himalayas, or the *suea saming*[1] of Thailand. The hills of Northern Thailand are no exception. Several myths have sprung up around them, myths that have been propagated for years, coming to be accepted by many as gospel. Foremost among these myths is one that concerns the mountains themselves. It is assumed by many that **all** mountains in Northern Thailand are steep, having slopes that are steeper than 35%. Many believe that the higher the mountain the steeper its slope. From this idea it follows that the **higher** the mountain the more run-off and the more erosion will occur.

The figure of 35% slope is an important one. It is the signpost dividing land that is arable from land that is too steep to cultivate. A special category has even been erected to describe land of this type, *slope complex*. This idea has permeated almost all thinking concerning these hills—the policies governing them and all the decisions that led up to these arrangements. Land with slope of 35% and above have been included in national forest policy—*strictly declared forest land.*[2] *Slope complex* has become such a part of the mind set of those working in the hills of Northern Thailand that it is regularly used as a **surrogate** for slope.[3] But is it really there—does it in fact exist?

The serendipitous answer to this question was uncovered while creating a Management Information System (MIS) for the Thai-Austraila Highland Agricultural and Social Development (TA-HASD). It will be described in the following section. The twelve project zones within this project are a good sample of the highland areas of Northern Thailand, encompassing terrain representative of the North as a whole. The findings from these areas should thus be applicable to the rest of the mountainous areas of Northern Thailand.

Background: TA-HASD

The Highland Agricultural and Social Development project had its beginning in 1980 as a World Bank funded project to assist Hilltribe development in Northern

[1] "*Suea saming*" is a kind of ghost or weretiger, during the day it assumes human form, while at night it turns into a tiger.

[2] National Forest Policy Committee, 1985 National Forest Policy.

[3] For example, Hutacharoen, M., 1987, *Application of Geographic Information System Technology to the Analysis of Deforestation and Associated Environmental Hazards in Northern Thailand.* In Proceedings GIS'87-San Francisco, 2nd Annual International Conference on Geographic Information Systems.

Thailand. The Australian government provided technical assistance in the form of advisors through the Australian Development Assistance Bureau (ADAB). The first phase of this project ended in late 1987. The project, headquartered in Chiang Mai, operated in nine zones or project areas spread over five provinces. Forty-eight key villages and 249 satellite villages benefited from the project. This amounted to over 50,000 people or about 9,800 hilltribe families.

The first phase of the project was deemed a success and the RTG requested Australian assistance to implement a second project phase to carry the project's benefits to additional hilltribes. The second phase of the project, now known as the Thai Australia Highland Agricultural and Social Development (TA-HASD), began in October, 1988. This project, a bilateral aid project funded solely by the Royal Thai and Australian Governments, will continue to October, 1993. The project consists of twelve zones in six provinces (*Table 4.1*). It encompasses 13,000 hilltribe families (over 55,000 people) in 49 key villages and 300 satellite villages. The total area for this phase of the project is over 1.8 million rai. *Map 1* shows the locations of the project zones within Northern Thailand. The primary counterpart RTG agency is the Hilltribe Welfare Division, Department of Public Welfare, Ministry of Interior.

The project staff have identified several problems in the Highlands including:

- **food supplies**: Most hilltribe villages have inadequate food supplies. Available land is being dramatically reduced by population pressures and national reforestation policies.
- **poor health and sanitation**: Severe health problems affect many hilltribe villages. Hilltribe villages commonly do not have clean water supplies or latrines. They are also remote and thus beyond the reach of most RTG health services.
- **poor education**: Many hilltribe's people are illiterate and do not speak Thai. There is no school or official RTG curriculum for most villages.
- **deficient infrastructure**: Many hilltribe villages can only be reached by walking. The inflow of goods and RTG welfare services is thus restricted. Marketable product outflows are also restricted, limiting a village's ability to improve its living conditions.
- **forest degradation**: Deforestation is a national problem. In Northern Thailand, some 2% of the forested land is being lost each year through encroachment by hilltribes and lowland Thais.
- **soil erosion**: It has been estimated that from 50 to 100 tons of soil are lost per year from traditionally farmed lands, this 10-20 times the acceptable limit. This problem has national implications, since many of the effected areas are the headwaters of some of the Kingdom's more important rivers.

- **national security**: Many hilltribes are nomadic and do not respect national borders. Incursions from Laos and Burma may create national security problems as well as interfere with forest preservation.
- **opium**: In the past, the principal cash crop in the Highlands has been opium. While RTG crop-substitution projects have largely eradicated opium production areas in Thailand, there still exists some cultivation of opium. Cross border traffic of opium and heroin is a major national and international problem.

Table 4.1 TA-HASD Project Zones

Province	Zone	Tribes	Area
Chiang Rai	Mae Suay	La, Ka, Ak	239,837
	Hua Mae Kum	Li, La, Ak	143,560
	Huai Lu	La, Ak	67,776
Chiang Mai	Tung Loy	Ka	110,557
	Khun Saab	Ka, Li	105,633
Mae Hong Son	Huai Peung	Ka, Me	92,898
	Mae Rid Pagae	Ka	105,336
Nan	Tung Chang	Kh, Me, Ht	298,138
	Chiang Klang	Kh, Me, Ht, Ya	160,050
Lampang	Mae Saan	Ka, Me, Ya	89,168
	Mae Mee	Ka, Me, La	171,577
Lumphun	Tung Hua Chang	Ka	219,354
TOTALS	**12**		**1,803,883**

Note: Area in rai. Hilltribes abbreviations: Ak-Akha, Ht-H'tin, Ka-Karen, Kh-Khamu, La-Lahu, Li-Lisu, Me-Meo, Ya-Yao.

Source: TA-HASD project

The main thrust of this project is to *improve the environment, social and economic welfare of the Hilltribe people of Northern Thailand.*[4] The TA-HASD emphasis is on sustainability and on helping hilltribe villagers to help themselves. The project's component objectives are:

[4] TA-HAD, 1990, Thai Australia Highland Agricultural and Social Development Project brochure.

- **the introduction of stable farming systems**: The yield from highland areas is drastically declining because land pressure is shortening the hilltribe's traditional swidden cycles. Stable farming systems allows farmers to continuously crop the same piece of land by preventing soil erosion and retaining soil fertility. Stable farming systems will also stabilize villages and help in returning swidden land to forest.
- **increase crop production for food and sale**: Overall living conditions cannot be improved if villagers are not self-sufficient in food—over 70% of hilltribe villages do not have an adequate, year-round supply of rice. Food self-sufficiency is thus the first goal for the project. After a village has adequate food, the next target is improved cash crops. Raising cash crops will allow the farmer to meet other family needs and generally improve living conditions.
- **improve social conditions of the Hilltribes**: Basic education and health services, adequate water supplies and sanitation, as well as sufficient infrastructure are also required if the hilltribes' overall social conditions are to be improved and their absorption into mainstream Thai society guaranteed.
- **strengthen the capacity of the Hilltribes Welfare Division**: The Hilltribes Welfare Division (HWD) must be capable of identifying and resolving the many technical and social issues that arise during the course of the project. If the project is to be successful, the HWD staff's skills, knowledge, and motivation must be built up.
- **encourage other RTG line agencies to work in the Highlands**: The ultimate benefit of the project will be the acceptance of the hilltribes into Thai society and the full provision of required services by RTG line agencies.

TA-HASD GIS Needs

For a number of reasons and end uses, the TA-HASD requires ready access to accurate and quantative data. In several cases, this information needs to be interpreted and presented spatially in order to be fully utilized. Furthermore, much of the required output is secondary information derived from the acquisition, collation and analysis of large quantities of unrelated data. In some specific instances, the required data can only be derived from the analysis of geographic information. The above are best achieved in an integrated manner through the use of GIS. The specific needs of the TA-HASD Project with respect to GIS are summarized in the following:

- **project definition:** In defining the physical boundaries of the Project area and therefore the target population, cartographic information in combination with certain criteria needed to be collated. For example, the present Project zones were the result of a process of reconnaissance surveys to determine the location, numbers and general needs of the hilltribe people in selected areas. This was then combined with criteria such as no support from any other projects, lack of support from mandated government agencies and low living standards. Furthermore, project areas had to be confined to a single *amphoe*, preferably be

confined to a single watershed or subcatchment and already be classified under the Watershed Classification act.

- **identifying location and extent of problems**: Once the above has been completed, the location and extent of problems such as lack of water supply, schools, health facilities, poor yields or road access can be identified and mapped as required.

- **assigning priority to the problem**: After problem identification, problems can be prioritized according to effects, extent, or population affected. This may help to rationalize assistance where it is most needed or can do most good.
- **problem solving/planning**: Once the problem has been identified, then problem solving according to these priorities can begin. A GIS can be invaluable at this level. For example, if village water supplies are seen as a first step in solving the health needs of the hilltribe villages and encouraging permanent settlement, then a requirement is a source of clean water which gives sufficient yields of water all year . Furthermore, this source of water needs to be close to the village for the cost to be affordable or economic. Through a GIS, villages meeting both these criteria can be selected and matched against population and infrastructure data from these villages to give a list and or spatial plot of villages that could be helped by this type of approach. In other words, there is a problem and a perceived economic solution. The GIS can be used to see if this is readily applicable to a significant number of villages in the target area. The validity of the proposed solution, its cost effectiveness and situations where this is not a solution are readily checked.

From the outset of the second phase of the project, TA-HASD staff has seen the need for an inventory and an information system of the conditions existing across the 12 project zones. TA-HASD project staff has appreciated the fact that most of the important planning and monitoring variables in their project zones could be derived from maps—they were spatial information.

For example, one of its first acts upon commencement of the project was to commission the Geography Department of Chiang Mai University to prepare large scale (1:10,000) maps of the key villages' land use and land ownership. These maps, in conjunction with village and household socioeconomic surveys, are used for planning and monitoring.

Other, smaller scaled (1:50,000), maps were prepared by TA-HASD project staff to serve **macro** level planning needs. Information relating to topography, watershed classifications, village locations, and infrastructure were maintained on these maps but it was realized early that these physical maps had severe limitations inherent to them—updating them, physically storing them, their information content, etc. *Maps 2-5* are examples of these data layers.

TA-HASD project staff recognized in GIS a technology that could enable them to establish a spatially oriented MIS of their project zones. Specifically, their MIS needs consisted of:

- **an inventory** of the physical conditions within each project zone, thus information on elevation, slope, aspect, surface streams, infrastructure, villages, watersheds, political boundaries and land use would need to be cataloged and organized.
- **a flexible database system** that could let project staff iteratively model potential land uses to *rationalize* land use in the project areas and explore the spatial relationships between various variables such as villages and slope or elevation, a further requirement was the ability to integrate socioeconomic and physical variables.
- a system to easily produce **map graphics** and **3-D views** as a form of reporting. The 3-D views are seen as an important tool in explaining project needs and ideas to HWD staff and villagers to generate feedback.

End of a Myth: Real Slopes *vs* Slope Complexes

One of the most important variables about highland areas is slope. It is a requirement for land use modeling (see below), erosion estimation, accessibility testing, analysis of travel restrictions, resolution of dead ground for military purposes, etc. Slope is one of the two most commonly used terrain parameters, the other being aspect.[5] It is also one of the most difficult pieces of data to obtain because slope information needs to be **derived** from elevation data. Manual measurement of slope from physical topographic maps is a slow and extremely tedious task. Because of this, errors and biases can be easily introduced through operator fatigue or inexperience. These errors, when compounded with preconceived ideas about mountainous slopes, can yield very misleading results. Slope calculation is thus an ideal candidate for automation by a GIS and as such was one of the first specific GIS products demanded by the TA-HASD project.

Slope is defined as the rate of change of elevation. It is usually expressed in **degrees** (the angle measured from the horizontal to a plane tangent to the surface) or **percent** (the change in elevation divided by the corresponding change in horizontal distance). Percent is the most common form of slope measurement in Thailand.

[5] Aspect is the downhill direction of slope, it is important data in situations where the amount of sunlight or the type of scenic view are important. Coffee plantation or hotel siting are examples.

Conceptually, the calculation of slope and aspect at a point can be thought of as fitting a plane to the elevation values of the surrounding points. The slope of this plane and the direction it faces in is the slope and aspect of the point.

Slope's critical importance to the TA-HASD MIS inventory and land use model required that it be measured as **precisely** as possible. It was not enough to know that some land was classed as *slope complex*, rather the actual slope over these areas needed to be measured. To do this, the terrain modeling functions found in the TIN module of TDRI's GIS was used. The slope modelling functions required the input of raw elevation data, that is X, Y, Z data. The elevation contours provided by the TA-HASD project were utilized as a primary data source (see *Map 3*) as well as samples taken along profiles of what is termed *VIP*s (Very Important Points), that is stream and river courses, mountain ridges, peaks, passes, cliffs, valleys, etc. found on the appropriate RTSD 1:50,000 topographic maps. VIPs are important in that they help to accurately define the landscape, much of which is shaped by running water.

Once the raw contour data and VIPs were input into the GIS database, slope calculations were made for each of the 12 zones. It was at this stage that it was discovered that the slopes measured by the GIS were vastly different from the slopes previously reported for these areas. These areas are almost entirely classified as *slope complex* land, that is areas with slopes greater than 35%. Thus, the slopes measured by the GIS did not fit the preconceived notion regarding these mountains—that these areas were steeply sloping. *Maps 6-9* portrays slopes for 4 areas typical of the 12 project zones. *Figures 3-6* provide graphical summaries of this data, while *Figure 7* summarizes the slope conditions found over all 12 project zones.

Because these results were so controversial, the slope calculations were verified by applying different methodologies and comparing the slopes produced from each. Slopes over one project zone (Khun Saab Zone, Chiang Mai province) were also independently authenticated by an outside researcher.[6] Slope measurements, since made in the field, have likewise confirmed these results. Moreover, other researchers in

[6] Ben Maathuis, 1990, Department of Geography, Chiang Mai University using a different GIS, ILWIS.

Northern Thailand are too finding similarly shallow slopes. For example, on Doi Inthanon, in Chiang Mai province, analogous slope distributions have been found.[7]

From these, it can be concluded with some confidence that the slopes measured by the GIS do, in fact, closely resemble the actual slopes in these mountains. The idea that all mountains in Northern Thailand are *slope complex* land is therefore defunct and should not be further used in conjunction with these mountains.

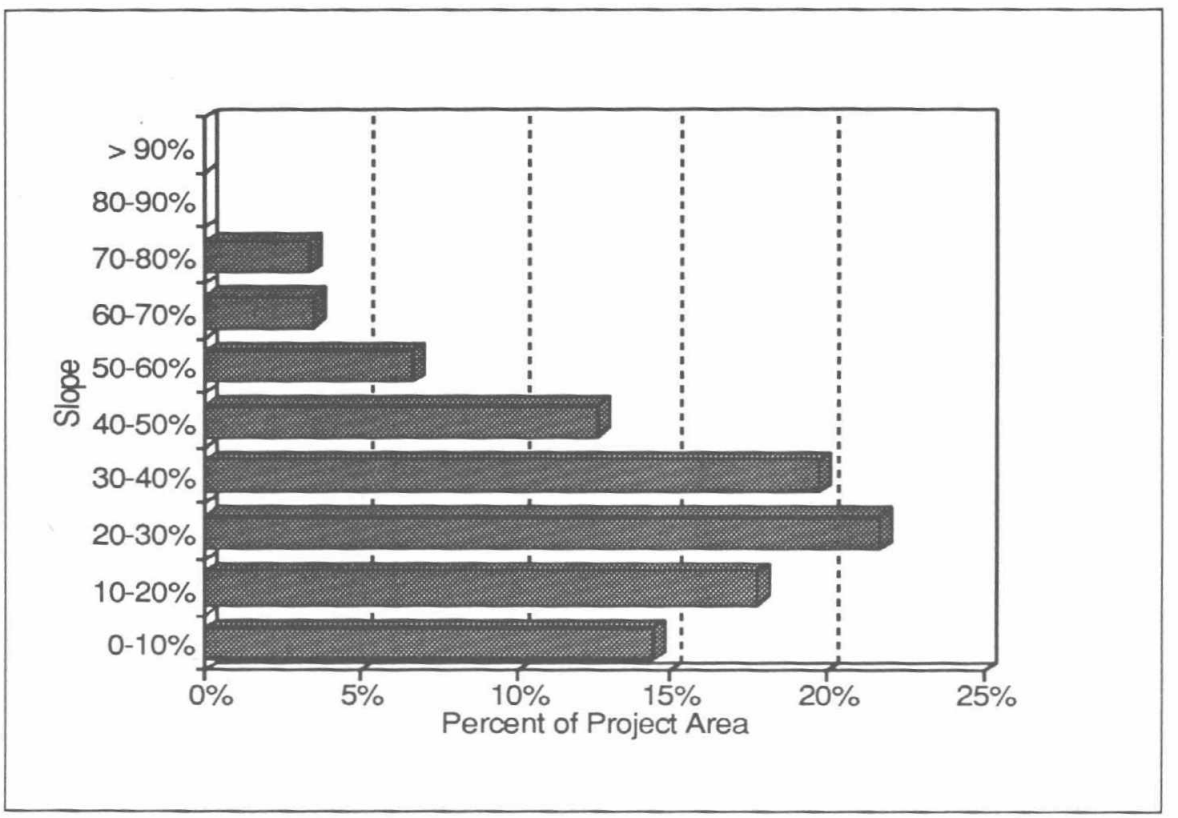

Figure 3: Slopes in Khun Saab Zone, Chiang Mai

From these findings it is apparent that there is more than a 50% error in the previously accepted slope classifications for these highland areas. This is true even if one is generous and assumes that the 30-40% slope class is *slope complex* (only part is). Thus, any area-specific plans and policies based on this data would have been right less than half of the time. For example, the national forest policy of having 40% of the country under forest cover—was this figure based on the concept of all mountains being

[7] Pandee, P., Maathuis, B., 1990, *Using GIS-Technology to Come to Potential Landuse Planning Strategies*, Unpublished manuscript, Department Of Geography, Chiang Mai University, Chiang Mai.

slope complex land? If so, this goal will almost certainly never be attained. We must change the ways we think about the mountains of Northern Thailand. Forest encroachment, for example, may now be seen in a very different light. From a farmer's perspective, it now seems almost logical that *slope complex* land was deforested, for much of it was, in truth, arable land. The land pressure now being exerted by lowland Northern Thais moving into highland areas may also be seen from the same point of view, an inevitable move onto **arable forested** land.

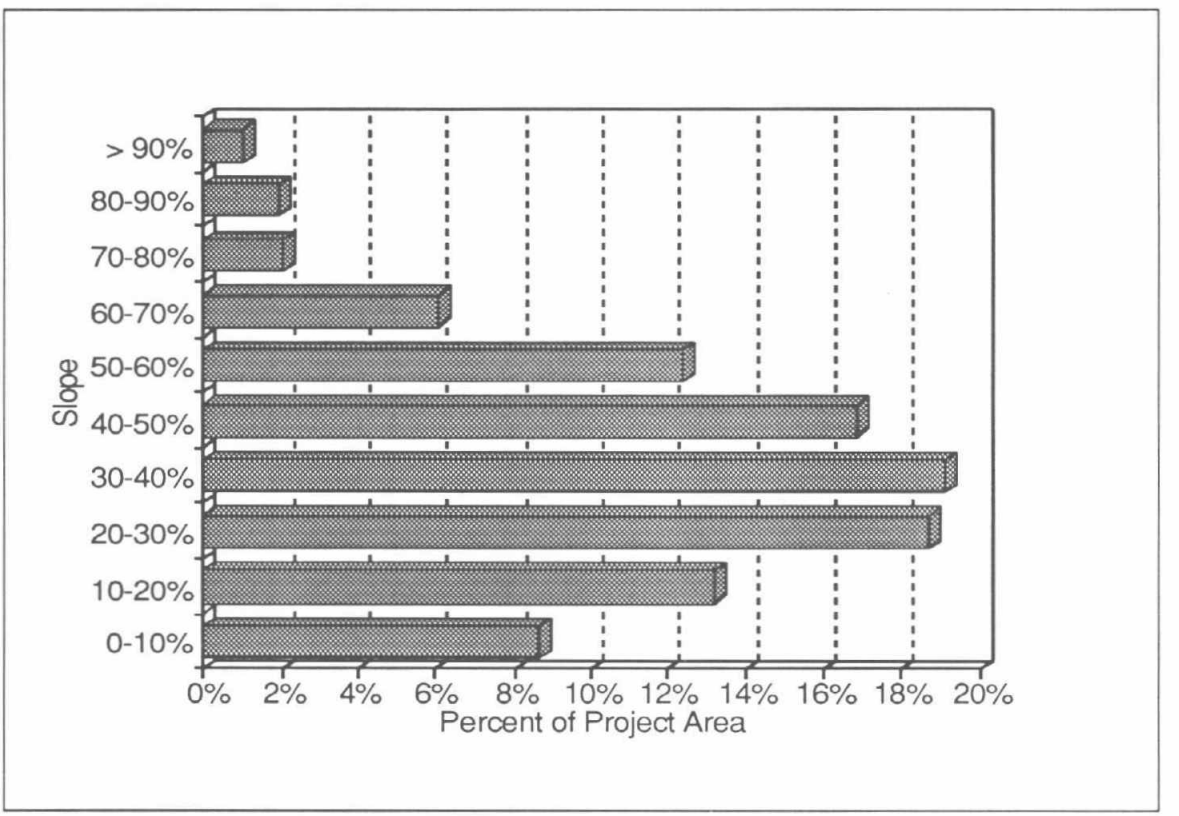

Figure 4: Slopes in Mae Rid Pagae Zone, Mae Hong Son

TA-HASD Land Use Model

The rational use of land is one of the primary aims of the TA-HASD project. Land use planning models are thus, one of the project's more important tools. Modelling allows one to examine the potential land uses before implementing them, by permitting planners the opportunity to safely evaluate all possible implications of the proposed land use changes. *What-if* games can be played once the requisite databases have been constructed. Questions like *is there enough paddy land to support the present population*

or *should we institute a program to grow coffee*, can be modelled and understood before expending and perhaps wasting time or budget. GIS technology makes these iterative modelling exercises simple and relatively inexpensive. Better decisions should result.

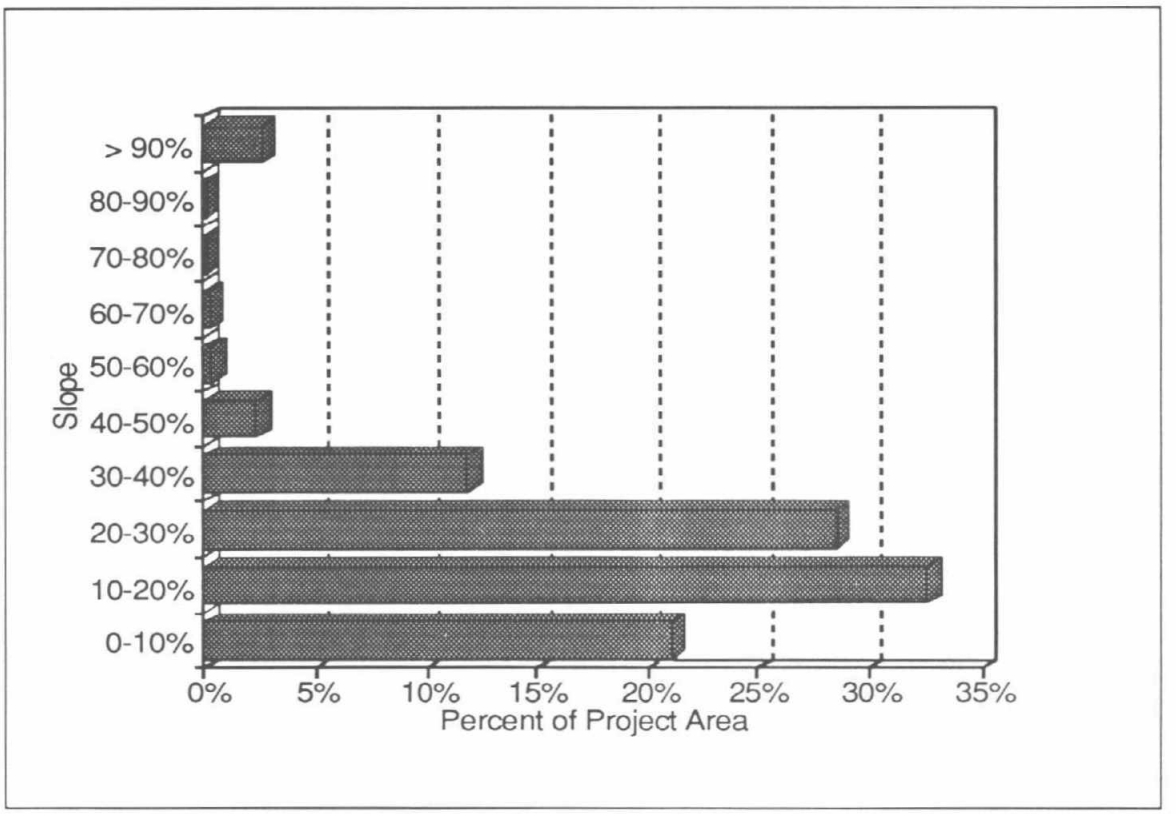

Figure 5: Slopes in Hua Mae Kum Zone, Chiang Rai

In the mountains of Northern Thailand several factors have significance for land use planning: climate, proximity to water, slope, and elevation. Elevation in the mountains can be used as a proxy for temperature, rainfall, and other climatic factors, thus the important variables can reduced to elevation, slope and proximity to water.

The following model was developed by the TA-HASD project in light of project needs and the requirements for sustainable land use. The data required for the model included: stream locations, stream types (annual *vs* non-annual), stream order, slope, and elevation (100 meter resolution).[8]

[8] The original land use model was modified to include stream order following suggestions from Ben Maathuis, Department of Geography, Chiang Mai University, Chiang Mai.

Stream order is an important hydrological concept first proposed by A. N. Strahler in 1952. A stream is assigned an order which increases downstream of the junction of two streams having the same order (an example of stream ordering is shown in *Map 10*).[9] Thus, two first order streams combine to form a second order stream, two second order streams combine to form a third order stream, etc. First order streams are usually found at the top of a stream network, in the mountains of Northern Thailand this usually means near peaks or high ridgelines. Stream order when combined with stream type can be used as a surrogate for stream flow. Higher order streams will have higher flow rates than lower order ones. The more stream flow, the higher the potential irrigation capacity of that stream. The irrigation capacity is important in determining suitability for paddy.

The model's components consisted of:

- **rice paddy**: Food self-sufficiency is the first goal of the project. A sufficient food supply to hilltribes people is expressed as the amount of rice produced adequate for home consumption. From crop trials and other experiences in the field, project staff have arrived at the following criteria for paddy: shallow to flat slopes (0-10%) that are adjacent to water. Adjacency to water was originally defined at a blanket value of 200 meters. This has since been modified to account for stream flow as reflected in stream order, with stream orders of 1, 2-3, 4 being buffered out to distances of 50, 100, 200 meters respectively. Project staff also indicated that paddy along annual and non-annual streams should be distinguished. Paddy land along annual streams would have access to water year round. Two crops could thus be grown on the same piece of land, a rice crop followed by a cash crop such as soybean. This would go a long way towards helping reduce the amount of land required by a family unit.
- **field crops**: After achieving self sufficiency in paddy, the next step in development would be the provision of cash crops. Cash crops would, however, have to be environmentally benign. The criteria for these cash crops reflect this concept: *group 1*—slopes less than 10% and more than 200 meters away from water; *group 2*—slopes 10-35% and less than 1000 meters ASL; *group 3*—slopes 10-35% and elevation more than 1000 meters ASL.
- **tree crops**: Tree crops are another type of environmentally safe cash crop and include fruit trees and wood for charcoal. The project has divided these into three groups: *village woodlot*—slope 36-55% and within a one kilometer radius of a hilltribe village; *low altitude trees*—slopes 36-55% and elevation less than 600 meters ASL; *high altitude trees*—slopes 36-55% and elevation more than 600 meters ASL. Establishing village woodlots should help preserve the remaining forest by providing secure sources of fuelwood and helping to insure the survival of any reforestation efforts taking place in the project zones.

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[9] Strahler, A.N., 1952, *Dynamic basis of geomorphology*, Bulletin Geological Society of America, 63, pp 923-938.

forests: These will be sites of active reforestation measures. The slopes, more than 55%, for this potential land use are seen as the most environmentally sensitive and should therefore be left unexploited as much as possible. Forests are split into two groups: *low elevation*—slopes greater than 55% and elevation less than 600 meters ASL; *high elevation*—slopes greater than 55% and elevation more than 600 meters ASL.

Examples of the model's results from project zones in Chiang Rai, Chiang Mai, Mae Hong Son and Lampang are shown in *Maps 11-14*. Tabular summaries from these models are found in *Table 4.2*. As an example of the usefulness of GIS in a situation of this sort, let us examine some aspects of the results of these potential land use models. The examples will help illuminate some of the basic problems found in the hills of Northern Thailand and how using a GIS can provide information to help solve them.

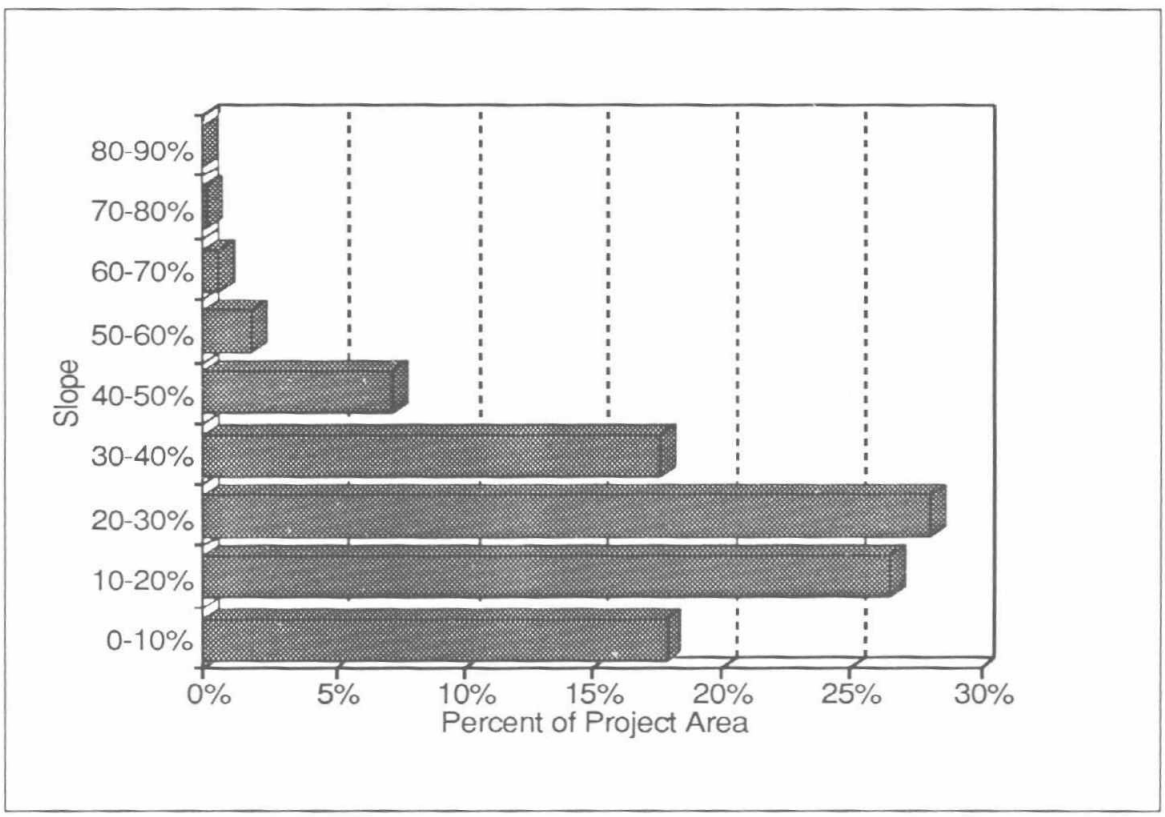

Figure 6: Slopes in Mae Mee Zone, Lampang

To begin with, let us compare the results of the paddy model with the present population for each of the four zones presented here. As stated above, rice production in permanent paddy land is important in terms of food self sufficiency and in reducing swidden area. While hill rice can be used as a supplementary source of rice, it cannot nor

should not be used as a total replacement for paddy land except in instances where paddy area is found to be deficient. Hill rice yields are considerably lower than paddy, forcing the use of larger areas to sustain the same population. Its potential for environmental damage is higher than permanent paddy land, as hill rice will often replace forest. The following discussion will therefore focus on paddy land as the main food source.

TA-HASD project staff has estimated rice consumption for hilltribes at 300 kg/person/year. Rice production, using traditional hilltribe farming methods, has been estimated at about 400 kg/rai/year. Thus each man, woman, and child would, on average, need about 0.75 rai of paddy land to be self sufficient in terms of rice.

Khun Saab Zone, in Chiang Mai province, has a population consisting of Karen and Lisu tribes, that together totals 1,532 people. The potential paddy land in this zone amounts to over 5,500 rai. Potential rice production from this paddy area would therefore be around 2,200 tons per year. The present hilltribe population in Khun Saab Zone requires only 460 tons per year. The paddy land found in this zone can therefore support a population of approximately 7,300 people.

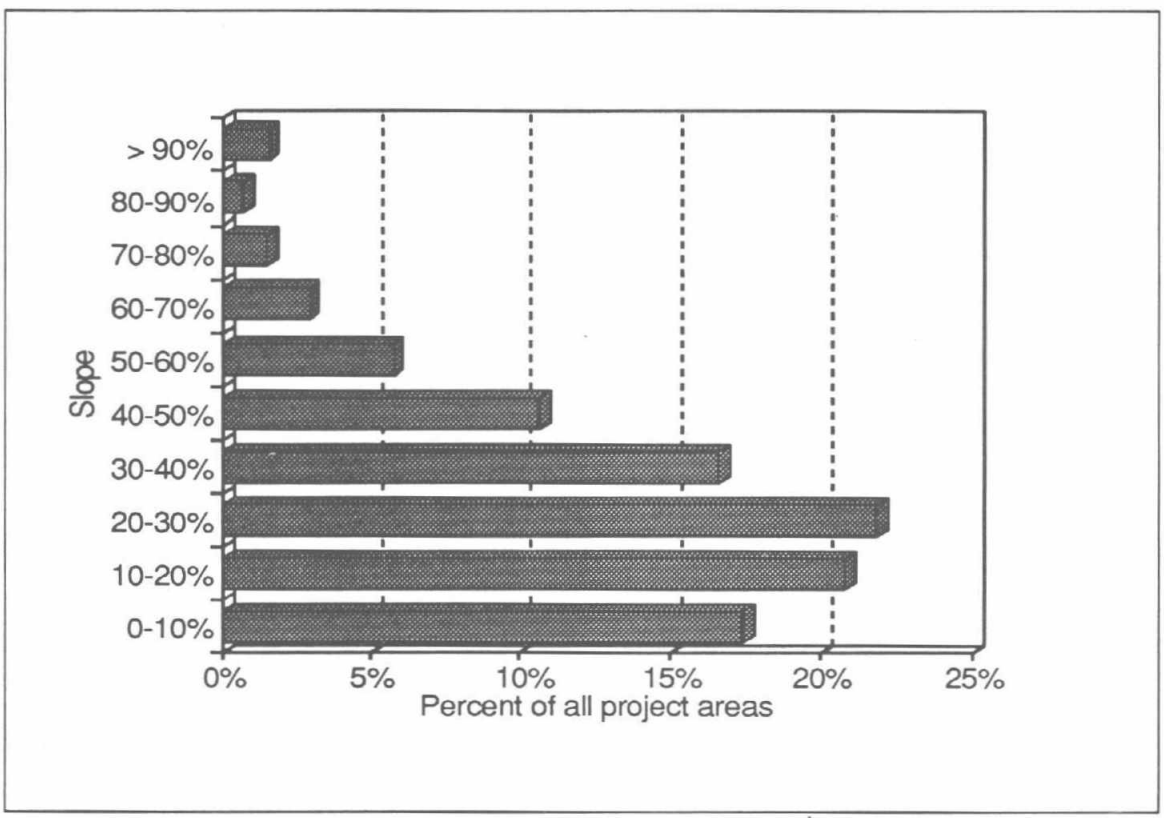

Figure 7: Slope Summary of All TA-HASD Project Zones

If the population in Khun Saab continued growing at the present hilltribe population growth rate (3%), this amount of paddy would be sufficient for 53 years (until the year 2043 AD). From this analysis, Khun Saab Zone is relatively well off in terms of food and attention can be diverted to cash crops and reforestation.

Mae Mee in Lampang province, is another zone with an adequate supply of paddy land. The model's results indicate that there is about 10,000 rai of paddy land supporting a population of only 1,490. This amount of paddy land should be satisfactory until 2065 AD (another 75 years at the present population growth).

Table 4.2 Potential Land Use Model Results

Land use	Zone KS	MRP	HMK	MM
Paddy				
annual	2,214	1,265	4,159	3,623
non-annual	3,341	1,900	3,942	6,404
Totals	**5,555**	**3,165**	**8,101**	**10,027**
Field crops				
group 1	9,891	5,303	12,112	19,976
group 2	45,065	33,682	48,428	66,189
group 3	14,048	12,613	20,615	48,045
Totals	**69,004**	**51,598**	**81,155**	**134,210**
Tree crops				
woodlot	7,702	15,651	15,011	2,992
low	1,853	7,935	3,186	3,318
high	16,607	10,407	16,800	18,661
Totals	**26,162**	**33,993**	**34,997**	**24,971**
Forests				
low	0	2,127	31	0
high	9,834	13,414	15,579	2,371
Totals	**9,834**	**15,541**	**15,610**	**2,371**

Notes: Figures in rai. Zone abbreviations: KS-Khun Saab, MRP-Mae Rid Pagae, HMK-Hua Mae Kum, MM-Mae Mee. See text for explanation of potential land use sub-groups.

The Khun Saab and Mae Mee zones have seemingly adequate areas of paddy land for their respective **hilltribe** populations. Lowland Northern Thais are, however, moving

into these areas in growing numbers. Project staff have estimated that, at present, the lowland Thai population almost equals the hilltribe population. If their population influx equals the hilltribes' growth rate, then the paddy area in Khun Saab zone would be inadequate in 30 years and 51 years in Mae Mee zone.

There are serious nutrition problems looming in the other two zones. Mae Rid Pagae Zone in Mae Hong Son province has about 3,200 rai of paddy land supporting a Karen population of 3,012. **Its stock of paddy land will run out in the year 2002, in 12 years.** Hua Mae Kum Zone in Chiang Rai province is in the worst position of the four zones mentioned. It has 8,100 rai of potential paddy land sustaining almost 9,000 hilltribes people. Using the previous production and consumption values, **paddy land in this zone will run out in only 7 years.** Land pressure from lowland Thais in these two zones are quickly making this situation extremely critical.

Efforts aimed at improving paddy production will have to be concentrated in these two zones in order to head off possible future nutrition problems. With TA-HASD project assistance, average rice yields can reach more than 720 kg/rai/year, thus only 0.42 rai of paddy is needed to support one person. For Hua Mae Kum this improvement would mean deferring collapse until 2018 AD, another 28 years. Thus, buying time for other longer termed actions to take effect.

Family planning measures must also be concentrated in these two zones, to keep population growth in line with the restrictions of the available paddy land spotlighted by the GIS-based model. The push of lowland Northern Thais into these areas and their competition for scarce paddy land is further complicating matters. In-migration must therefore be delayed, be it from the lowlands or cross border. Using the GIS in this way can help pinpoint which zones to concentrate such police-type activities.

The extent of the paddy land limitations in these zones was highlighted by the GIS-based land use model. The model was able to provide TA-HASD project staff with statistics (areas) and the spatial distribution of available paddy land across the 12 project zones. This information was in turn integrated with population data collected by the project, to help evaluate needs in relation to the very real physical limitations of these areas. Knowledge of this kind, derived from the GIS database, is helping the project focus attention on zones in most need of aid. Project efforts can be concentrated where they will do the most good.

Another benefit of using this land use model within a GIS, is the flexibility the GIS allows in re-running the model. Changes, based on previous results, can be easily made and the model re-run. This is important because at first glance it is difficult to tell how much or how little there is of some particular type of land. The model must be run through at least once and the results checked against other variables—calibrating the model.

For example, figures in *Table 4.2* indicate that woodlot areas are excessive for the populations in these zones. In Khun Saab Zone, there is about 7,700 rai of land suited for village woodlot, an average of 5 rai/person. If all this land were planted with a fast growing tree, such as *Eucalyptus*, 15,600 of tons of green wood could be produced per year.[10] That is over 10 tons per person—plainly an excessive amount and far beyond any conceivable fuel requirements for this village. The land use model will be re-run, and this area reduced in line with the population's actual fire wood needs. Former woodlot land (that is land within one kilometer of a hilltribe village) might be better used for some other, more lucrative crop that requires constant attention.

Watershed Classification

The political and institutional implications of the land use models' results can also be examined with the GIS. For example, Thailand is classifying its major watersheds as a means of controlling land use in these headwaters. The Faculty of Forestry, Kasetsart University has been responsible for the technical development of watershed classes. Five classes (class 1 has been split into two sub-classes to accommodate existing human activities) of watershed have been conceived:[11]

- **1A**: This class is reserved for protected forest areas and includes headwaters of rivers. These areas are defined as having **high elevations and steep slopes.** There is no present human activity in this zone.
- **1B**: Similar conditions as class 1A, but with major human activity already present in area.

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[10] Based on three year harvest cycle and a yield of six tons/rai per year. Fifteen tons/rai per year was used in Hastings,P. et al, 1989, *Fast Growing Tree Plantation Siting Using GIS.* In Proceedings Economic Forest: Myth or Reality!. TDRI Seminar.

[11] Tangtham, N., Chunkao, K., 1989, *Methodology and Application of Watershed Classification in Thailand.* Paper presented at the Second Expert Group Workshop on River/Lake Basin Approach to Environmentally Sound Management of Water Resources, Ambassador Hotel, Bangkok.

- **2**: Higher elevations and steep to very steep slopes but with landforms that will erode less easily than classes 1A and 1B. Mining and logging will usually be permitted in these areas.
- **3**: Upland areas with steep slopes. Fruit trees and commercial logging would be allowed in these areas.
- **4**: Upland farming would be acceptable in these areas of gentle slopes.
- **5**: Paddy fields or other agricultural activities would be allowed in these areas with few or no restrictions. Slopes are very shallow to flat.

Map 4 provides the official watershed classification for the Khun Saab Zone in Chiang Mai. The watershed classes over this zone are summarized as: class 1A—74,900 rai; class 1B—5,000 rai; class 2—25,500 rai; class 3—5,450 rai. Class 1A is the most relevant, as it restricts activities to at most reforestation. In theory, the entire class is restricted to permanent forest cover.

With the aid of the GIS, we are able to isolate this class and examine its characteristics in terms of the conditions existing in this zone. In Khun Saab Zone, the elevation in class 1A ranges from as low as 600 meters ASL up to 1300 meters ASL—covering the entire range of elevations in this zone. Plainly, class 1A is not restricted to the higher elevations of its definition.

The slopes found in this class are illustrated in *Map 15* and summarized in *Figure 8*. If we are again generous and assume *steep* constitutes slopes 30% and above, then class 1A in Khun Saab Zone is almost equally divided between shallow and steep slopes (51% *vs* 49%). Again, these findings do not correspond with the definition of the class.

What are the implications of this class in terms of the land use in these zones? *Map 16* depicts the potential land uses within class 1A for Khun Saab Zone. A comparison of the land use model results and class 1A is made in *Table 4.3*. The amount of paddy land found in class 1A is significant as almost 50% of the zone's total is found in this class. If these paddy lands were to be removed from utilization, the carrying capacity of this zone would be almost halved. Collapse would occur in 31 years instead of 53 mentioned above. The situations found in other project zones with watershed classifications also tends to parallel this zone.

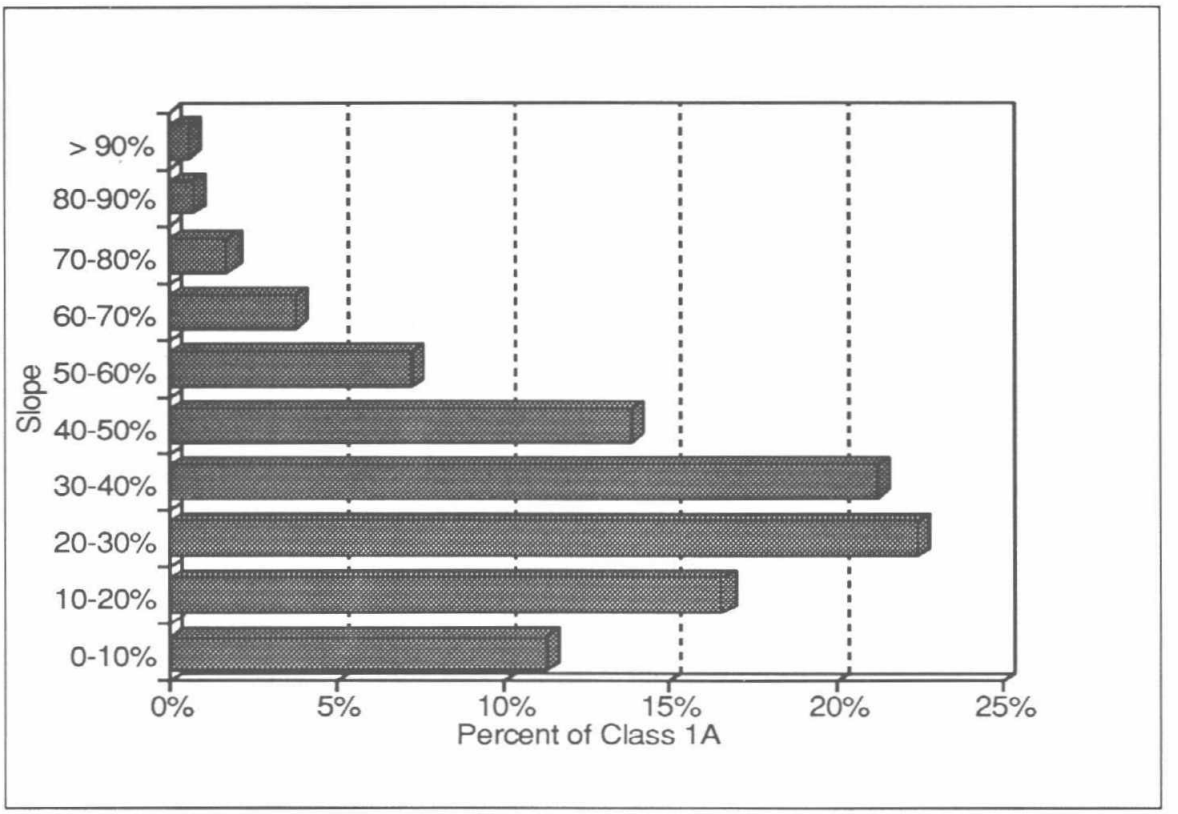


Figure 8: Slopes in Watershed Class 1A, Khun Saab Zone

Village Inventories

One other information requirement of TA-HASD project staff has been the characterization of each village in the project—its slope, aspect, elevation, watershed class, previous land use, etc. Prior to establishing the GIS database, this had proved an elusive objective because of the limitations imposed by manual methods. Once the GIS database was created, this delineation proved elementary. *Table 4.4* characterizes the villages in Khun Saab Zone.

It is widely reported that hilltribe villages usually restrict themselves to certain elevations for social or cultural reasons. For example, it is often asserted that the Karen tribe is found at 500 meters ASL and that the Lisu tribe is only found at 1,000 meters ASL. From the village characterizations in Khun Saab it can be seen that the elevation distribution of villages in this zone (at 600, 700, 800, 900, 1000 and 1100 meters ASL) does not fit this widely held concept.

Table 4.3 Class 1A Watershed *vs* Potential Land Use, Khun Saab Zone

Potential Land Use	Total Area	Area in Class 1A	Percent of Total
Paddy	5,556	2,294	41%
Field crops	69,004	45,015	65%
Woodlot	7,702	5,079	66%
Tree crops	18,461	14,713	80%
Forests	9,834	7,680	78%

Note: Area in rai.

Table 4.4 Village Characteristics in Khun Saab Zone

Village	Slp	Asp	Elev	Lu	WSC
Khun Sarb Nua	31	265	600	open	3
Khun Sarb Tai	32	279	600	open	1B
Mae Ware	11	254	700	paddy	2
Pang Khun Karn Luang	12	148	700	open	1A
Den Hua Dong	9	262	700	open	3
San Klang	17	232	700	open	3
Hang Dong	1	304	700	dense	1B
Huai Hok	43	46	700	dense	1B
Ang Kai	5	111	700	open	1A
Mae Joom	30	307	800	open	2
Mae Taad	28	301	800	open	2
Huai Tao	9	125	800	open	2
Na Ku	20	256	900	open	2
Khun Sarb Klang	11	108	1000	open	1A
Khun Om Long	32	109	1000	open	1A
Kiw Sua Nua	10	295	1000	open	1A
Kiw Sua Tai	30	198	1000	open	1A
Hong Taeng	27	185	1000	open	2
Huai Poo	12	331	1000	dense	2
Kavi	34	170	1000	open	3
Pha Yong	32	231	1100	open	1A
Averages	19	229	833		

Notes: Slp-slope in percent, Asp–aspect in degrees, Elev–elevation in meters ASL, Lu-pre-project land use (1969), WSC–watershed class. Land use abbreviations: paddy, open–open canopy forest, dense–dense canopy forest.

Another noteworthy point from this zone, is the number of villages that fall in watershed class 1A. Seven villages out of the twenty-one project villages (33%) are found in this watershed class. By definition, class 1A does not have any **presently** occurring human activities. This finding, coupled with the slope and elevation data from class 1A within Khun Saab Zone, tends to confirm that the watershed class definitions are fuzzy almost to the point of being arbitrary.

Three variables, elevation, slope, and pre-project land use, are summarized in *Figures 9-11*, for all villages across the twelve project zones. *Figure 9* shows the distribution of villages versus elevation. *Figure 10* displays the distribution of villages against slope. *Figure 11* shows villages and 1969 pre-project land use.[12]

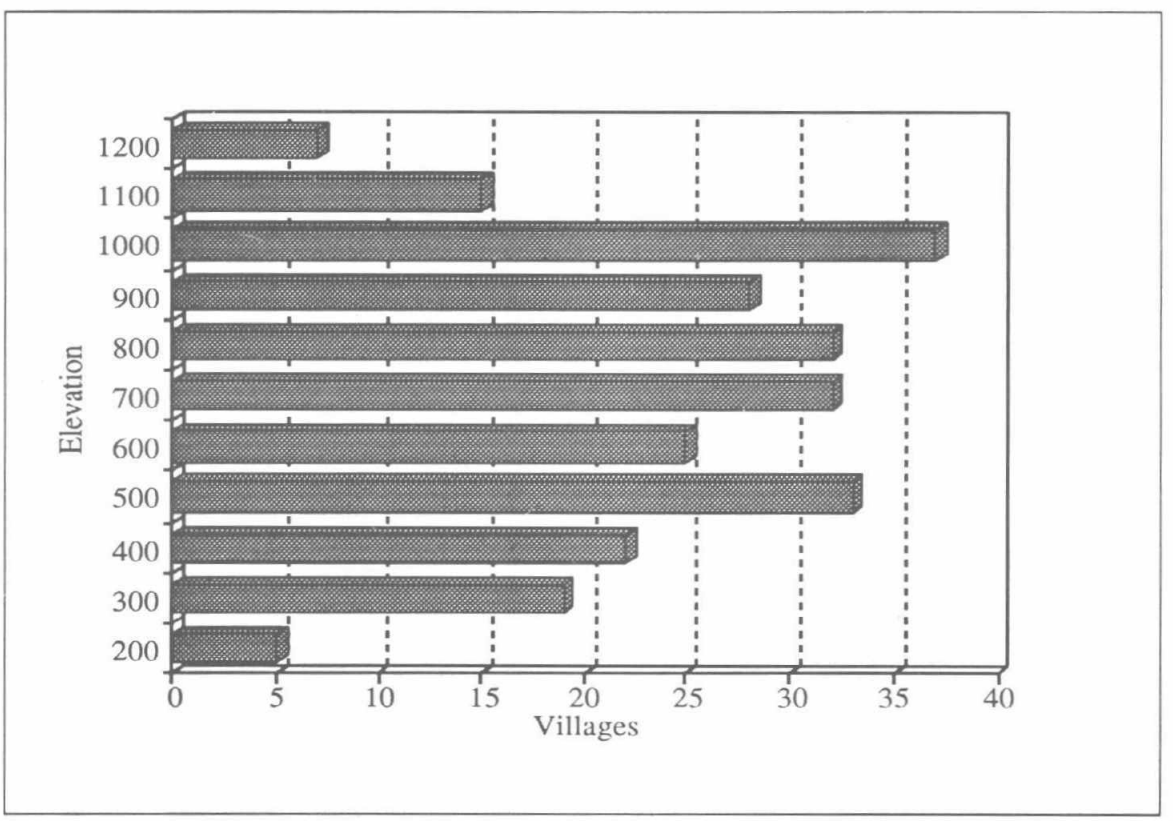


Figure 9: Village Elevation Distribution in TA-HASD Project

[12] The pre-project land use was obtained from the 1969 RTSD topographic maps of the zones. This information is being used as baseline data for land use, especially forest cover. This is another example of the overall usefulness of these base maps.

From *Figure 9* it can be seen that hilltribe villages do not restrict themselves to any particular elevation, as the range of elevation distribution is so wide. This may be due in part to the fact that there are nine different tribes (see *Table 4.1*) located in the project zones. There are, however, two somewhat larger groupings at 500 and 1000 meters ASL.

The majority of these villages are located in 1969 land uses described as *open canopy forest* (see *Figure 10*). Over 10% of these villages are directly located in some type of land use related to human activities (paddy, orchard, deforestation, etc.) in 1969. Furthermore, nearly 60% of the project villages are located within a two kilometer radius of such 1969 land uses. This is strong evidence indicating that these villages may have been located in these areas since at least 1969.

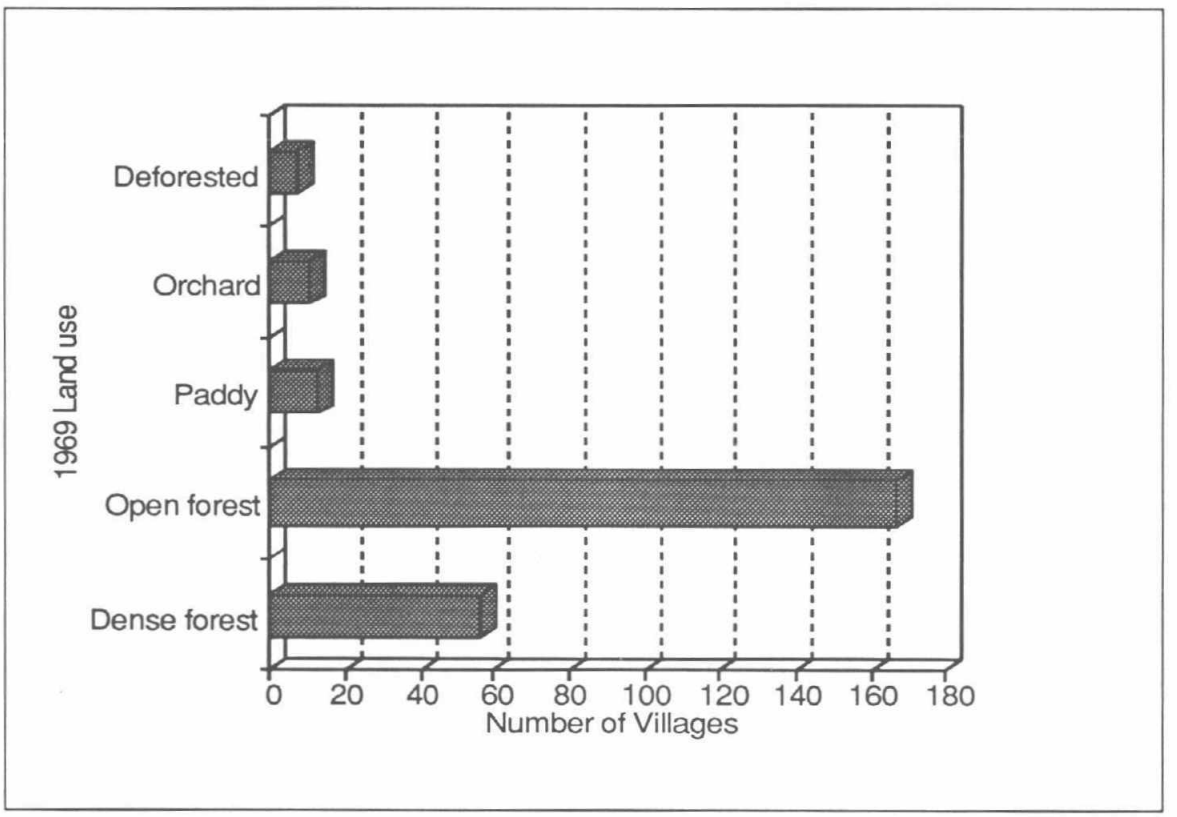


Figure 10: Village and 1969 Land Use Distribution TA-HASD Project

Hilltribe villages in the project tend to be found on shallow slopes, the vast majority on slopes below 30% (see *Figure 11*). There are very few villages located in the 30% to 40% slope range. There are no villages located on slopes steeper than 60%.

While some sort of slope is necessary for proper drainage, it is difficult to construct houses on steeply sloping lands. Furthermore, the human eye tends to exaggerate relief, making slopes seem steeper than they really are. Visitors to hilltribe villages may therefore *feel* that the village is located on steep land, while in fact it is not. This may have helped to perpetuate the myth concerning *slope complex* land.

Other GIS Products

Another major goal of the project is the provision of clean water supplies. A safe water supply is the first step in alleviating many of the chronic health problems found in hilltribe villages. *Map 17* illustrates use of the GIS in discovering which villages might have water supply problems. Because of technology and opportunity for contamination, villages that are farther than 200 meters from an annual stream are deemed to have potential water supply problems. Additionally, it can be readily seen from this map which villages may be polluting the water supplies of villages downstream. Villages sited at head waters can be given priority for sanitation projects.

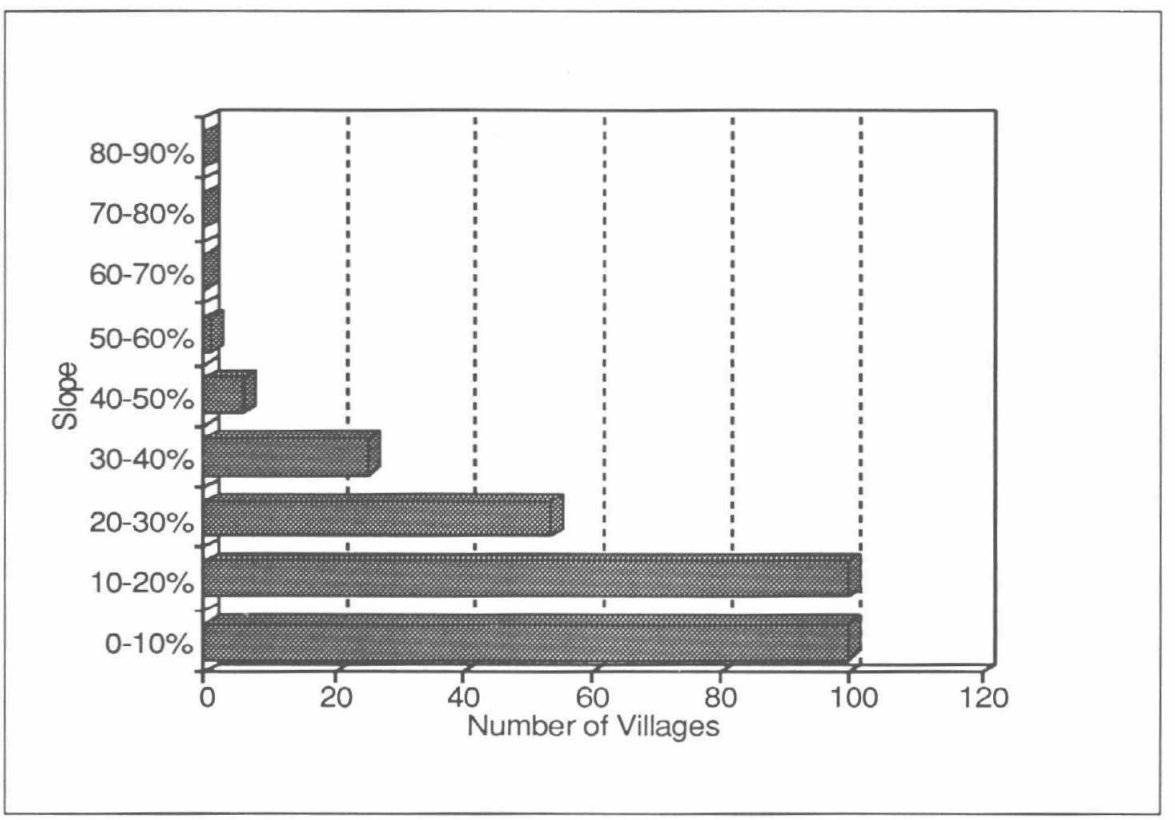


Figure 11: Village Slope Distribution TA-HASD Project

Improvements in the quality of life may in some cases mean access to electricity. Some of the fundamental problems for the villages in the project stem from their remoteness—it is very difficult or sometimes impossible for RTG line agencies to undertake their responsibilities in these areas. Small hydroelectric plants may be of use in providing electrical supplies to remote villages without recourse to RTG line agencies. Their small size, makes them less a threat to the surrounding and downstream environment than larger-scale dams.

Map 18 depicts the application of the GIS to finding potential areas for small-scale hydroelectric plants. The areas considered suitable for small-scale hydroelectric plants are those along streams with an order of four or above and have slopes 30% and above. This should insure a sufficient supply of fast moving water for use in generating electricity.

Some people have difficulty visualizing ideas from two dimensional maps. A hindrance like this may sometimes lead to frustration and ultimately cause them to mistrust the maps' ideas and those presenting them. Three dimensional views can be of use when explaining some spatially related concept as an aid in visualizing the data. The final maps for this example, *Maps 19* and *20*, provide two examples of this type of product. *Map 19* is a three-dimensional view of Ban A Di, Chiang Rai, while *Map 20* shows the terrain in Huai Lu 2 also in Chiang Rai.

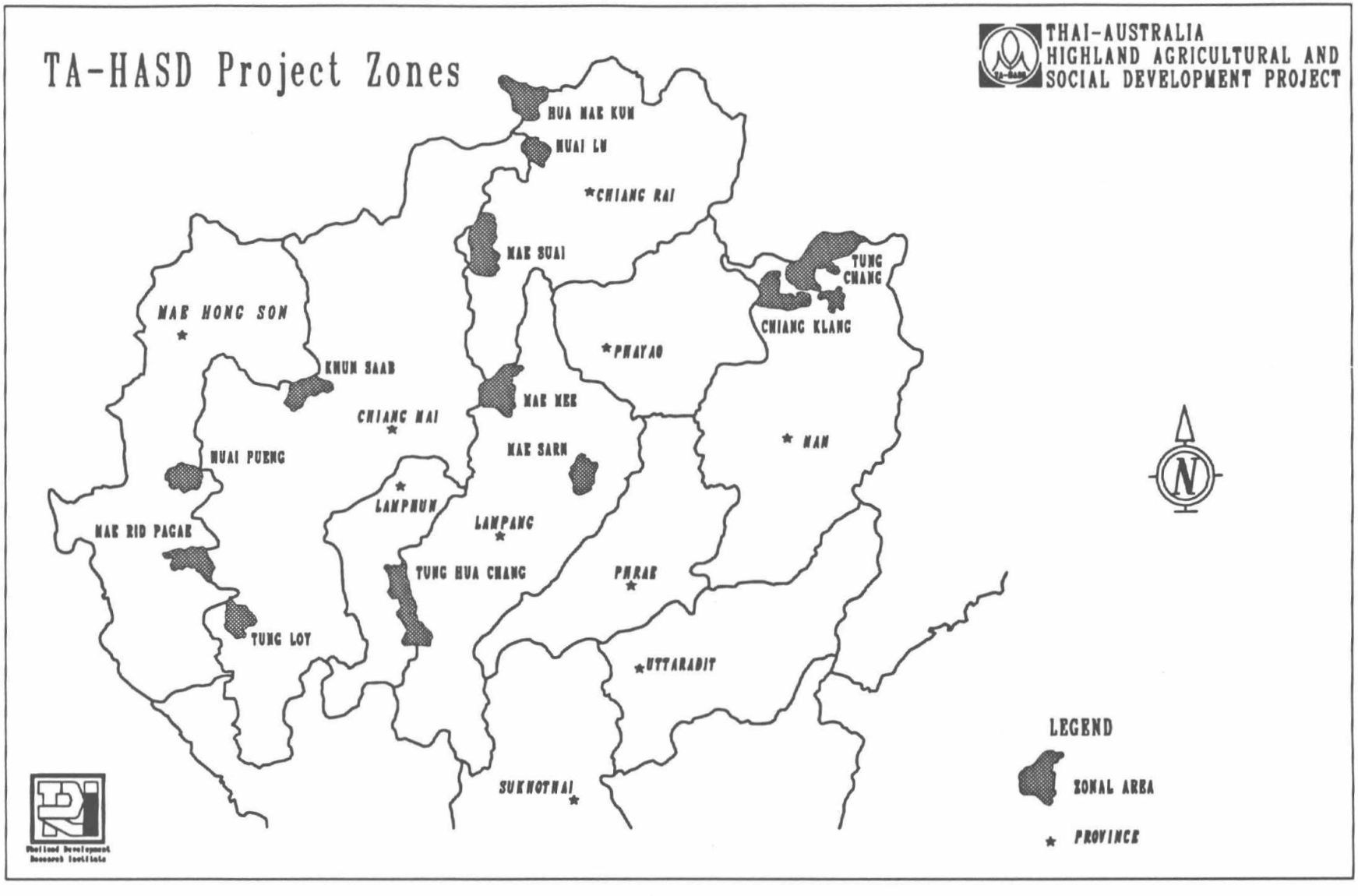
Data to create these views were obtained from 1:10,000 scale topographic maps being used by the project to monitor key village land use and ownership at the individual plot level. These maps have also been built into a micro-level database to complement this work.

Conclusion

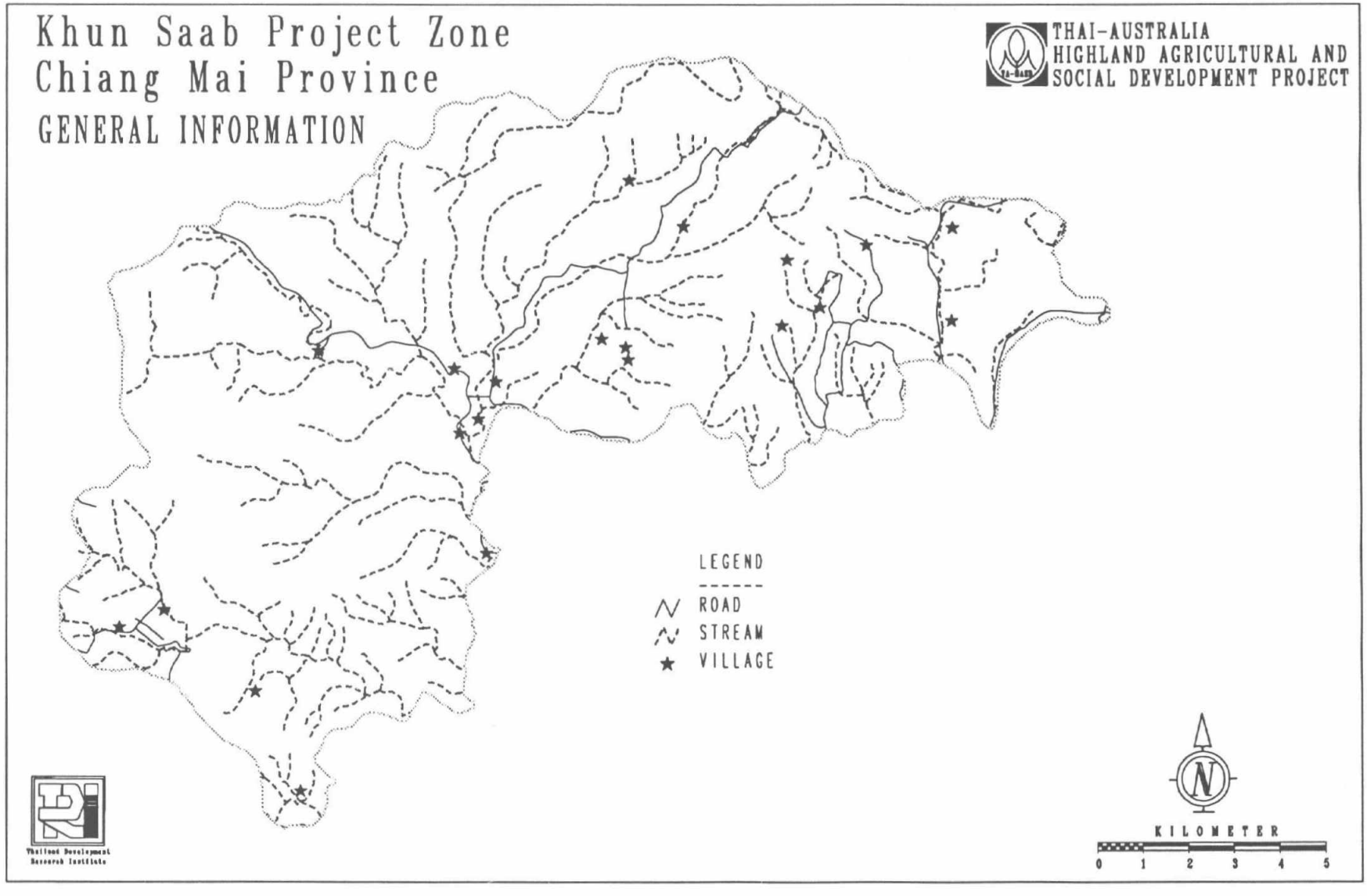
The work described above represents the very first use of GIS in **real** land use planning in Thailand. The GIS-produced results are actually being applied. The GIS has and is influencing project decisions. For example, a proposed major program to grow coffee is now being re-examined in light of what has been revealed by the GIS-based land use models previously described.

The GIS is having direct and indirect impacts on the ways project decisions are being made by helping TA-HASD staff to understand the complicated relationships

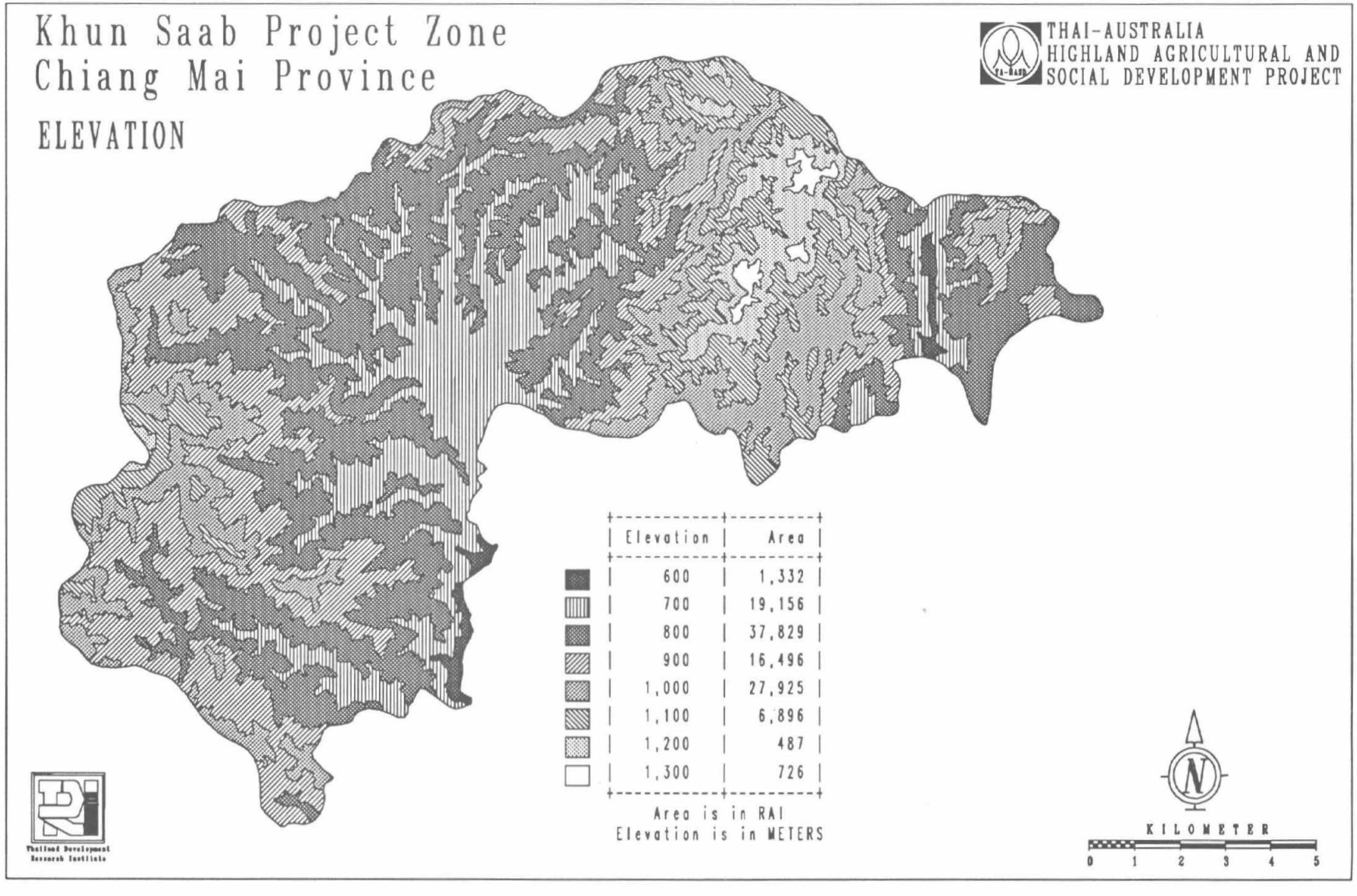
among hilltribe population and the various physical variables operating over the project areas. Certain ideas and theories about the project areas have either been confirmed or rejected by spatial analysis. Confidence levels in decision making have increased as a result. The ultimate benefactors of this would be the project's subjects, the hilltribes people of Northern Thailand.



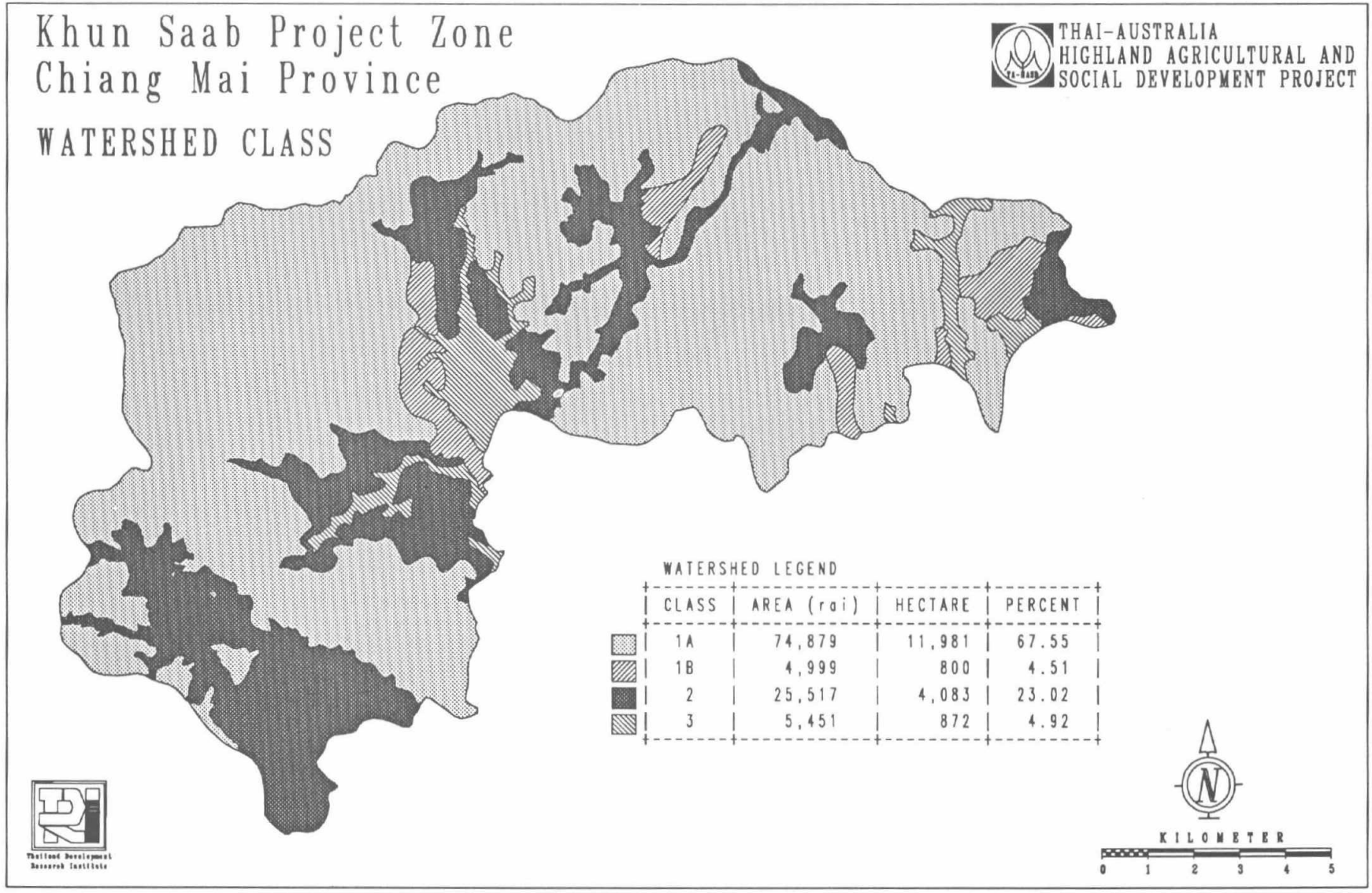
Map 1: General Locations of TA-HASD Project Zones



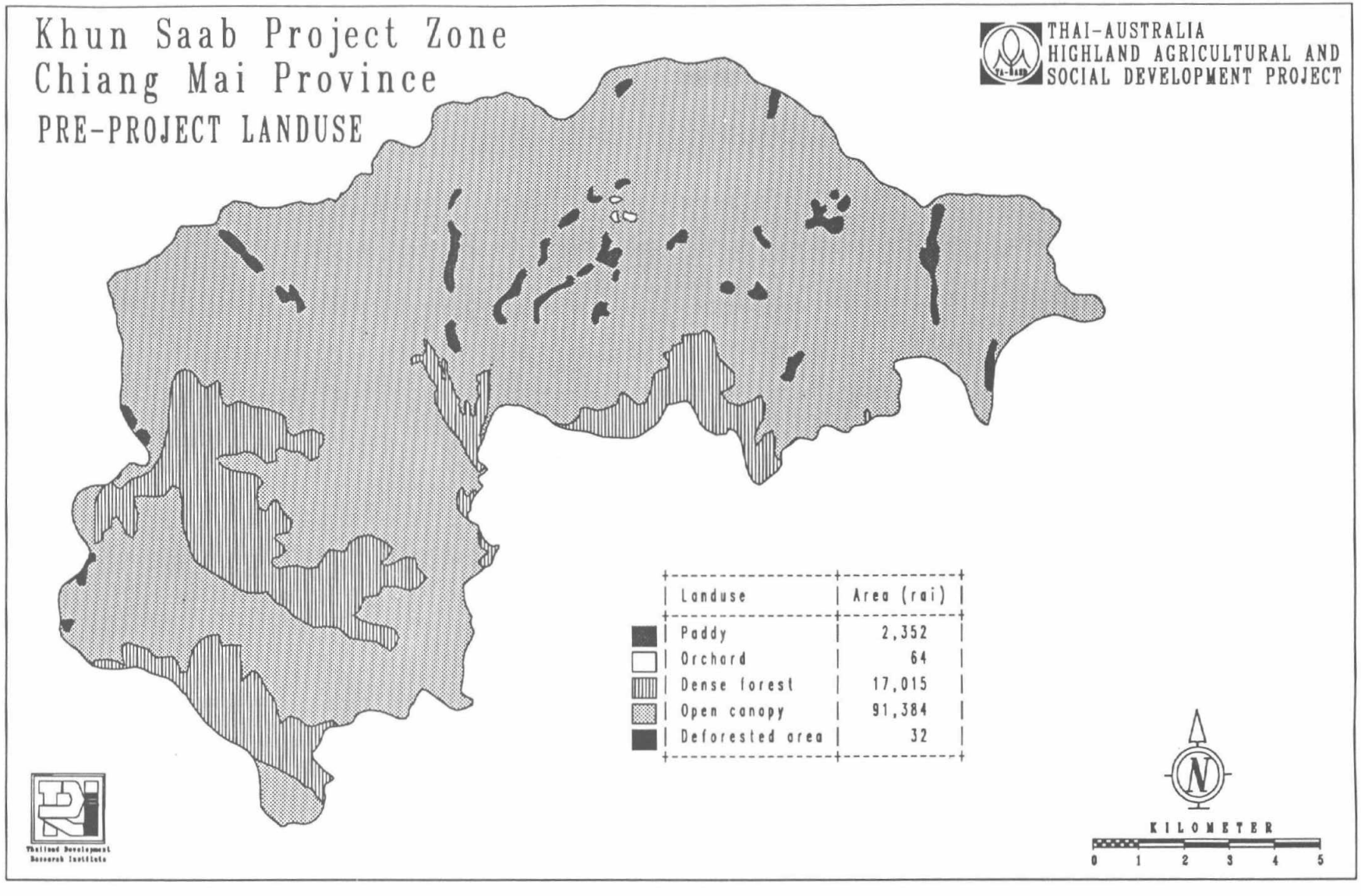
Map 2: General Information Khun Saab Zone, Chiang Mai



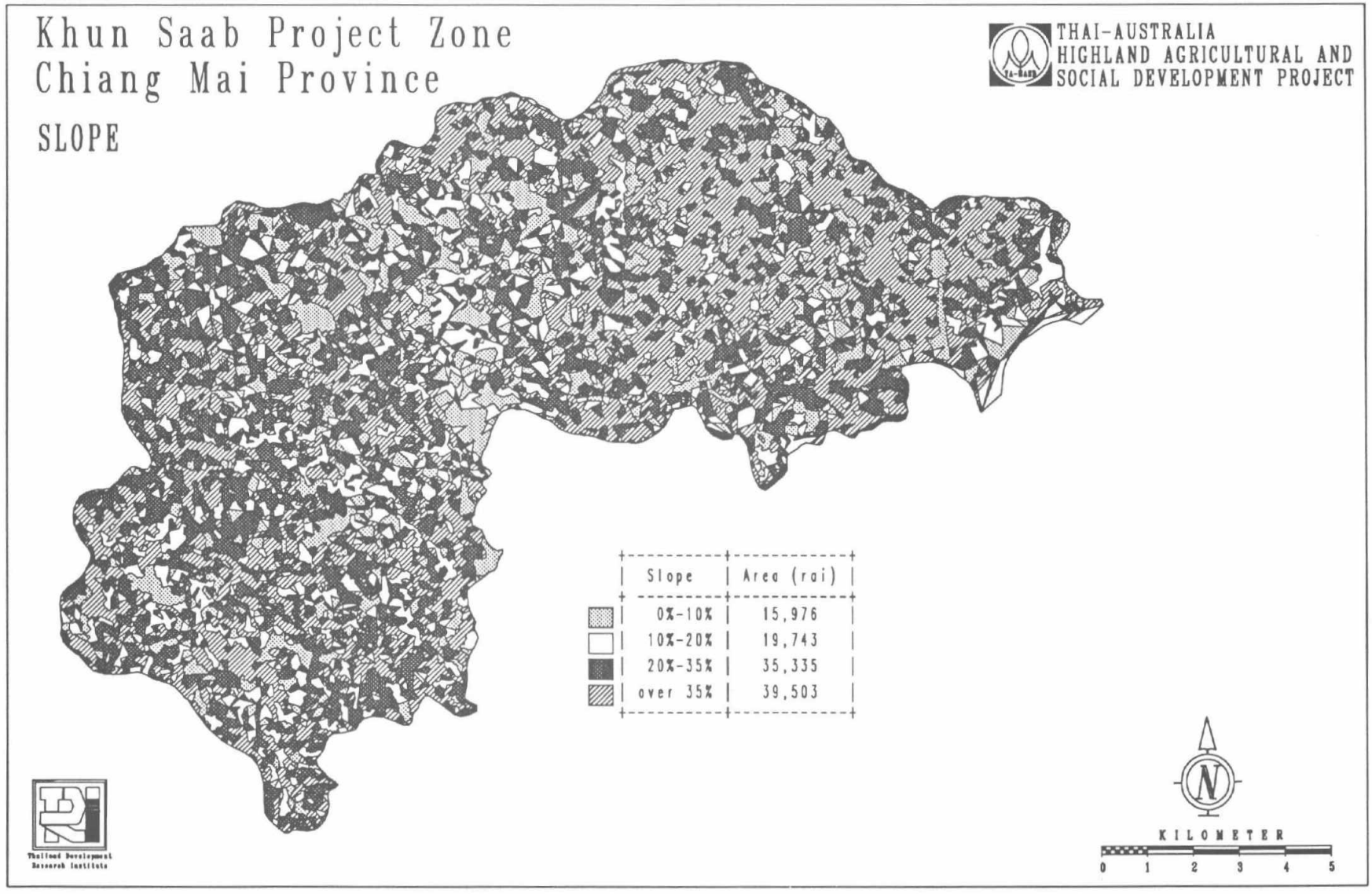
Map 3: Elevation Khun Saab Zone, Chiang Mai



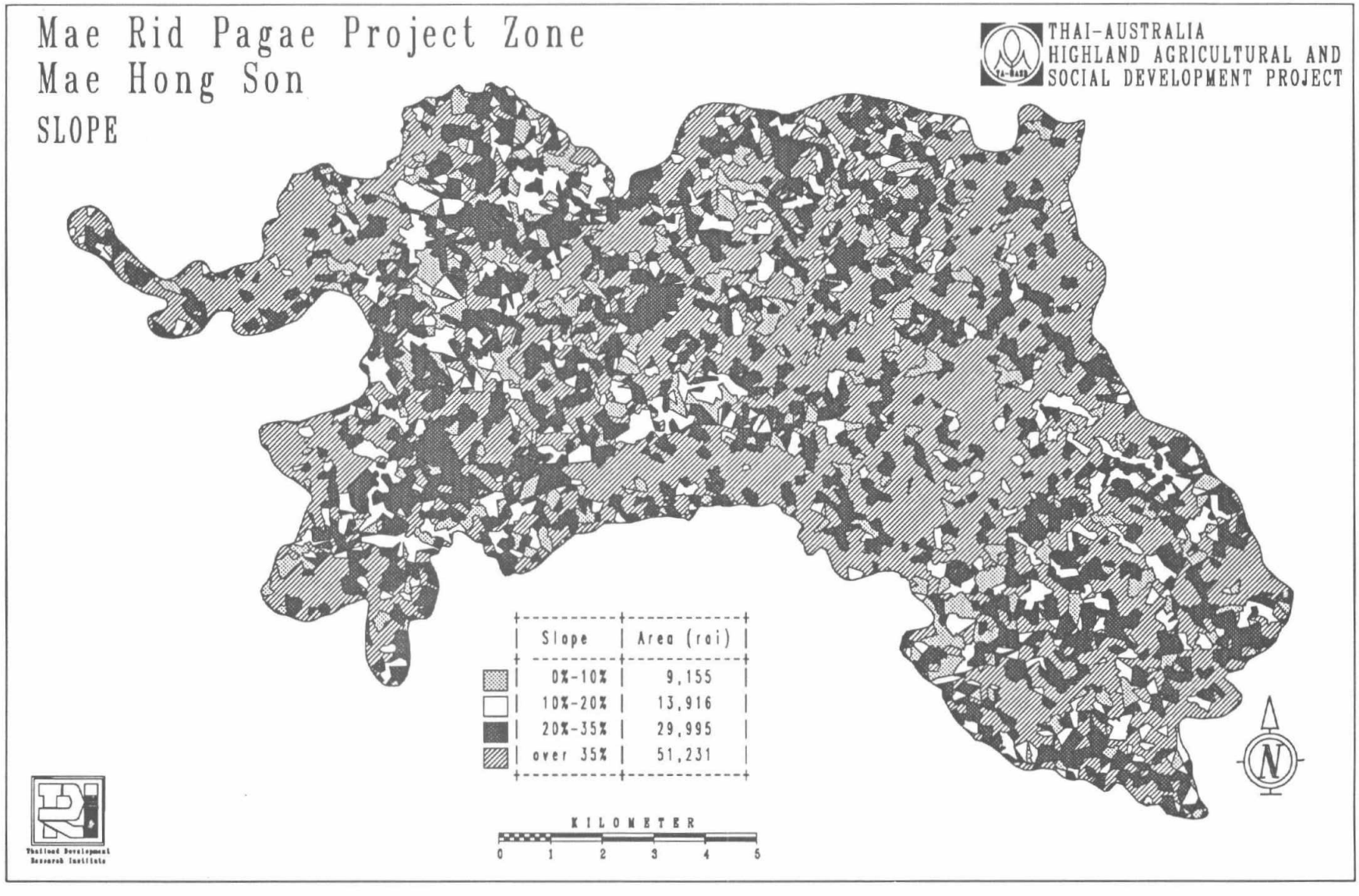
Map 4: Watershed Khun Saab Zone, Chiang Mai



Map 5: Pre-project Land Use (1969) Khun Saab Zone, Chiang Mai

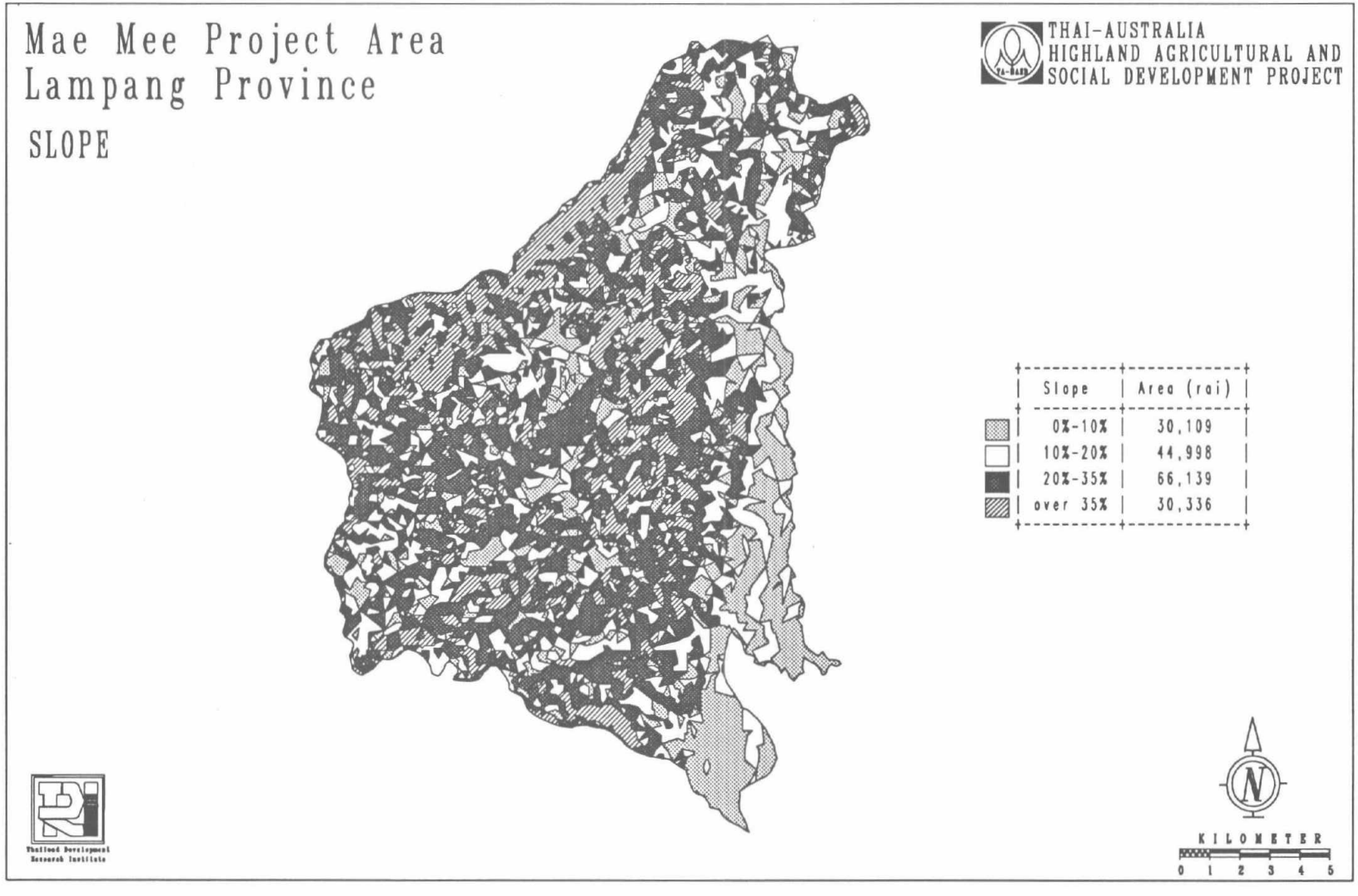


Map 6: Slope Khun Saab Zone, Chiang Mai

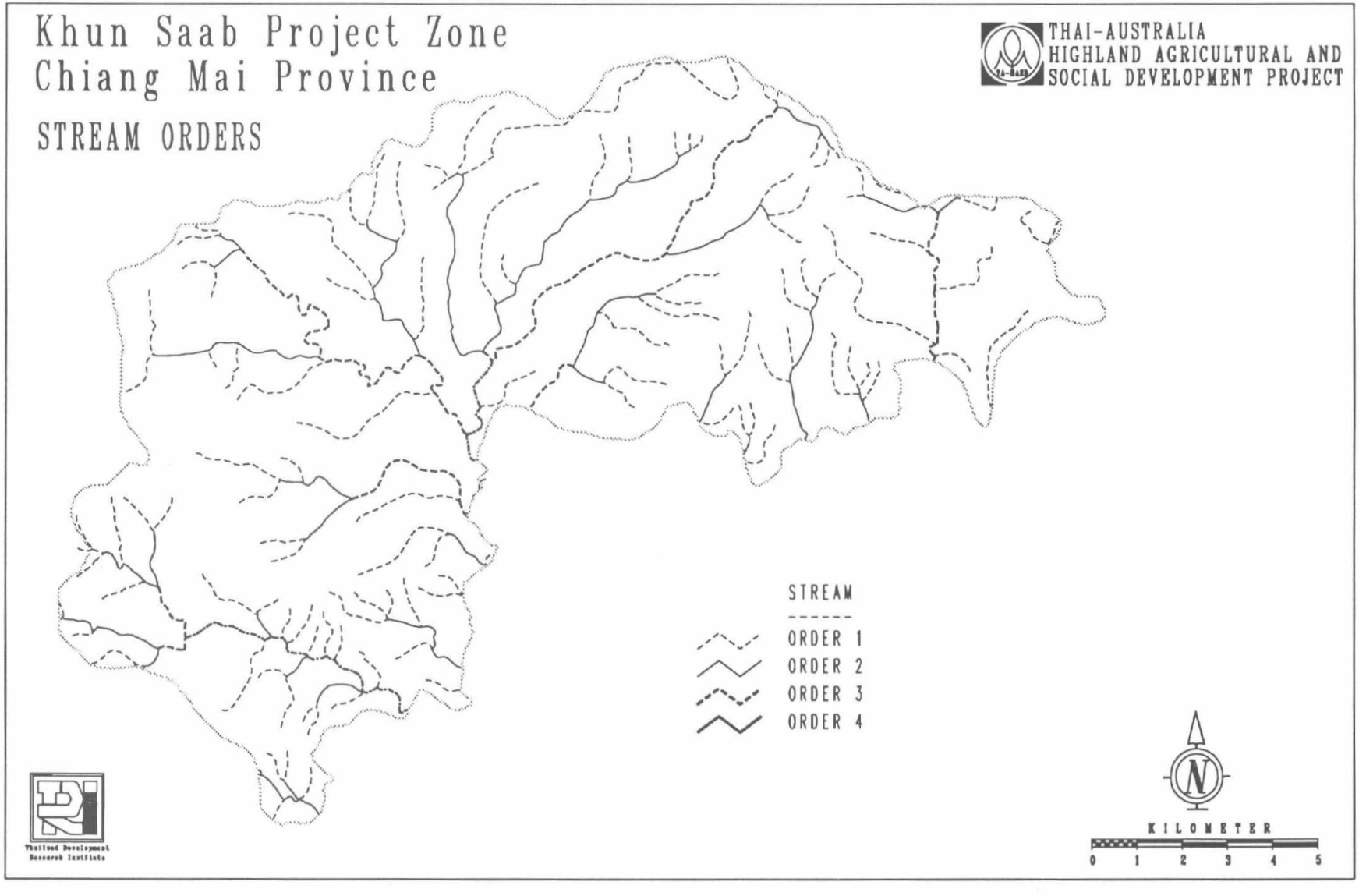


Map 7: Slope Mae Rid Pagae Zone, Mae Hong Son

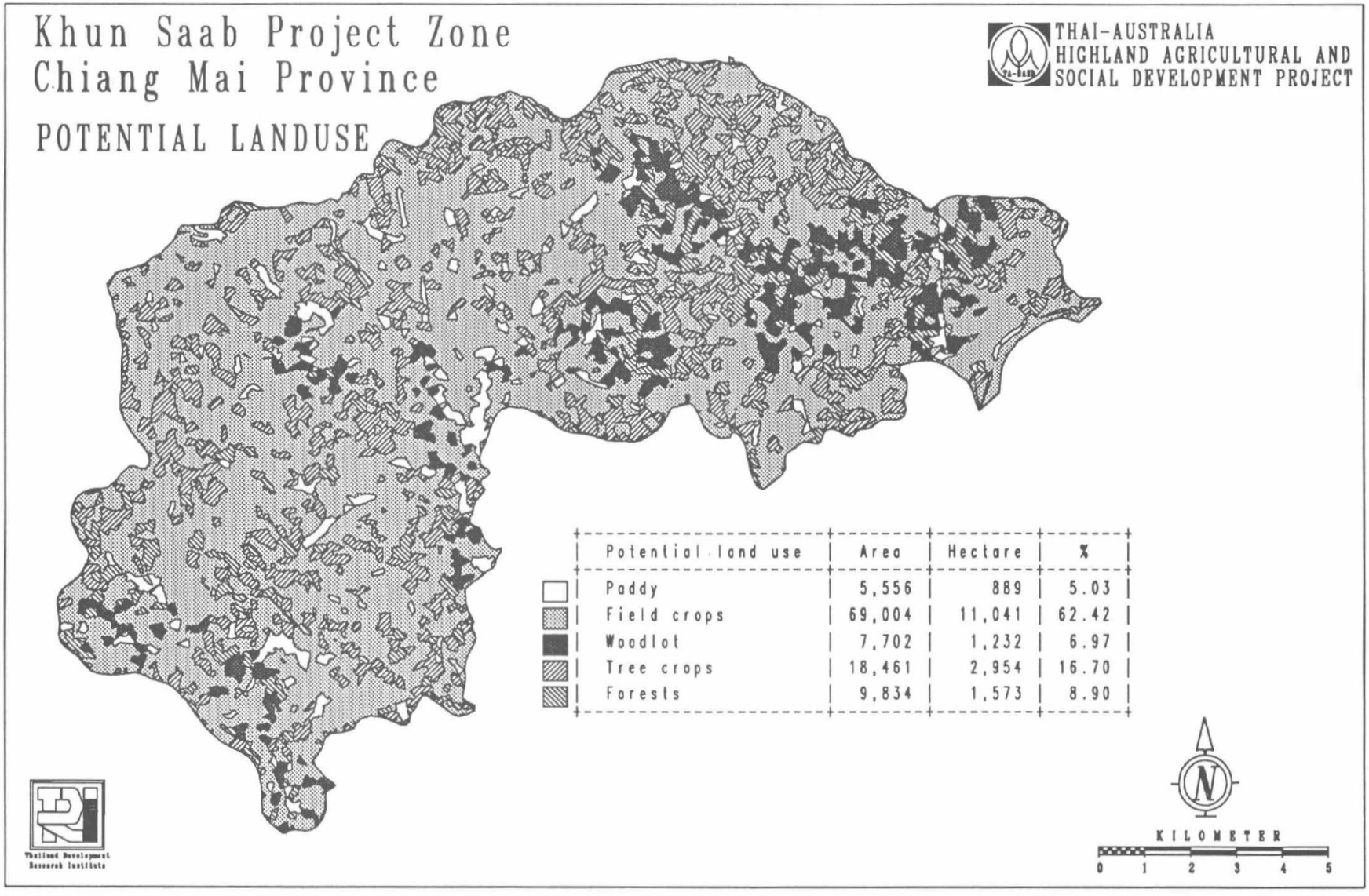
THAI-AUSTRALIA
HIGHLAND AGRICULTURAL AND
SOCIAL DEVELOPMENT PROJECT
Hua Mae Kum Project Zone
Chiang Rai Province
SLOPE
Slope | Area (rai)
0%-10% | 20,795
10%-20% | 25,972
20%-35% | 40,396
over 35% | 52,706
N
KILOMETER
0 1 2 3 4 5



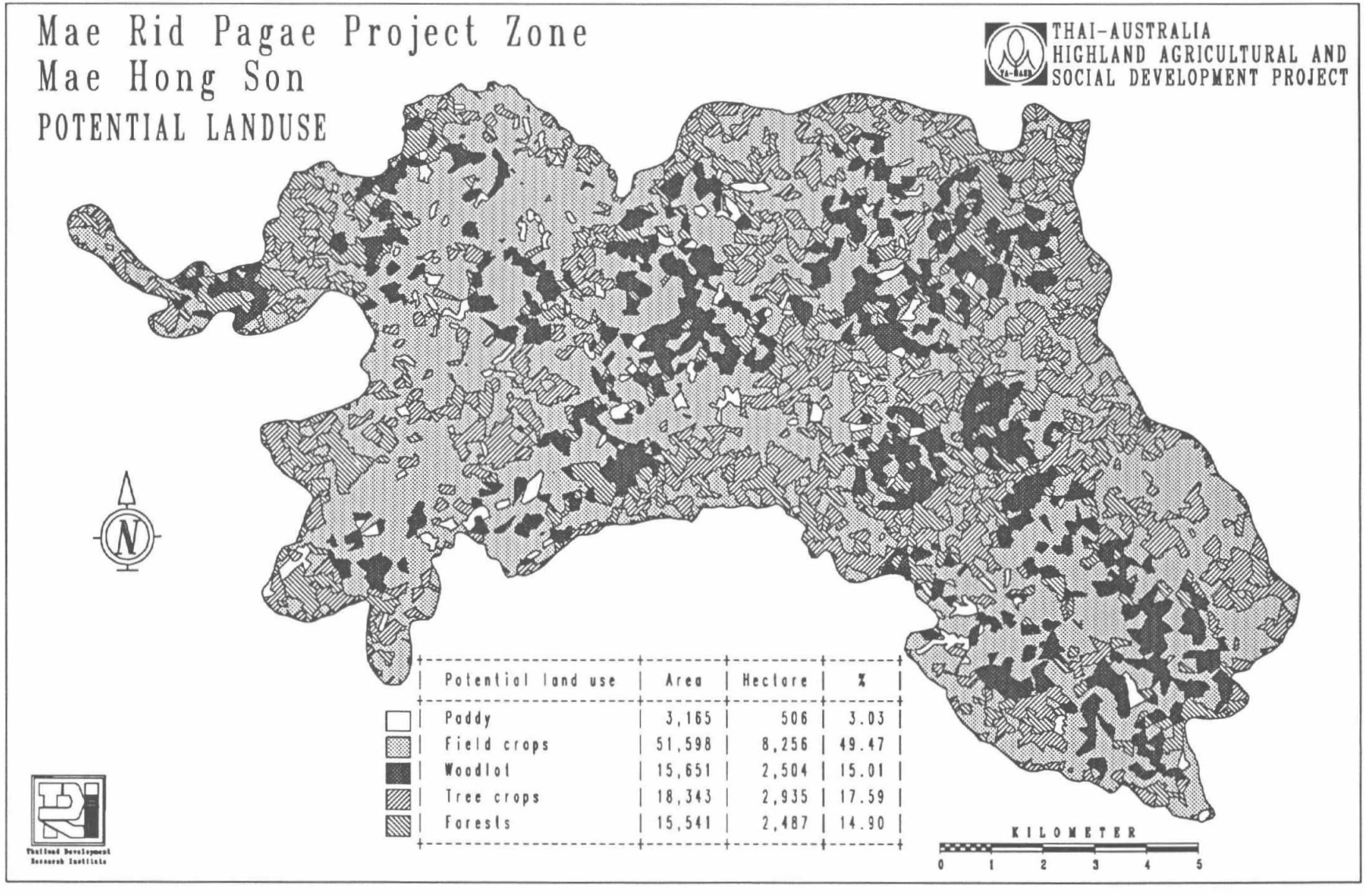
Map 9: Slope Mae Mee Zone, Lampang



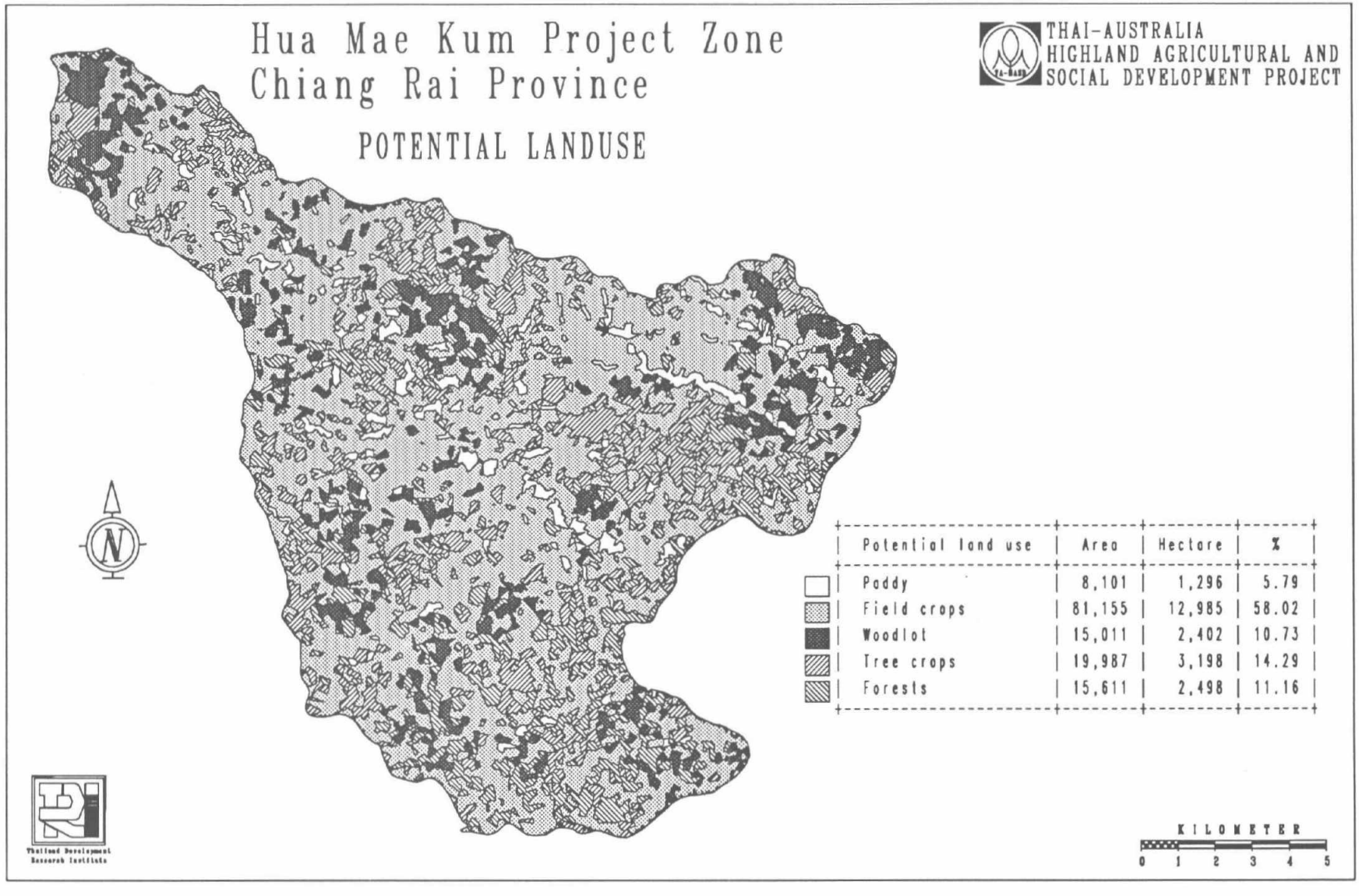
Map 10: Stream Orders Khun Saab Zone, Chiang Mai



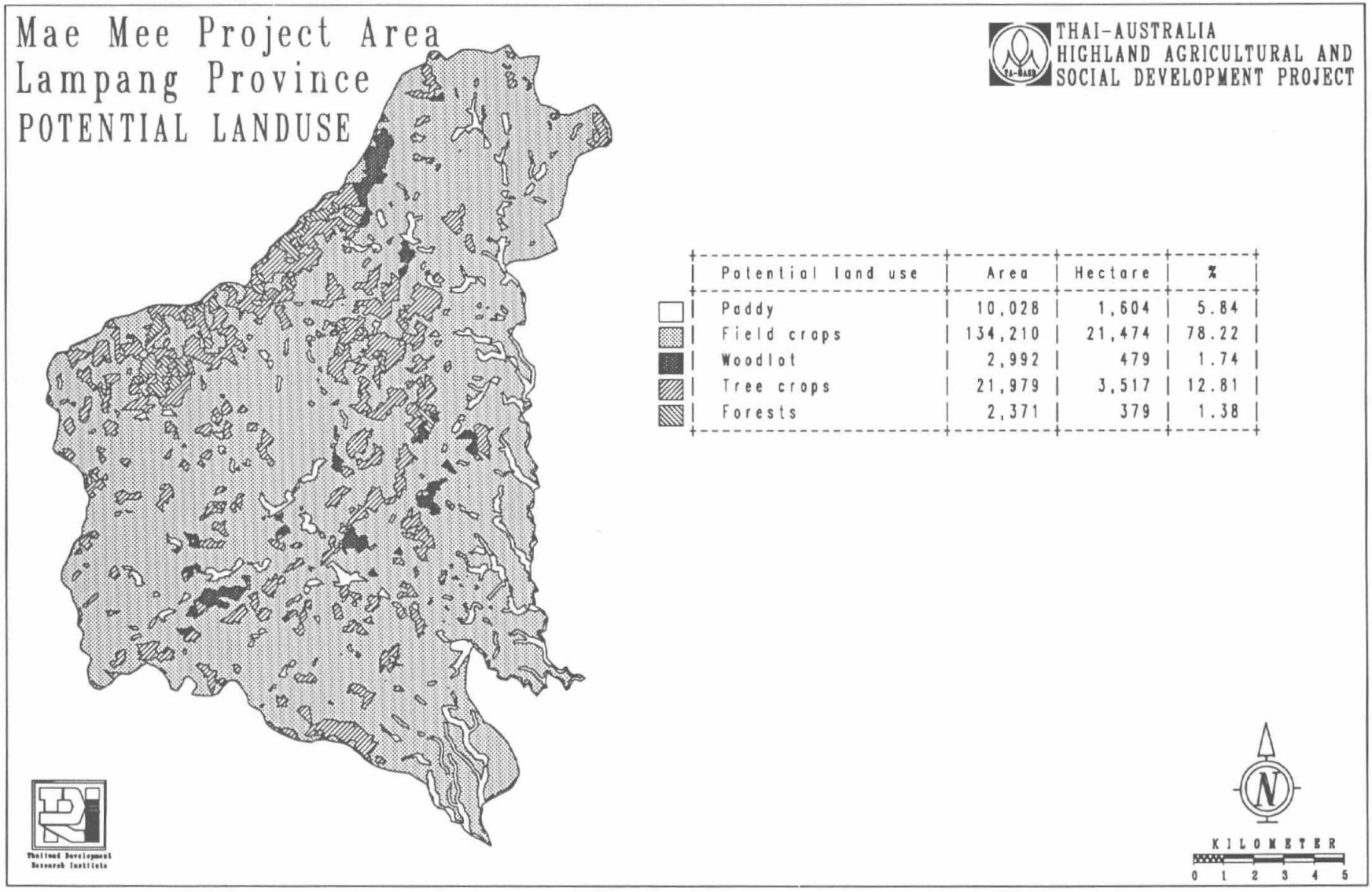
Map 11: Potential Land Use Khun Saab Zone, Chiang Mai



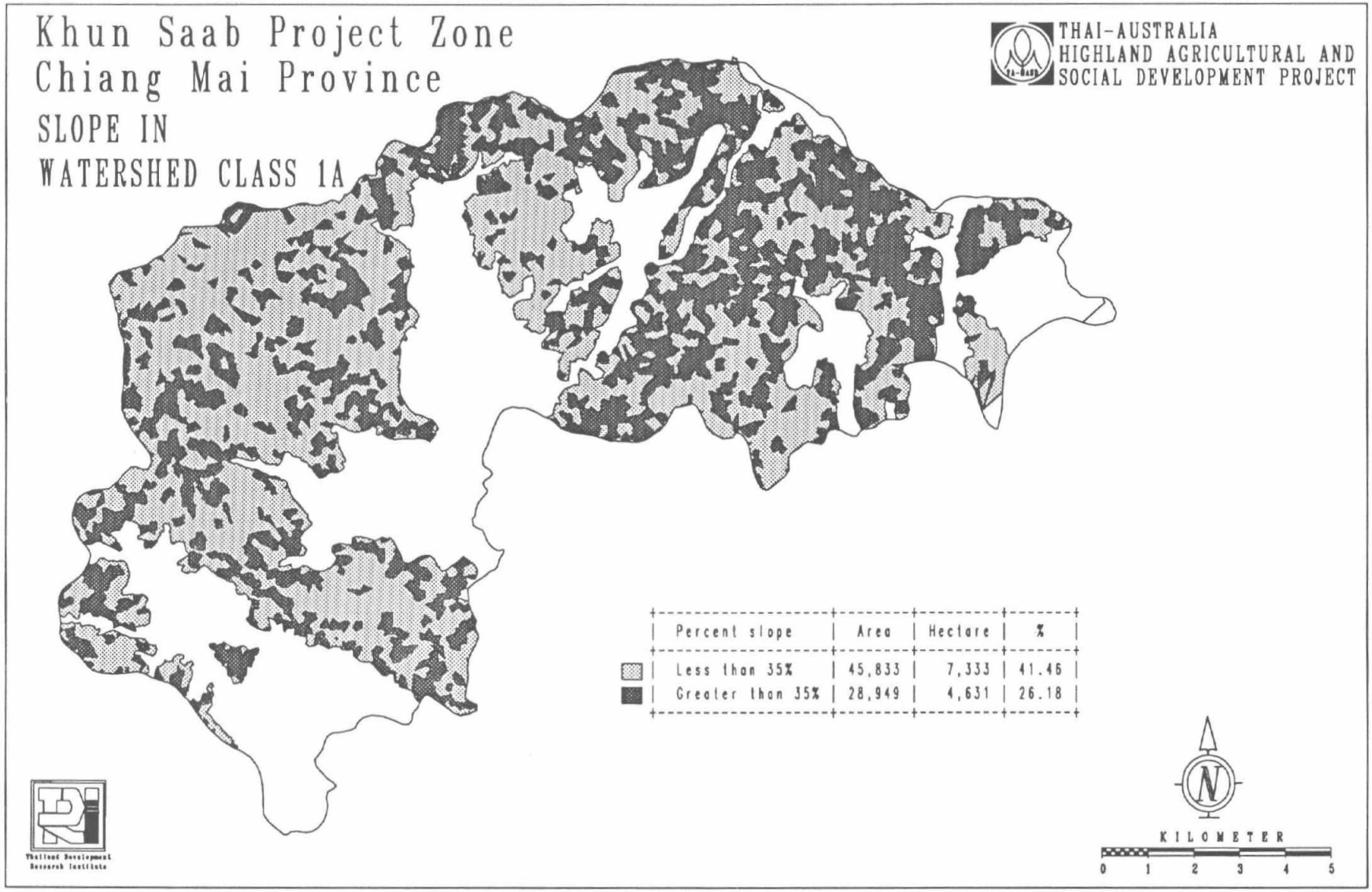
Map 12: Potential Land Use Mae Rid Pagae Zone, Mae Hong Son



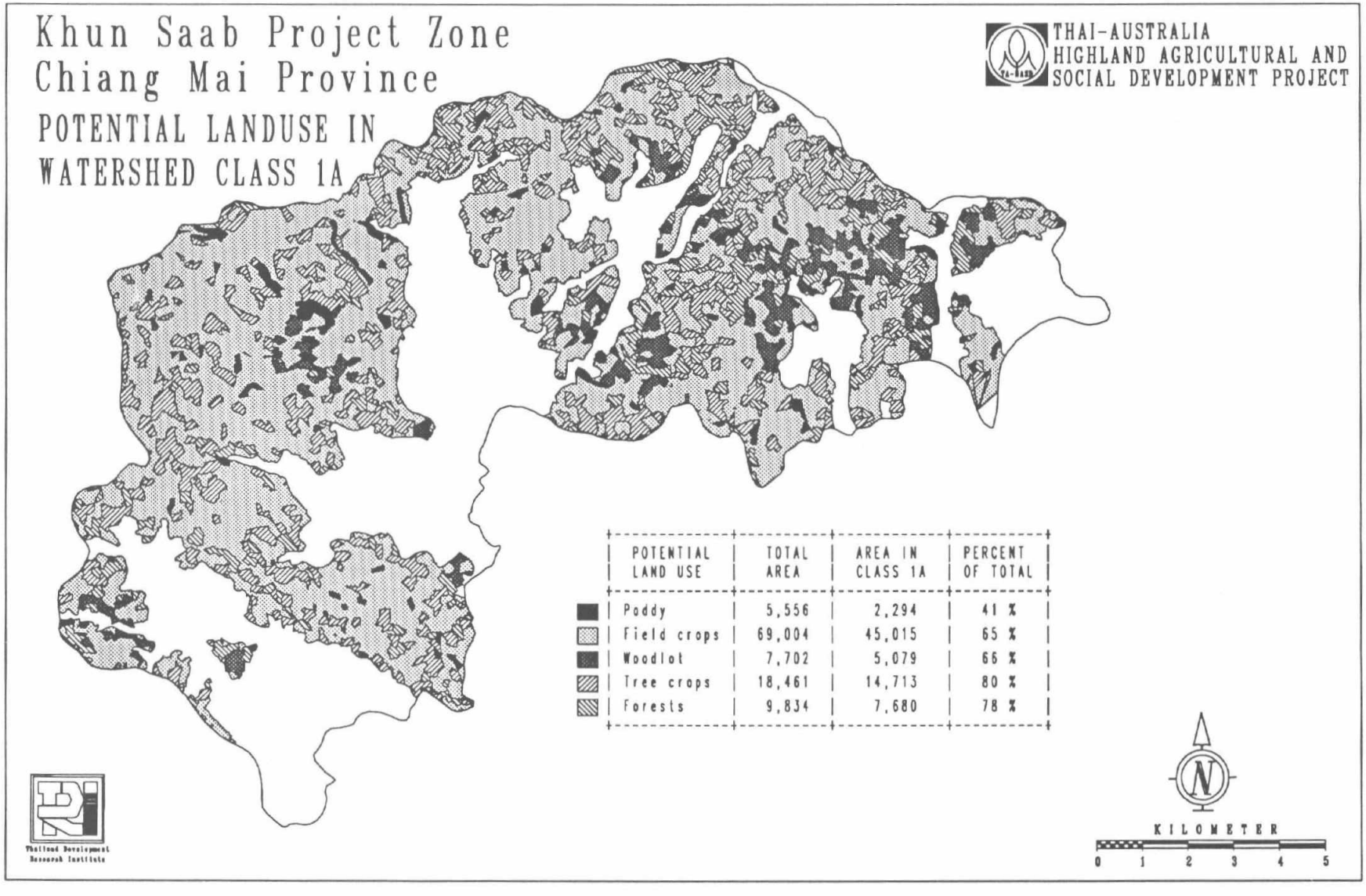
Map 13: Potential Land Use Hua Mae Kum Zone, Chiang Rai



Map 14: Potential Land Use Mae Mee Lampang Zone, Lampang

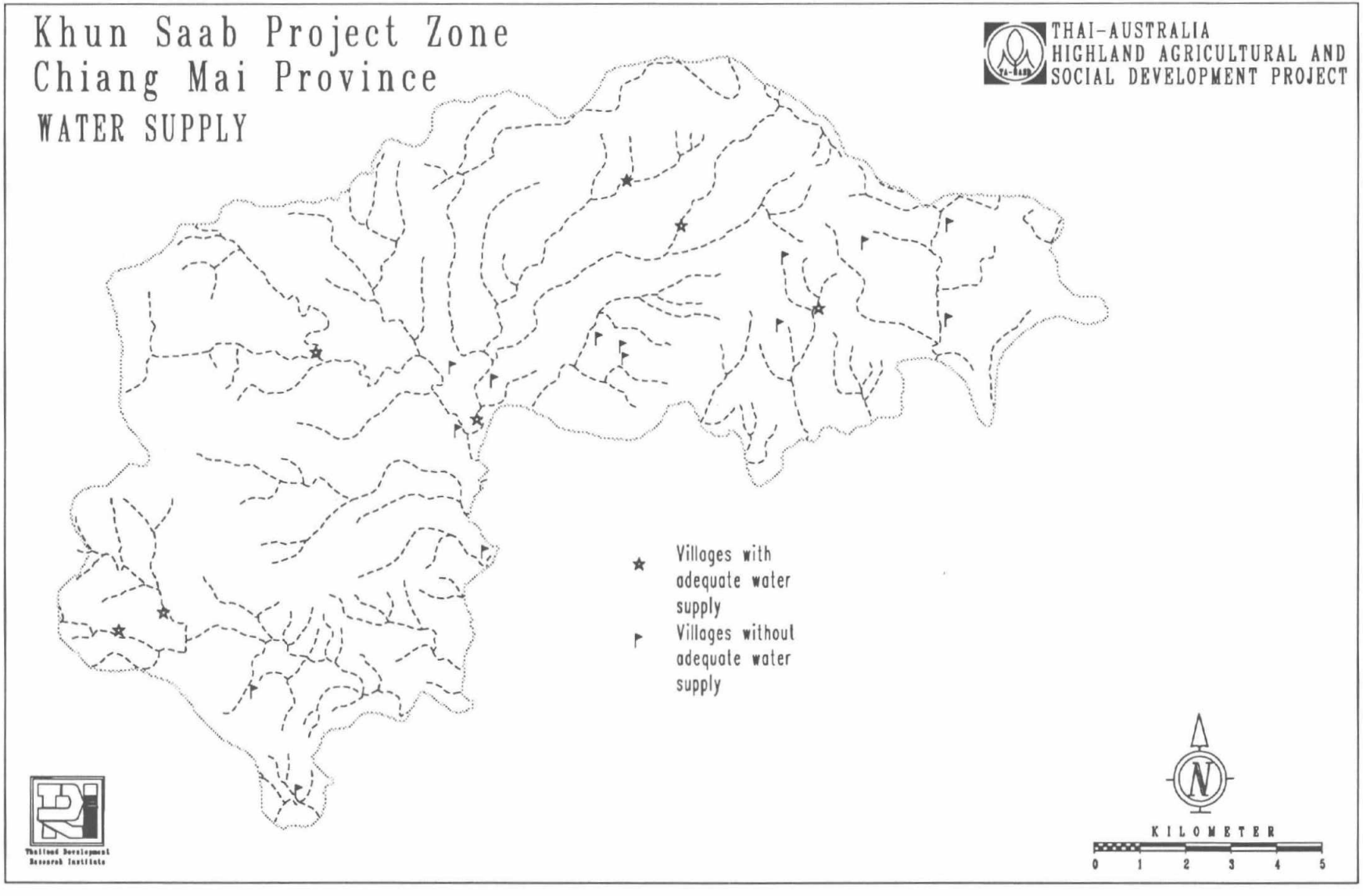


Map 15: Slopes in Watershed Class 1A, Khun Saab Zone, Chiang Mai

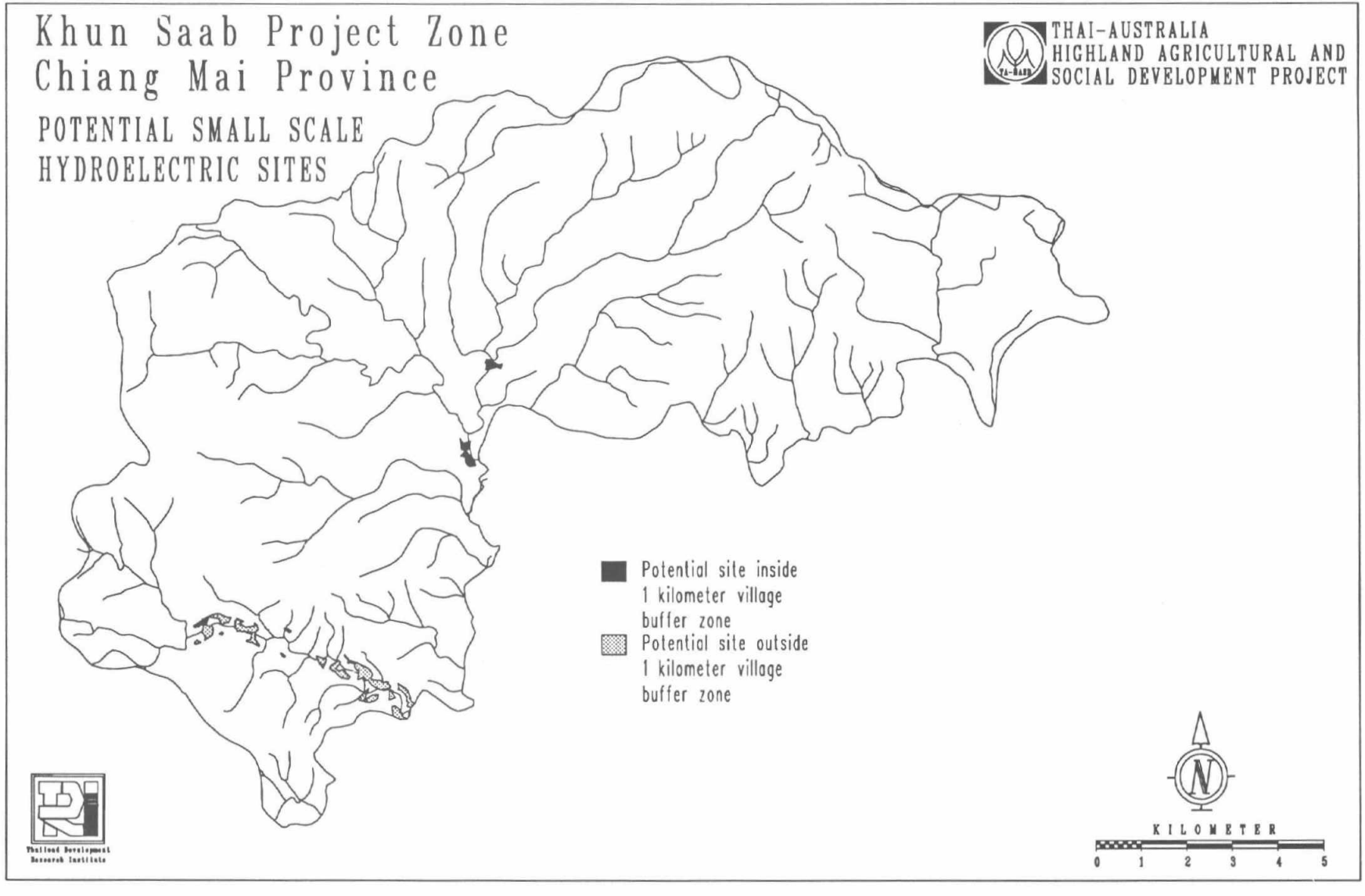


POTENTIAL LAND USE	TOTAL AREA	AREA IN CLASS 1A	PERCENT OF TOTAL
Paddy	5,556	2,294	41 %
Field crops	69,004	45,015	65 %
Woodlot	7,702	5,079	66 %
Tree crops	18,461	14,713	80 %
Forests	9,834	7,680	78 %

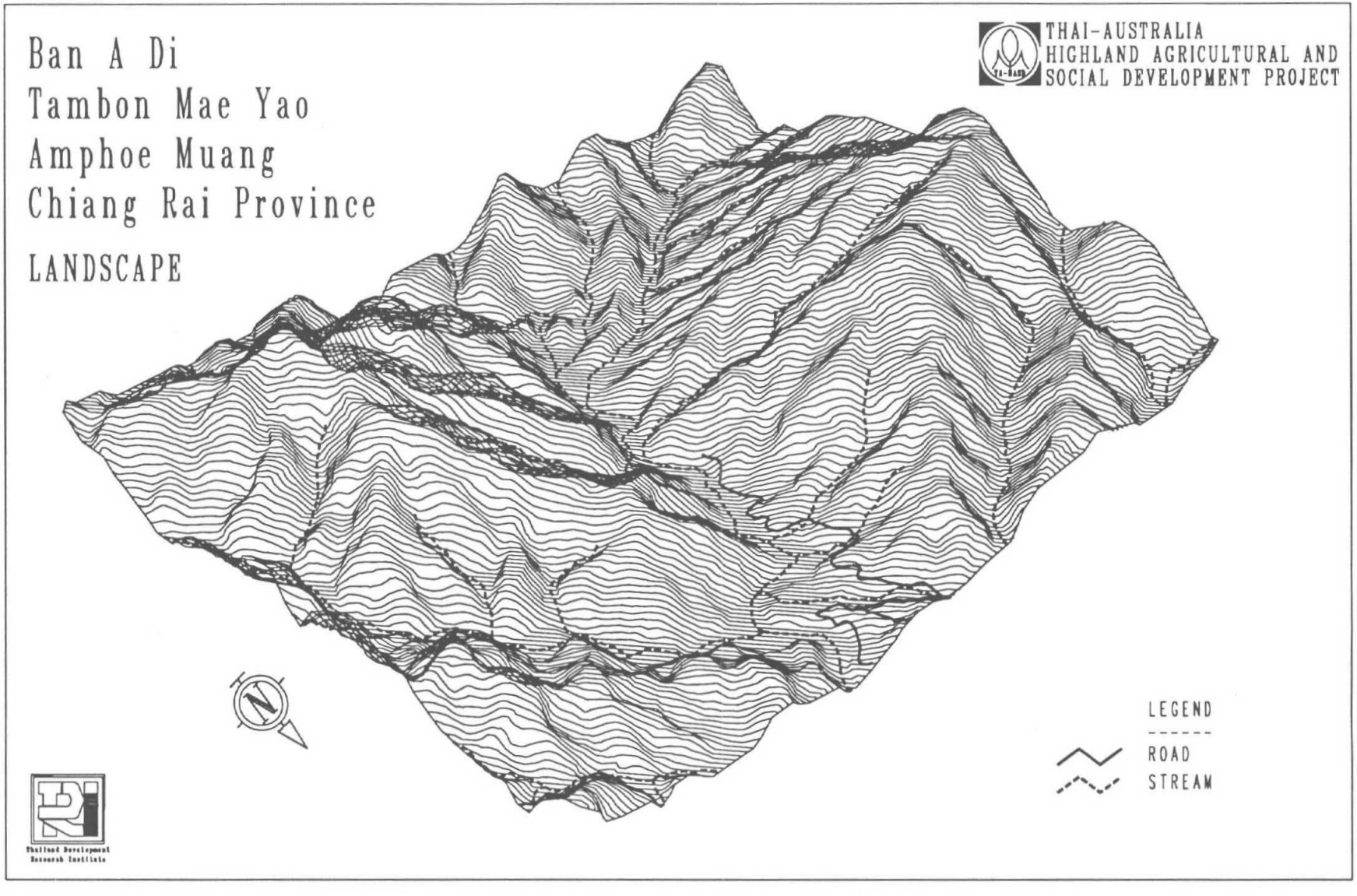
Map 16: Potential Land Use in Watershed Class 1A, Khun Saab Zone, Chiang Mai



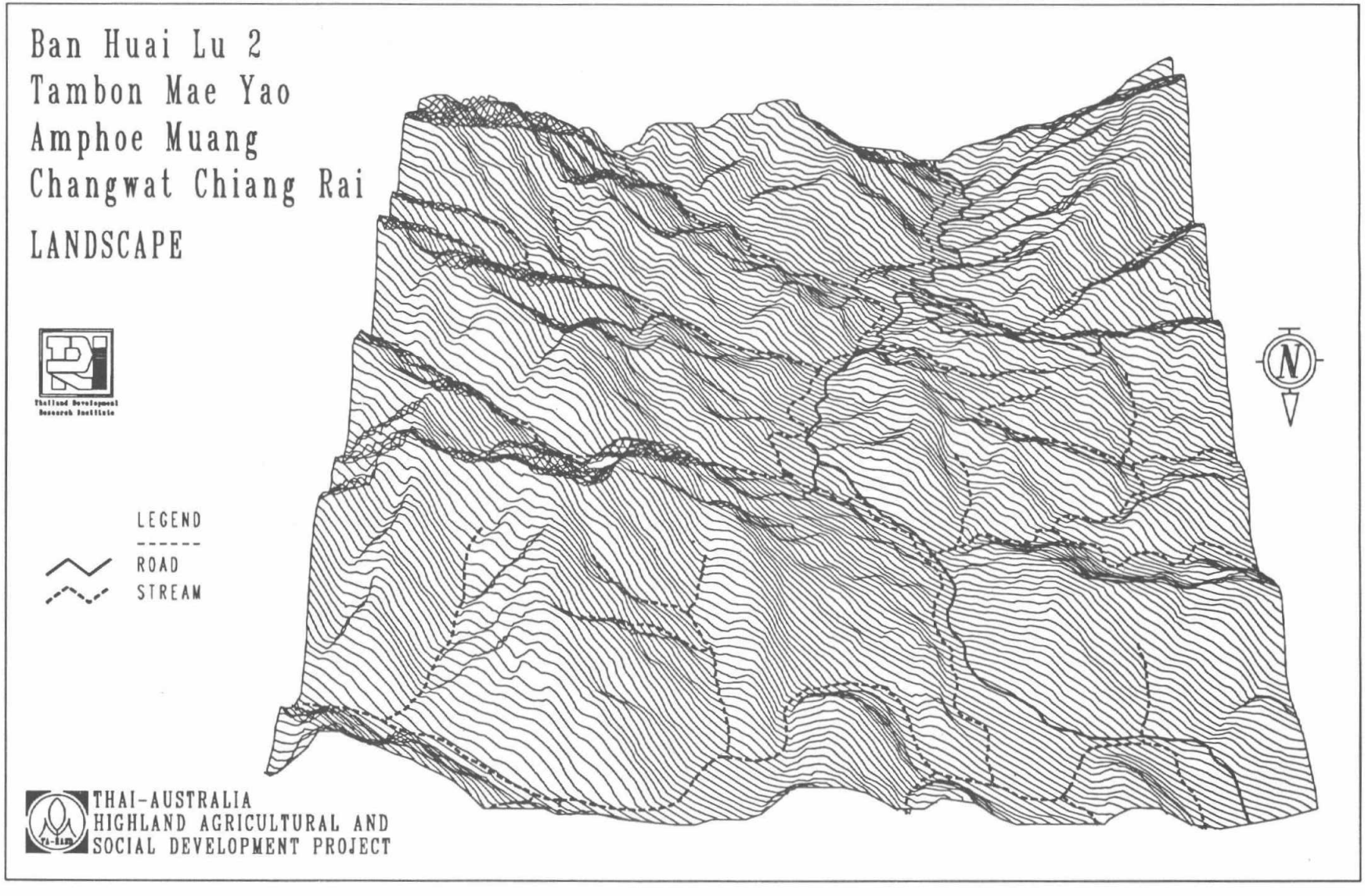
Map 17: Village Water Supply Situation, Khun Saab Zone, Chiang Mai



Map 18: Potential Small Scale Hydroelectric Sites, Khun Saab Zone, Chiang Mai



Map 19: 3D View Ban A Di, Chiang Rai



Map 20: 3D Huai Lu 2, Chiang Rai

FARMS *VS* FACTORIES: SAMUT PRAKAN & URBAN EXPANSION

Background

The face of Thailand is changing. Change is happening so fast, that many times we are able to see it occurring before our eyes. Everywhere we look, we can see changes—farms are being replaced by housing estates and fish ponds by factories. The current economic boom is the root cause of this shift in land uses away from an agricultural based economy towards a more urbanized one. The rapid growth in Thailand's economy is thus reflected in rapid changes in land use patterns. Population shifts are also occurring as more rural people come to live and work in urban areas.

Abrupt land use changes tend to be unplanned—serious damage to the environment and a lowering of the quality of life usually follows. Overcrowding and traffic jams; noise, air, and water pollution; floods, fires, and worse can result. Like the paddy lands of the highland areas, urbanized land has a finite carrying capacity. The amount of people and pollution it can absorb is limited, it can collapse and become uninhabitable as easily as the highland areas. Urban land's carrying capacity can be improved by upgrading public infrastructure (analogous to improving the farming techniques of the hilltribes to improve paddy yields), and by reducing the amount of privately generated waste being dumped into public air, water and land.[13]

In order to strike a balance between population, economic activity and an area's carrying capacity, planners must possess information. *Where do people live*? *How many people live there*? *In what directions is the city spreading*? *How has land use changed with time*? *What are the dimensions of urban spread*? Understanding historical land use changes is also important, for once we are able to explain historical land use changes, we can then predict future changes.

There are several questions arising from Thailand's rapid urbanization:

- **what exactly is an urban area**? The word *urban* has many meanings to many different people and is often used rather loosely. How we define *urban* will effect any subsequent decisions we make regarding these areas. A precise definition using readily measured variables should be arrived at and used.

[13] TDRI, 1990, *Urbanization and Environment: Managing the Conflict*. TDRI Year-End Conference Research Report #7.

- **how fast did urban areas spread?** Did urban areas develop as fast as is commonly thought? What are the dimensions of its expansion? (Tens of rai, hundreds of rai, or thousands of rai?) What is its rate of expansion?
- **in gaining urban areas, what rural land uses did we give up?** In Thailand, urban areas most often expand into rural areas. How much farm land was lost? Was it *good* farm land?
- **how did rural land uses change to urban ones?** Was there some intermediate step or steps in going from rural to urban land uses? Or was the change sudden and abrupt?
- **how is irrigation infrastructure affected by land use changes?** Along with concerns about agricultural land, many people are apprehensive about irrigated land being converted to urban uses. How many kilometers of irrigation infrastructure is being lost to urban expansion? Are these canals becoming new pollution pathways?
- **is a greenbelt policy going to be an effective tool in controlling land use changes?** Can a greenbelt policy be implemented?

The use of a GIS can help in analyzing urbanization and in providing answers to some of the more pressing questions and issues regarding land conversion. The following sections will deal with an example of applying GIS technology to urbanization issues. The area selected for this example is Samut Prakan province, part of the Bangkok Metropolitan Region (BMR).[14] (*Map 21* shows the general location of Samut Prakan). It was selected as an example area because it is perceived as one of the fastest growing industrial areas in the Kingdom. As such, it should provide some insights into other areas experiencing rapid urban expansion. For more background on Samut Prakan please refer to the 1990 TDRI Year-End Conference Research Report #7.[15]

Land Use Changes: 1982, 1987, 1989

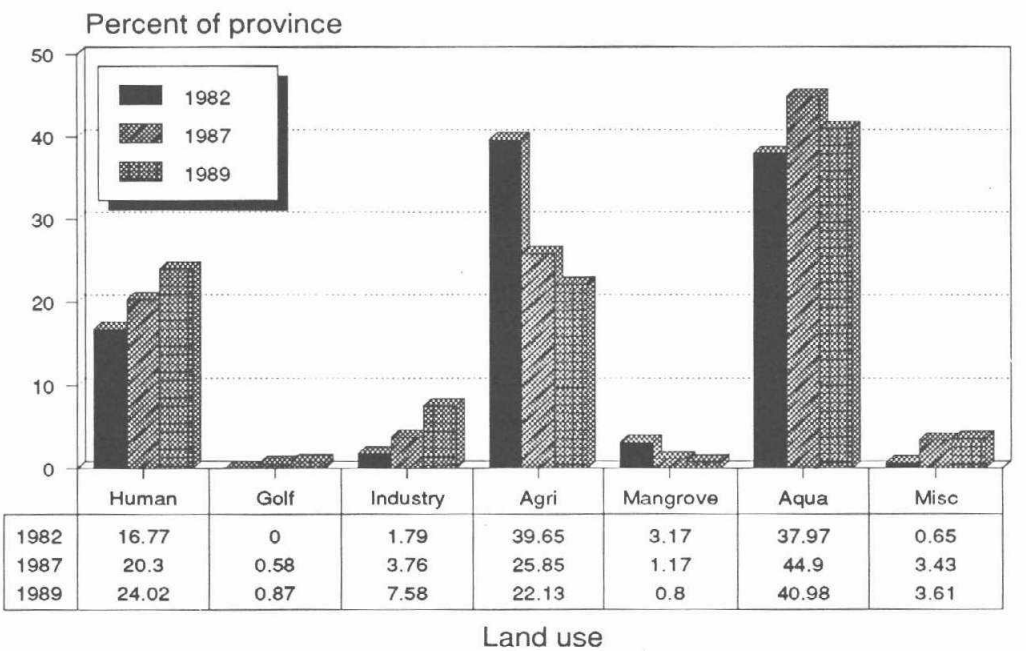
Understanding past land use shifts is one key to understanding how land use changes. Once we develop an understanding of the mechanisms of land use change, we can begin predicting specific future land use patterns. Knowledge of future land use patterns can help predict infrastructure needs, potential pollution sources, tax base changes, population shifts, educational needs, etc—valuable information to urban planners.

[14] The other provinces in the BMR are also being analyzed using GIS as part of the Urban Working Group for the National Urban Development Policy Study. These provinces include: Nonthaburi, Pathum Thani, Samut Sakhon, and Nakhorn Pathom. Bangkok itself is being treated as a separate issue.

[15] TDRI, 1990, *Urbanization and Environment: Managing the Conflict.* TDRI Year-End Conference Research Report #7.

The first step to developing an understanding of land use changes is the creation of a database of **historical** land use patterns—a task well-suited for a GIS. *Maps 22-24* show the generalized land use patterns for the years 1982, 1987, and 1989, while *Figure 12* makes a comparison between the major land uses for these years. The database was developed from land use maps provided by the Department of Land Development (DLD), Ministry of Agriculture and Cooperatives, which is the RTG line agency responsible for land use planning.

The 1982 and 1987 land use data was derived from aerial photo analysis while the 1989 land use was created from satellite imagery. Once the land use database was constructed, these three land use maps were intersected together into a single, integrated database.



	Human	Golf	Industry	Agri	Mangrove	Aqua	Misc
1982	16.77	0	1.79	39.65	3.17	37.97	0.65
1987	20.3	0.58	3.76	25.85	1.17	44.9	3.43
1989	24.02	0.87	7.58	22.13	0.8	40.98	3.61

Notes: Human-refers to areas of human habitat, such as homes, etc. Agri-is agricultural land, including paddy, orchards, etc. Aqua-is aquaculture, fish and shrimp ponds. Misc-stands for miscellaneous land uses such as pasture, unused, etc.

Figure 12: Samut Prakan Land Use Changes 1982-1989

1982 Land Use

In 1982, Samut Prakan was not a particularly urbanized province. The predominate land uses were agriculture and aquaculture which together covered about 78% of province. Rice paddies (40%), and fish and shrimp ponds (38%) dominated the landscape. Human habitat areas covered over 100,000 rai of land, while industrial areas covered a negligible 10,000 rai. There were no golf courses in the province in 1982. Mangrove forests still existed and covered about 3% of province.

Referring to *Map 22*, one can clearly see the ribbon pattern of the human habitat areas. It is apparent that these areas have developed along canals—traditionally Thailand's main transport networks. In fact, there are still some parts of Samut Prakan that can only be reached by boat. Development patterns that follow transport routes is therefore not something *newly* imported to Thailand, it was a traditional development pattern here.

1987 Land Use

Significant changes in Samut Prakan's land use patterns began to be seen in the 1987 data. Aquaculture became dominant covering 45% of the province's area. Agriculture land uses lost considerable area, falling to only 26% of the province total. Agricultural land was mainly converted to aquaculture (about 48,000 rai) and human habitat areas (about 30,000 rai). The aquaculture area advanced inland, encroaching on rice growing areas in the north of the province.

Golf courses also made their appearance, replacing about 2,000 rai of farm land.[16] Mangrove area decreased considerably, from 3% of the province in 1982 to only 1% in 1987. Mangrove forest was replaced mainly by aquaculture, a pattern repeated throughout coastal areas of Thailand. Miscellaneous land uses, largely unused land, increased considerably, from 0.65% in 1982 to 3.4% in 1987. Industrial areas experienced a 100% increase in area, from 1.8% to 3.8% of the province.

[16] From the available data, it can only be said that golf courses appeared sometime between 1982 and 1987.

1989 Land Use

Aquaculture began to decline in 1989. This was largely a result of pollution and falling product prices. The form of aquaculture practiced in Samut Prakan relies heavily on existing irrigation infrastructure. The irrigation infrastructure in Samut Prakan serves as both intake and outlet systems for these fish and shrimp ponds. As one operator pumps out a pond upstream, a downstream operator may inadvertently pump this waste water into its own ponds, resulting in severe damage to the shrimp or fish crop. Of the 24,000 rai of aquaculture land that was converted to other uses, about 9,000 rai (38% of the area converted) was located near the coast and thus at the bottom of the irrigation network where it might receive the full load of aquaculture generated pollutants generated by those upstream.

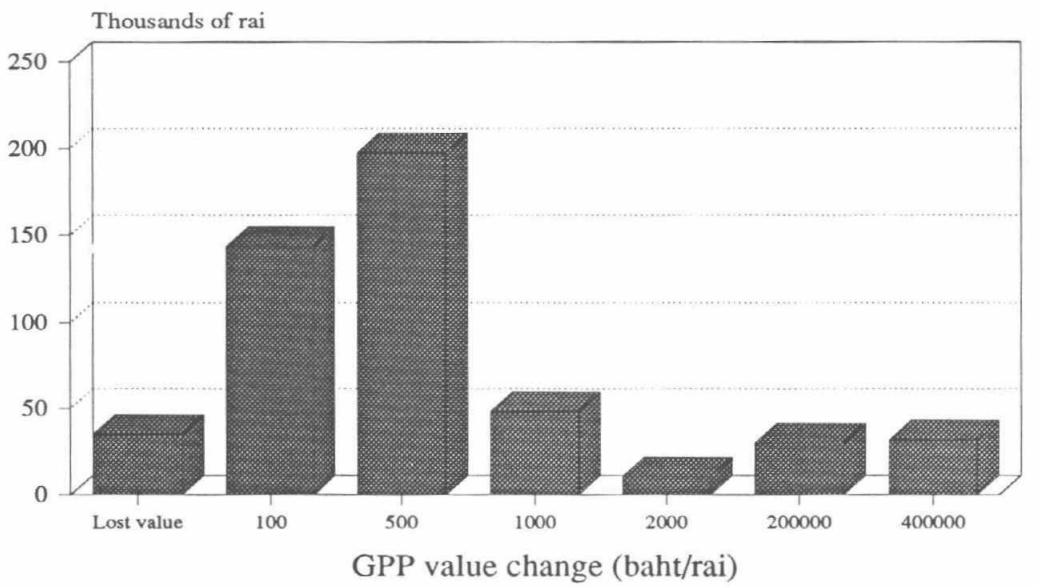
Agriculture continued its decline from 1987, dropping to only 22% of the province's area. Most of this land was converted to human habitat areas (18,000 rai), while the remainder went unused. It is noteworthy that almost all of the unused land in 1987 was converted to human habitat areas by 1989. The total amount of unused land, however, remained more or less constant at about 3.6% of the province. The total area of changed land use amounted to about 11% of the province (about 5% per year). Between 1982 and 1987, about 24% of the province changed, also about 5% per year. Thus, the 3.6% figure for vacant land probably represents about one year's worth of land use change. This change was literally *caught-in-the-act* by the land use mapping team at DLD.

Map 25 shows the vacant land in relationship to industrial and urban areas and golf courses. Most of the unused areas are directly adjacent to these types of land uses. Their vacancy is probably in preparation to changing land use to one of the adjacent types.

Industrial land uses continued to undergo rapid growth (100%), with about 7.5% of the province covered by industrial areas. Mangrove in Samut Prakan was almost wiped out by 1989, with less than 1% of the province remaining under mangrove forests. For the most part, this land was converted to human habitat areas. The majority of the remainder was converted to vacant land and can be expected to switch to human habitat areas as well in the very near future.

Land Use Change Implications

The overall land use change patterns in Samut Prakan closely reflect changes in the economy of the province. *Table 4.5* provides Samut Prakan's Gross Provincial Product (GPP) per rai for 1982 and 1987, while *Map 26* shows the GPP value changes. *Map 26* provides a view of the economic development of Samut Prakan province between 1982 and 1987. *Figure 13* summarizes the extent of the GPP changes from 1982 and 1987 data. This is a very clear example of the types of linkages between data sets possible with a GIS.



About 70,000 rai did not have GPP data
GPP values in 1972 constant prices.
Source: NESDB

Figure 13: Samut Prakan GPP changes 1982-1987

A neighbor analysis,[17] performed using the GIS, indicated that there was a 60%-70% chance of a land use with a poorer GPP per rai to convert to one of the adjacent land

[17] A neighbor analysis consists of determining the characteristic of those polygons that surround a particular polygon. For example, we might want to see how paddy land changed by selecting polygons that were paddy in 1982 and that changed to something else in 1987. The neighbor of that paddy in 1982 would be determined to see what types of land use were adjacent to it in 1982. These might have influenced the land use change.

uses if these land uses generated higher income (in terms of GPP per rai). In general, the land use change pattern for Samut Prakan from 1982 to 1989 was:

agricultural land ⇨ aquaculture ⇨ urban/industrial.

The trend here is usually towards economically better-off land uses. Land use changes move **down** economic slopes, that is from land uses with low economic returns will taken over by land uses with higher economic returns.

Table 4.5 Samut Prakan GPP per rai

Activity	1982	1987
Agriculture	716	809
Aquaculture	1,271	1,703
Urban/Industrial	266,858	423,292

Note: Figures in baht per rai, 1972 prices.

Source: NESDB.

Samut Prakan is a province blessed with an extremely well developed irrigation infrastructure (see *Map 27*). There are over 2,000 kilometers of canals in the province, not to mention the Chao Praya river that flows through the western part. How has the changes in land use affected these canals?

Figure 14 provides a look at how land use changes have affected the irrigation infrastructure over the province. The dominant influence upon the irrigation system is clearly from aquaculture (at least as far as length affected is concerned). While its influence is waning, it is still the largest land use affecting irrigation in Samut Prakan. Human habitat areas have superseded agriculture, while industrial areas are on the rise. The significance in this analysis is that industrial wastes, while toxic and environmentally damaging, are still restricted to a relatively small portion of the irrigation system. It should therefore be comparatively easy to control, especially as this type of waste is derived from a point source.

The aquaculture and human habitat areas, on the other hand, are non-point sources and affect a substantially larger part of the irrigation system. The organic wastes

produced from these land uses would therefore be much harder to control primarily because their sources are so diffuse and hard to pin point.

Point sources of pollution are easily seen, felt, smelt, or heard. They are readily picked out from the background environment and identified as pollution originators. Since they can be so easily identified, they can also be used to heighten public awareness regarding this source in particular and pollution, in general. Because of this visibility, the present strategies for controlling pollution in Thailand are mainly focused on contributions from point sources. An often overlooked source of pollution is the non-point, or diffuse, source. In developed countries, it has become increasingly clear that once the point sources have been controlled, non-point sources must also be dealt with in order to effect additional improvements in environmental quality.

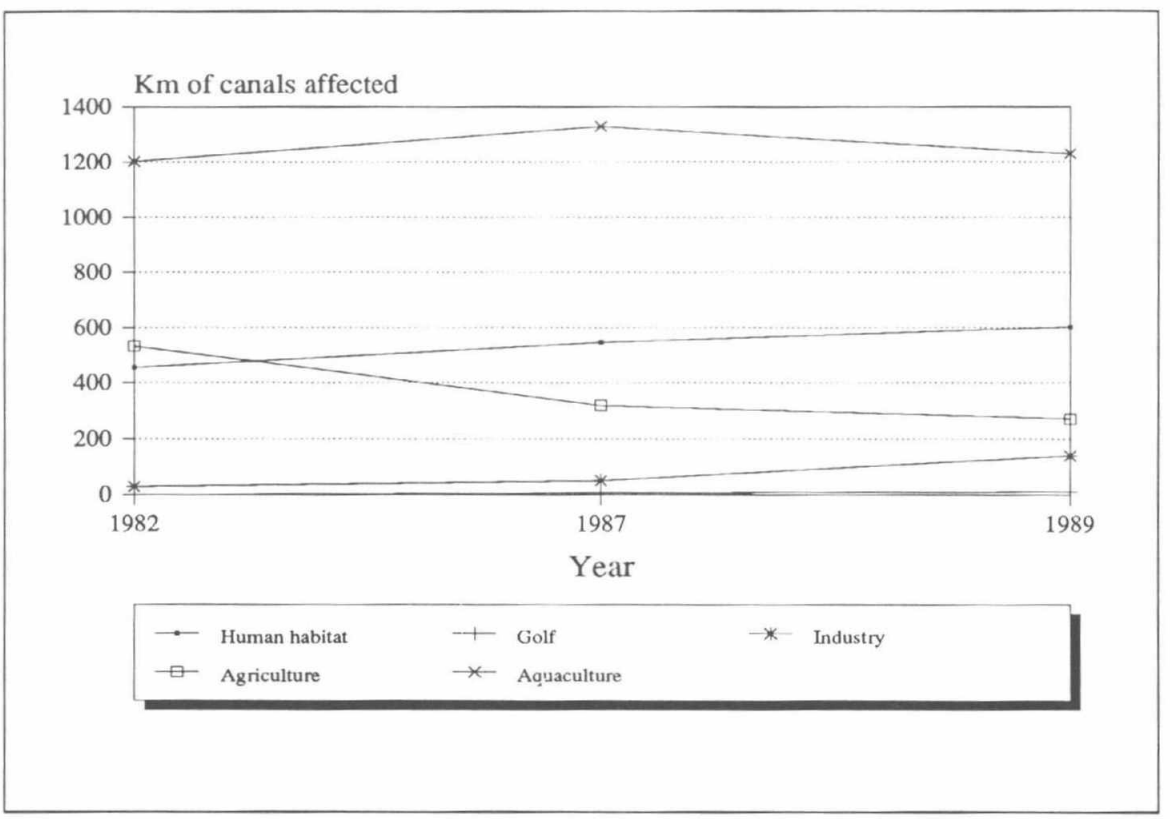


Figure 14: Samut Prakan 1982-1989 Land Use Change Affects on Irrigation

There are two main types of non-point source pollutants: those resulting from disruptions in the natural ecosystems from various human activities; and those resulting from the introduction of what might be termed exotic substances into the ecosystem. The first type of pollution includes sedimentation, water temperature changes, and changes in

dissolved chemical transport. These types of pollution can most easily be seen following drastic changes in land use, for example deforestation. The latter type includes chemicals such as fertilizers and pesticides—agricultural chemicals. The deleterious effects of these chemicals can be seen in the eutrophication of water bodies from unabsorbed fertilizer released from agricultural areas, to the accumulation of toxic substances from pesticides in sediment and in the human food chain.

The style of agriculture in Thailand, forest clearance followed by intensifying agriculture practices, would seem to indicate that there is a non-point source pollution problem looming in the near future. A random geographic sample from 20 provinces of fertilizer and pesticide usage derived from the 1988 version of the NRD2 indicates that almost 50% of the households in rural villages in these provinces make use of some kind of chemical fertilizer, while another 40% use some type of pesticide.

The annual amount of fertilizer and pesticide consumed in Thailand is on the increase, from 785,433 tons in 1978 to 1,548,765 tons in 1987—an increase of some 97%; pesticide usage increased from 9,000 tons in 1979 to 37,500 tons in 1987—an increase of 317%.[18] Yet, this situation has never been seriously addressed in detail in Thailand. As such it is an issue that needs to be raised, its magnitude needs to be determined, and the most critical geographic areas need to be located. Policies and strategies to mitigate or minimize these pollution sources should be developed now, in conjunction with policies to control point sources.

The timing for this issue may now also be correct, in that as Thailand continues to industrialize, and as agricultural land prices continue to spiral upwards, the change to other non-agricultural land uses might now be more easily affected.

The DTCP Plan *vs* 1989 Land Use

Map 28 provides the Department of Town and Country Planning (DTCP) 1990 plan for Samut Prakan province. *Figure 15* summarizes DTCP's view of how Samut Prakan's future land use pattern. This is the first time that DTCP has created a plan for a whole province. Basically, the plan reserves very large areas for agricultural purposes

[18] Office of Agricultural Economics, 1987, *Agricultural Statistics of Thailand Crop Year 1987/1988*, Center for Agricultural Statistics.

(more than 50% of the province), while restricting urban/industrial areas to the western and eastern parts of the province.

It is noteworthy that the main urban/industrial area in the eastern part of the province is located **upstream** of the remaining aquaculture areas along the coast. Because the system of aquaculture in Samut Prakan makes such heavy use of the existing irrigation infrastructure, the waste water flowing out of this urban/industrial area and into the irrigation system, would most likely contaminate the fish and shrimp ponds downstream.

Map 29 shows an overlay analysis of the DTCP plan and 1989 land uses. Let us examine two major categories of land use, urban-industrial and agriculture, to see how the DTCP plan and the existing land use matches.[19]

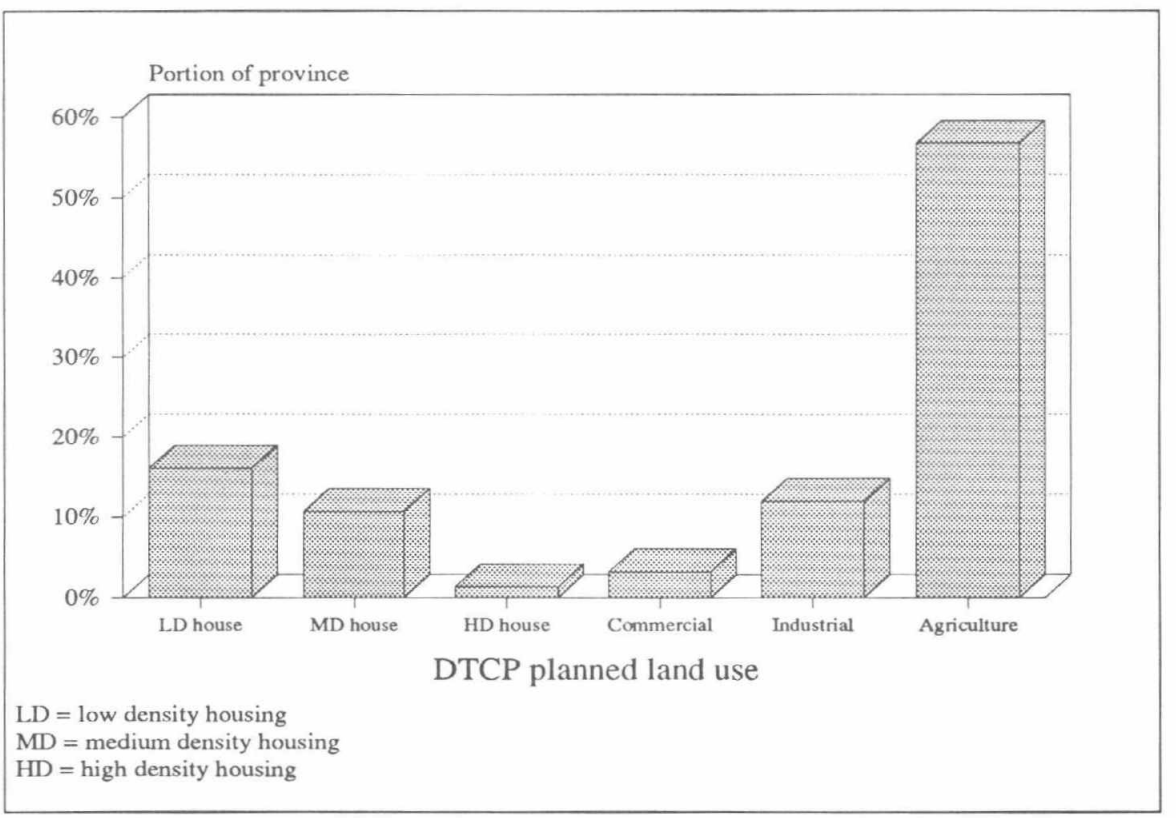


Figure 15: Summary of DTCP Plan for Samut Prakan

[19] Because of vacant land's tendency to change to human habitat area, as shown previously, it was included in the urban category for comparison purposes.

For the most part (74% of the province's area), the DTCP plan matches the prevailing land use. Existing urban-industrial land uses agree with DTCP housing-commercial-industry areas for 24% of the province, while agriculture-aquaculture land uses match the DTCP category of agriculture-rural over about 50% of the province. Some conflicts do, however, exist. Minor conflicts (3%) occur between urban-industrial land uses and DTCP agriculture reserved areas. More serious (18%), is the disagreement between present agriculture-aquaculture areas and DTCP urban-commercial-industrial.

Given the declining trend of agricultural land in Samut Prakan, more conflicts are bound to arise within the DTCP agriculture reserved areas. The fact that most of this so-called *green* area is being used for aquaculture—which is also declining—only makes this outcome more certain.

As a predictive tool, the DTCP plan was generally correct for the majority of land uses in Samut Prakan. *Map 29*, however, indicates that there are some problems in its spatial details. The proportions of the different land uses across Samut Prakan are more or less correct, but the locational details are at times wrong. The application of remote sensing and GIS technology to creating DTCP plans will greatly improve the accuracy of these plans. More importantly, these technologies can help make the plans dynamic. Reaction times can be significantly shortened, allowing for a more rapid creation, review, and revision cycle. Iterative fine-tuning of the plan (similar to the TA-HASD land use model) can be done more easily, thus making land use predictions longer termed and therefore more likely to succeed.

Land Prices

The real estate market is one key to understanding land use changes. Land price will influence how quickly an area becomes urbanized, for once a parcel of land reaches a certain price threshold it almost automatically precludes agriculture—the returns from it are simply too low and the owner is usually better off selling it or changing to a more lucrative land use.

Map 30 is a generalized picture of the RTG assigned land prices for Samut Prakan. This map was derived by interpreting the government land price assessments and location descriptions into GIS functions and processing this into a map. It is common knowledge that these prices underestimate actual market values. In order to test

this, and to assess the magnitude of the underestimation, TDRI undertook a survey of land prices in the eastern part of Samut Prakan. *Map 31* is the result of that survey. *Figure 16* depicts the results of an overlay comparison between the two sets of land prices. From this information it is plain that the RTG assigned valuations do not reflect the real market conditions and are, in fact, several orders of magnitude below them. This has implications for all RTG infrastructure projects that require the acquisition of land. If budgets are prepared based on RTG-assigned land prices, they will fall well short of the actual market values. The results will be stalled infrastructure projects and disgruntled land owners.

Map 32 is an interesting example of a GIS application for real estate. It is a map of slopes derived from the surveyed land prices. Those areas of very steep slopes are prime investment areas, as the price of land increases quickly relative to horizontal distance. Investment *hot spots* can thus be easily located or avoided for government projects (see for example the British Rail incident related in Chapter 3).

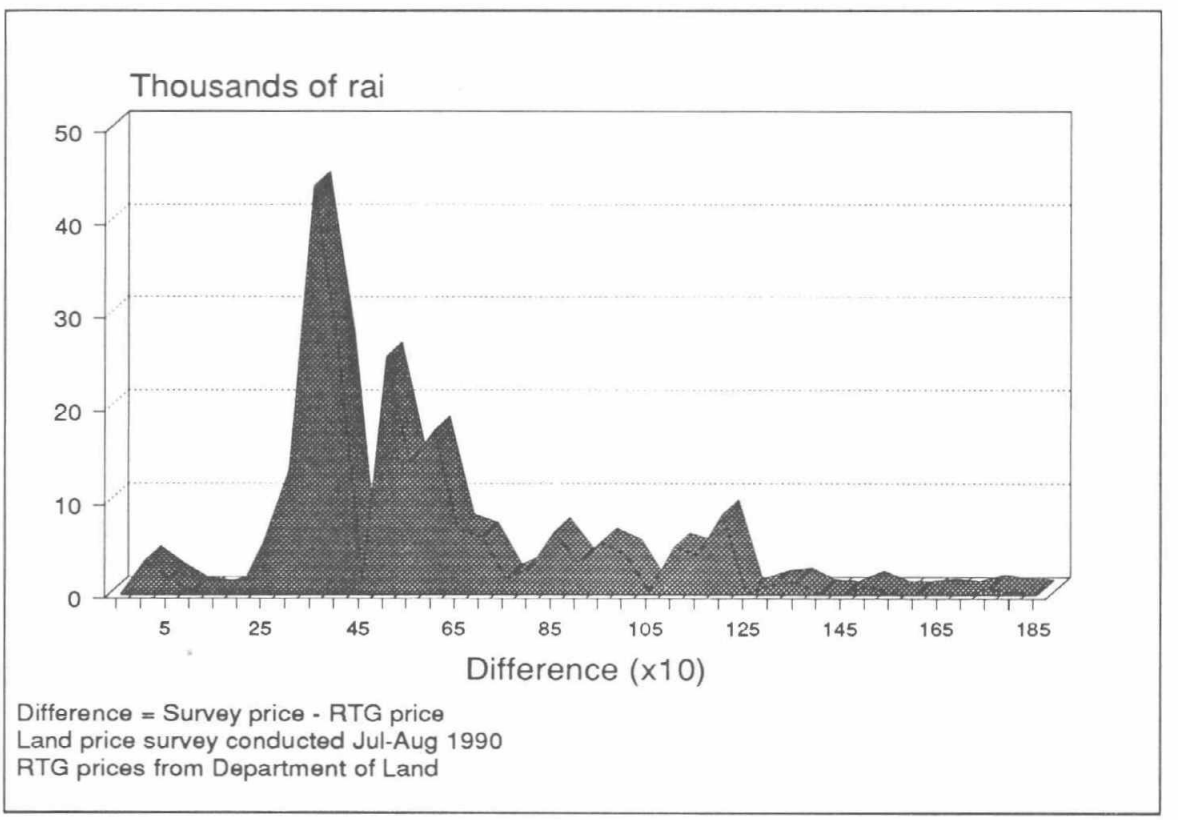


Figure 16: Market Prices versus RTG Assigned Land Prices

Greenbelt Policy

A Greenbelt policy has been suggested as one way of reserving land for agriculture and generally maintaining environmental quality. Besides legislative fiat, land acquisition is one way of implementing this policy. If we assume land purchase as the policy tool, then questions arise concerning *which land* and at *what cost*?

The first question of *which land* might be answered by assuming that we want to preserve **good** agricultural land. The DLD has classified the soils in Samut Prakan for agriculture and the Bangkok series was determined to be the best suited. *Map 33* is an overlay of the soil and 1989 land use maps for Samut Prakan. It shows the general land uses for areas covered by the Bangkok soil series. There is about 90,000 rai of land covered by Bangkok soil that is still being used for agriculture. *Figure 17* summarizes the land uses found on Bangkok soil.

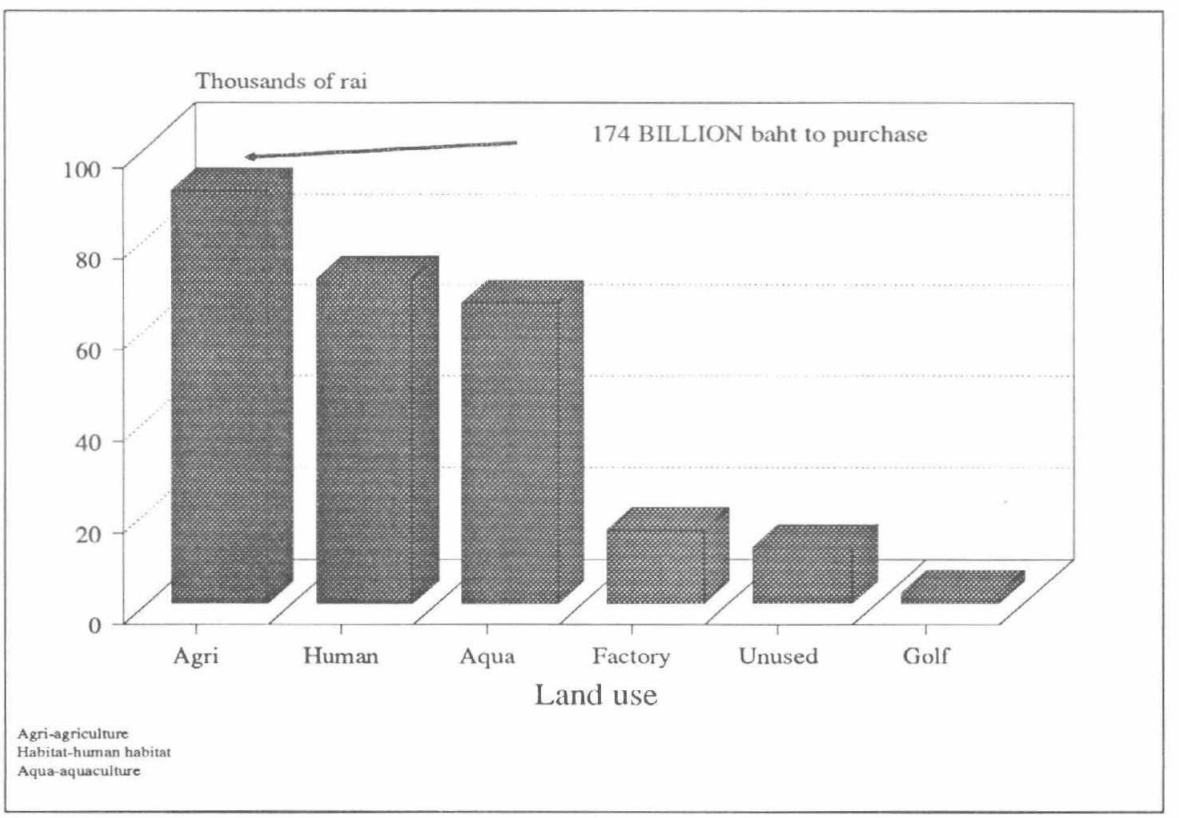


Figure 17: Bangkok Soil and 1989 Land Uses in Samut Prakan

Assuming that the government wants to shelter this 90,000 rai, *what will it cost to acquire*? This question can be quickly answered by intersecting the soil-land use map with the surveyed land price map to determine the prices of the areas having Bangkok soil and agriculture land use. From this overlay analysis it was determined that it would cost about **174 billion baht** (174,000 million) to purchase the 90,000 rai (this estimate was made using the **average** land price over these areas).

What is an Urban Area?

The way one chooses to define *urban* will color all subsequent decisions concerning those areas. As an extreme example, if we choose the presence or absence of utilities (such as electricity) as the prime determinate for urban areas, then almost all of the rural villages in Thailand could be classed as *urban*. It is therefore crucial that a precise and **measurable** definition be determined.

Population and population density are two common variables used to determine urban areas. While the use of population data is rather straight forward, there are subtleties about population density that may not be apparent to those using it. For instance, population density is regularly measured based upon political units, that is the population density for a particular tambon is the tambon's total population divided by the **total area** for that tambon. There is an in-built assumption about land uses being made here. By using the total tambon area, we are making the rather remarkable assumption that people reside **everywhere** within the tambon—in paddy fields, fish ponds, rivers, etc. It is assumed that population density is equal over the whole tambon. A glance at any of the land use maps (*Maps 22-24*) indicates that this is not true. Human residential areas are confined to certain, well-defined locations.

An example may help clarify this point. If a tambon has an area of 10,000 rai and a population of 5,000 people, the population density, as normally calculated, would be 0.5 people per rai. If, however, there are only 1,000 rai of human habitat area in this tambon, the **real** population density would be 5 people per rai—a ten-fold difference from the normally calculated density. Population density, calculated in this manner, would be completely misleading as to the true nature of this area.

A more precise definition of urban must therefore include **land use data**. The Human Resources and Social Development program at TDRI has arrived at a definition

for **urban** areas: areas with a population of 5,000 or more people and a human habitat density of 1,000 people Km^2.[20]

Another type of definition for urban area relies on the government to designate which areas are urbanized. These areas may be designated urban because of existing or predicted future conditions. The RTG has erected two political units to cover urban areas: municipalities and sanitary districts.

Map 34 represents the population from 1988 Registration data, Ministry of Interior, mapped onto 1989 human habitat land use.[21] This was accomplished by intersecting a tambon map obtained from the National Statistics Office with the 1989 land use map and spreading the population attribute data over the selected land uses. *Map 35* shows the urban areas using the above definition. Using this criteria, Samut Prakan's urban population amounts to about 460,000 people or about 62% of the total population. By intersecting the municipality and sanitary district maps for Samut Prakan with the population-land use map, we can assess the officially designated urban areas versus the real urban areas. *Table 4.6* summarizes the results of this analysis.

Table 4.6 Urban Population *versus* Sanitary District and Municipalities

Political Unit	Population Total	Urbanized
Municipality		
Phrapadaeng	23,317	23,317
Samut Prakan	161,130	146,726
Sanitary		
Samut Prakan	171,785	143,605
Totals	**356,232**	**313,648**

Note: Figures in persons.

[20] Teera Ashakul, personal communications, 1990, Human Resources and Social Development Program, TDRI.

[21] Because of migration, registration data is only an indication of the population minimum. Many people living and working in urban areas have their household registrations in another province.

About 48% of the total population lives within a sanitary district or municipal area. Of the urban population, some 68% live within these **official** urban areas. Therefore about 32% of Samut Prakan's urban population is not included in official urban plans. While this is somewhat surprising, *Table 4.7* shows that the RTG has erred on 79% of the urban **area**.

Table 4.7 Urban Areas in Samut Prakan

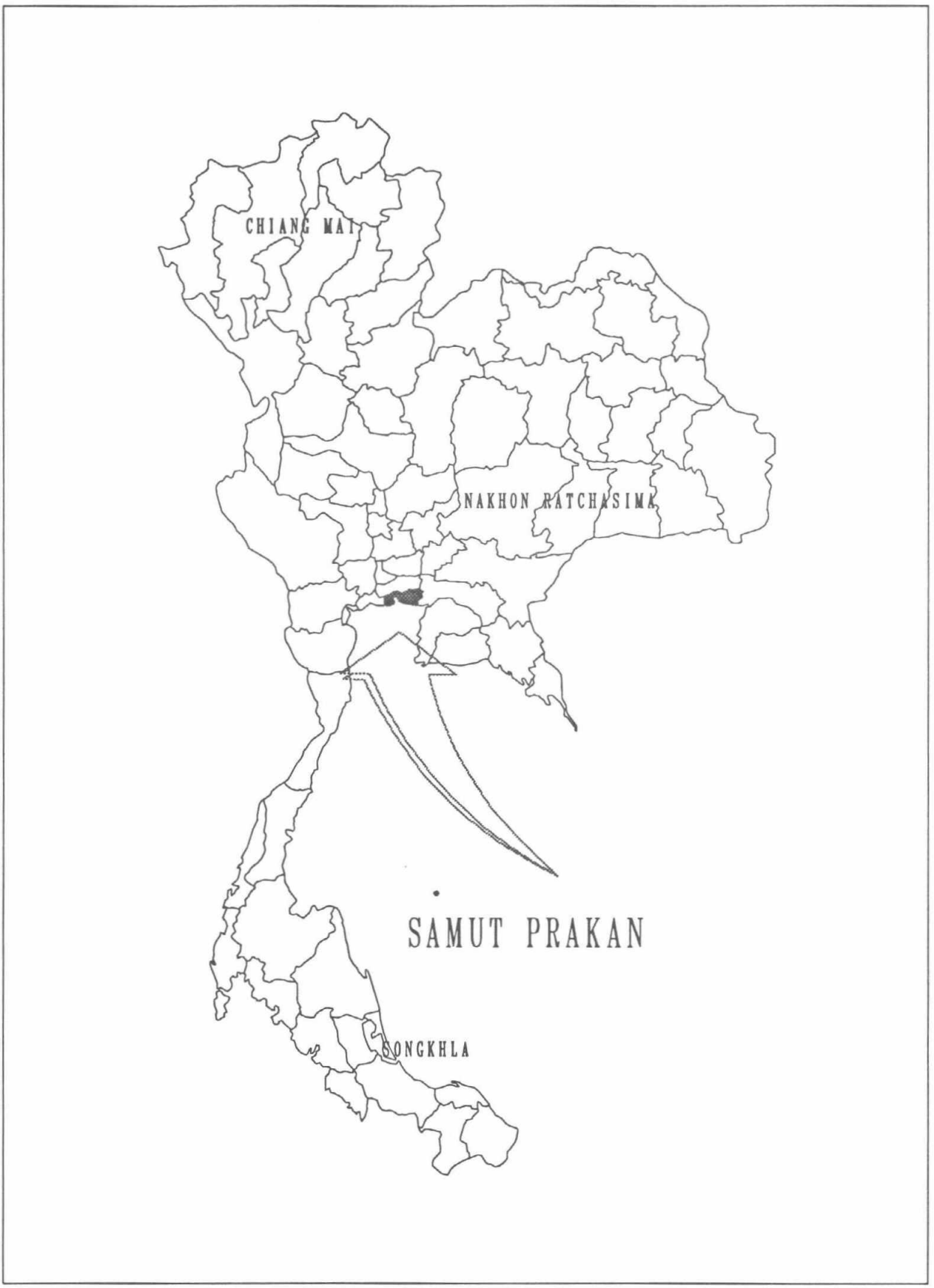
Urban Areas	Size	Percent
Sanitary	6,533	14
Municipal	3,404	7
Outside	37,300	79
Total	**47,237**	

Note: Size in rai. Percent refers to the portion of total urban areas for the province.

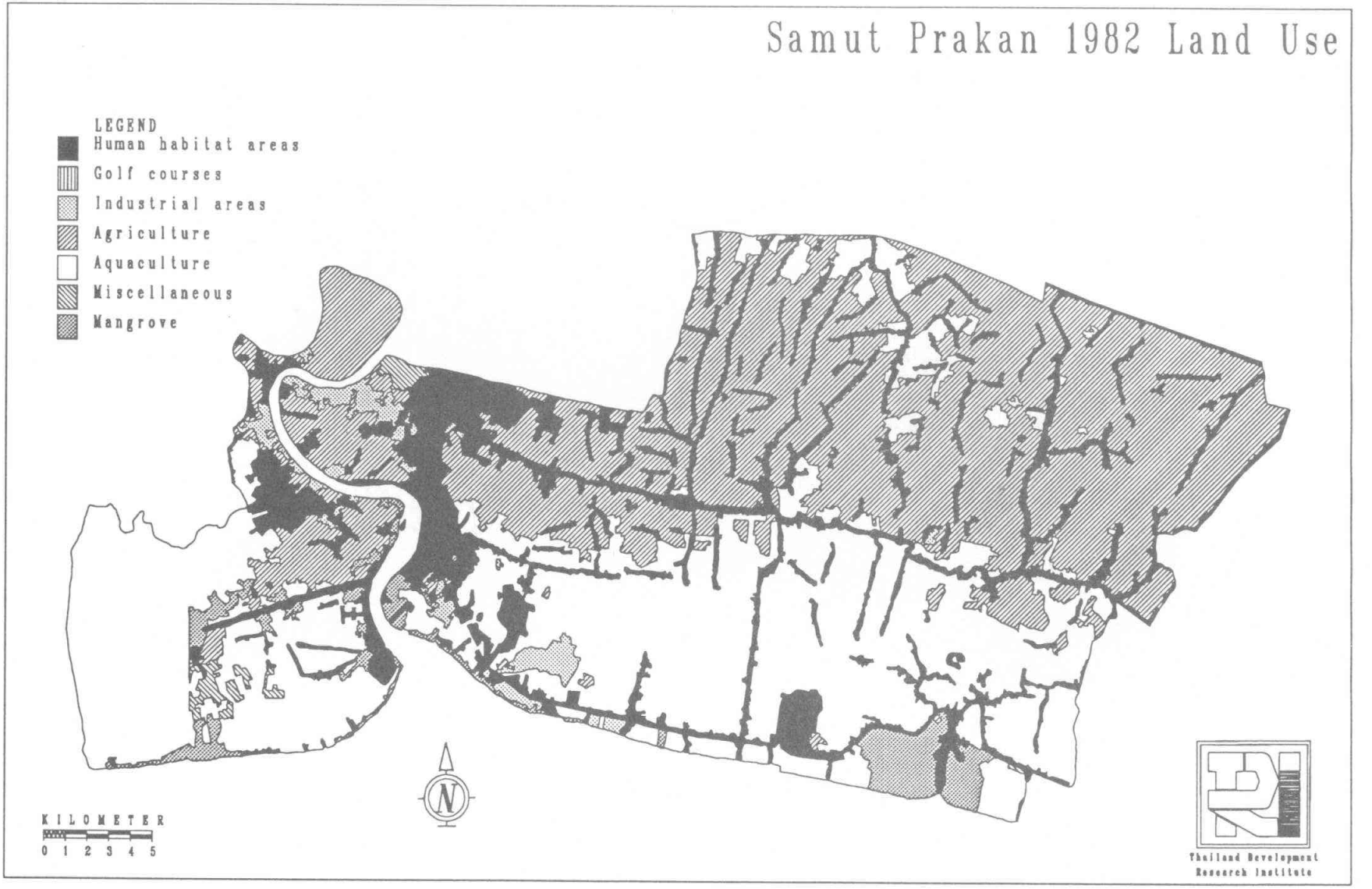
This is especially unfortunate because these substantial areas will receive little or no attention from urban planners. Urban facilities and services (garbage collection, building and traffic controls, etc.) will therefore most likely **not** be allocated to these quite sizable areas.

Conclusion

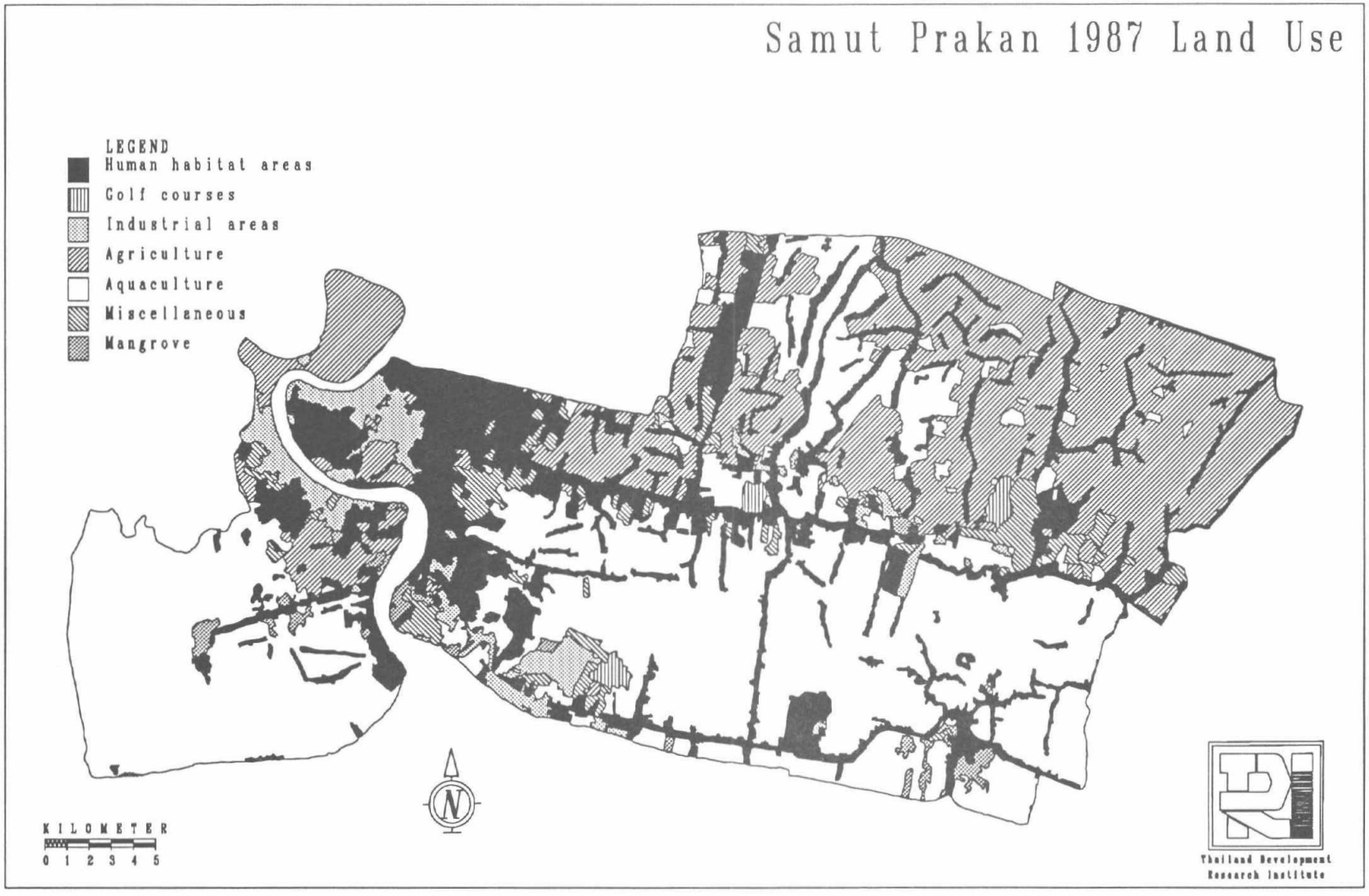
The preceding has shown that issues dealing with urbanization are amenable to GIS analysis. The application of GIS to this field will give planners new insights into the way urbanization occurs as well as highlight previously unknown facets of the problem. Policy and the instruments used to implement it can be readily modelled using a GIS. Thus, policy makers can now be given an opportunity to test and re-test a policy directive **before** announcing what may very well be an unrealistic policy. More precise and measurable definitions of physical and social conditions, such as urban areas, can be arrived at using GIS technology. Analyses using these definitions will be more precise as a result.



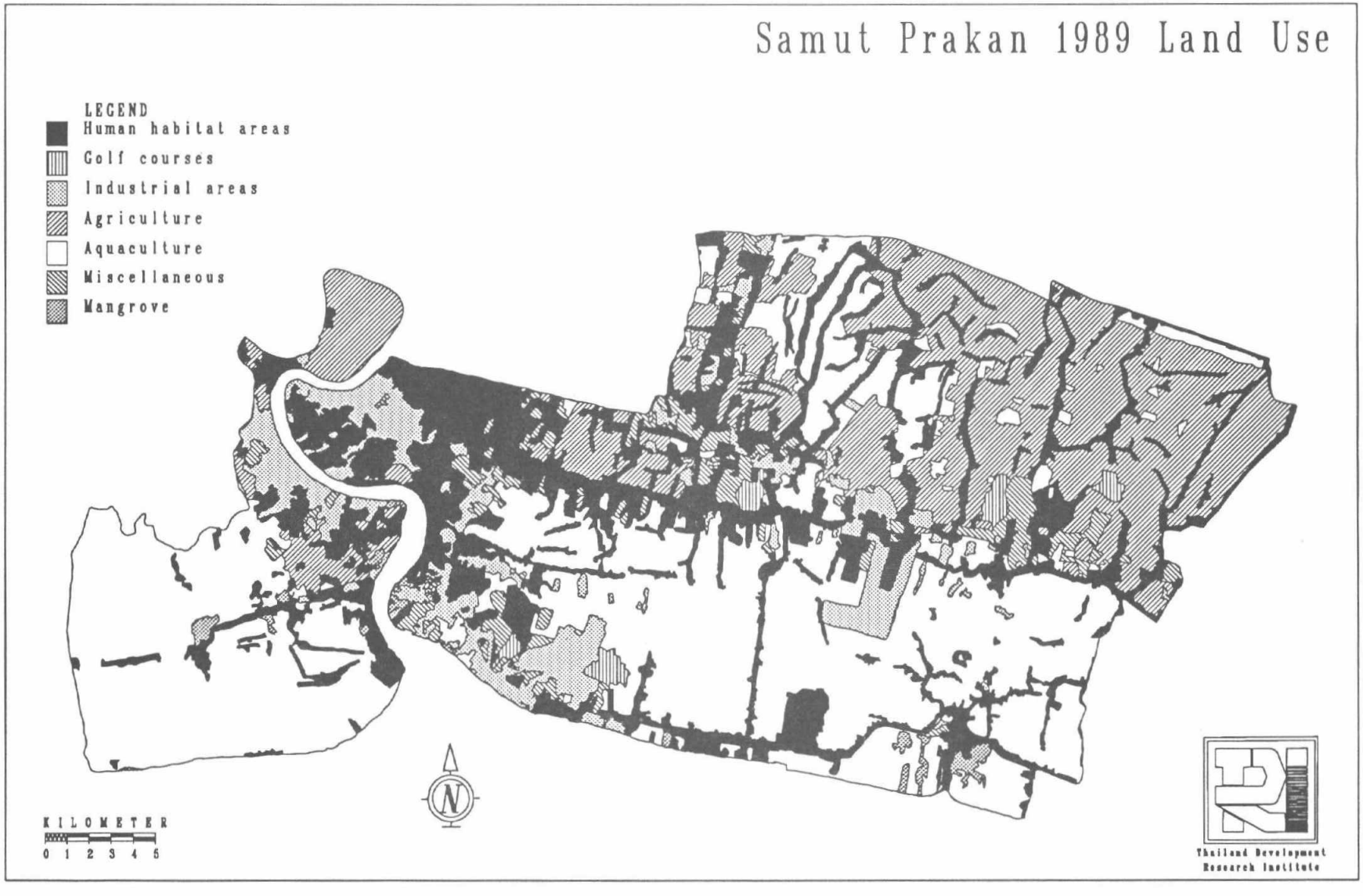
Map 21: General Location of Samut Prakan Province



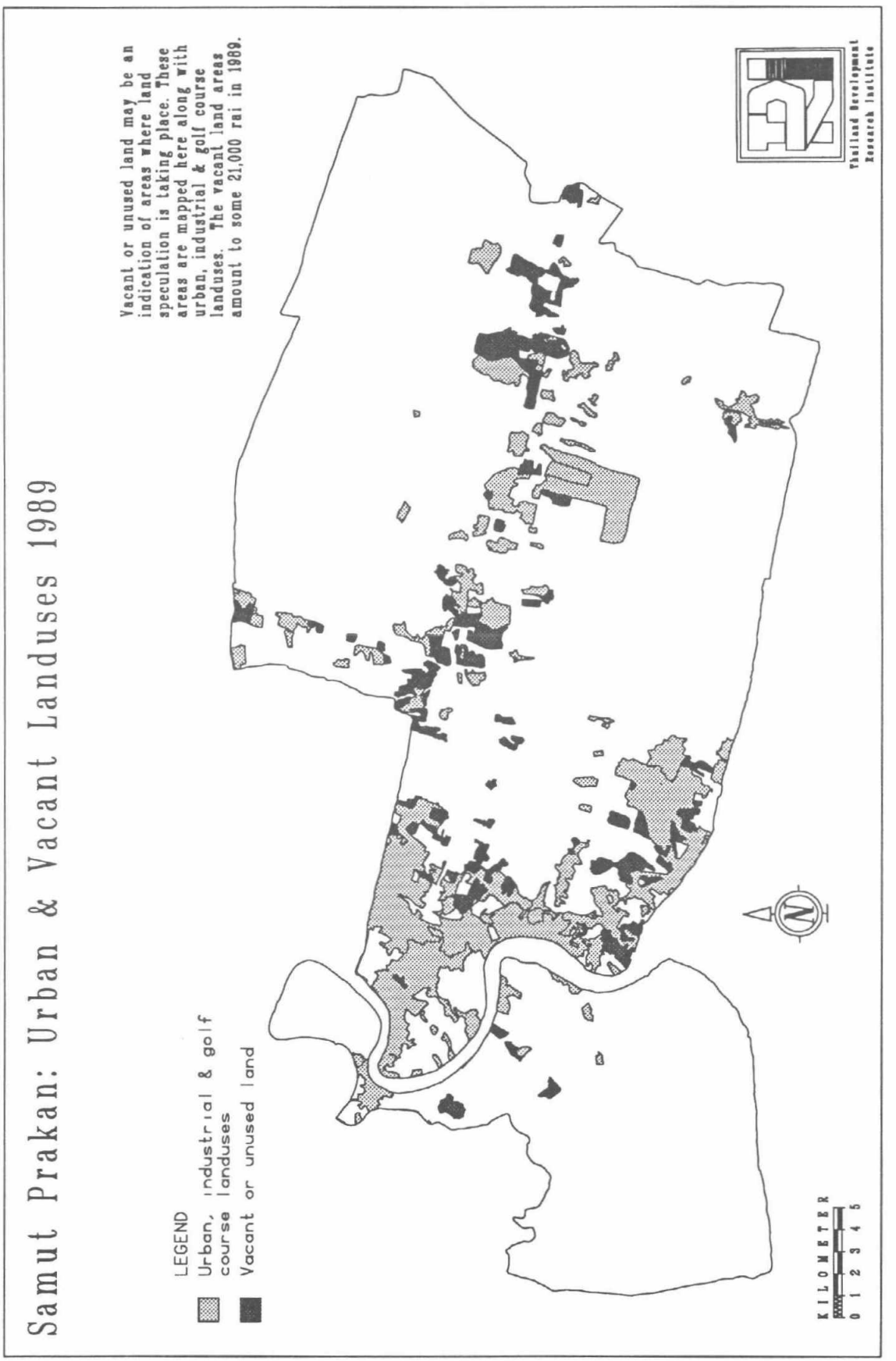
Map 22: 1982 Samut Prakan Land Use



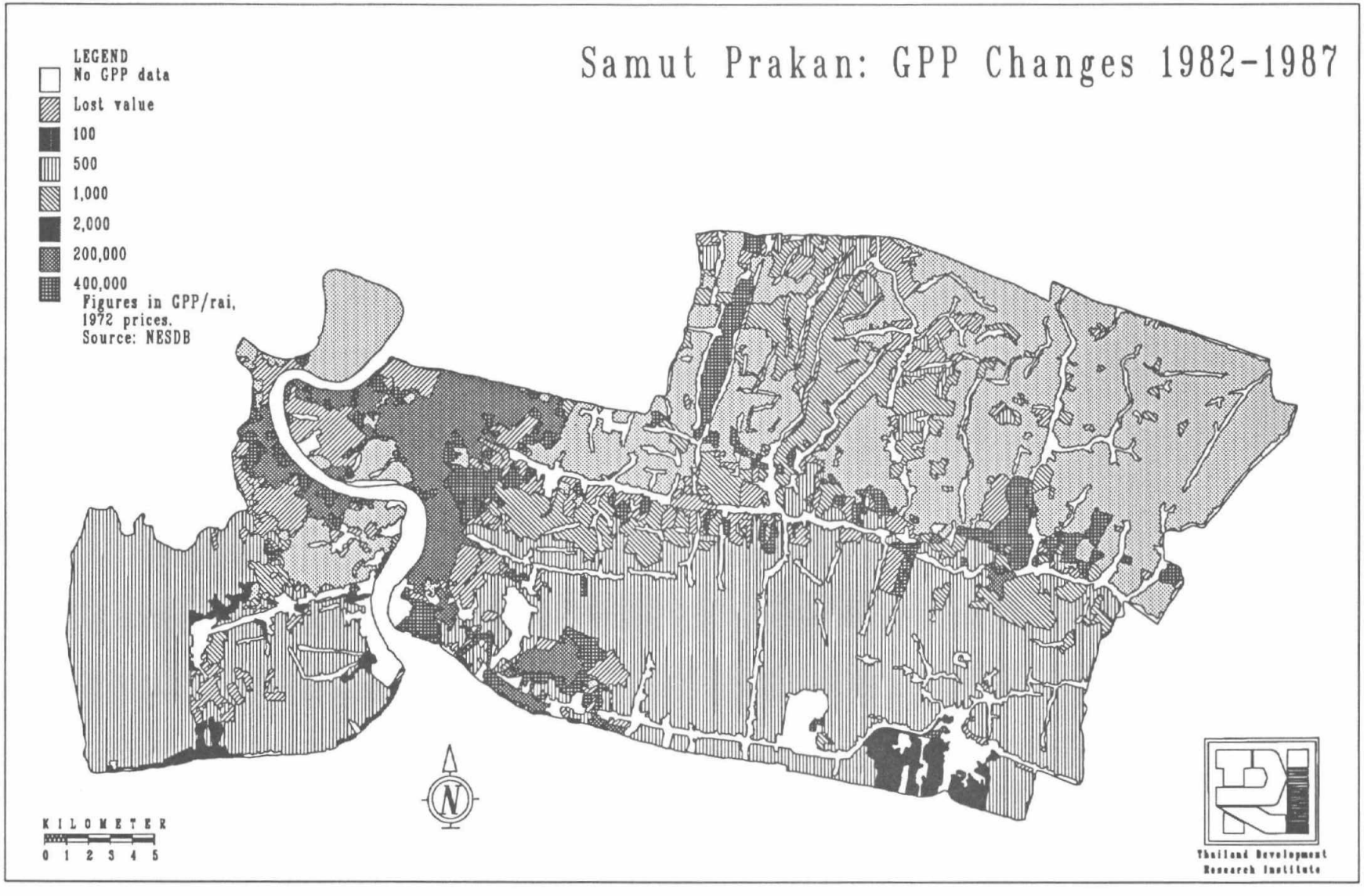
Map 23: 1987 Samut Prakan Land Use



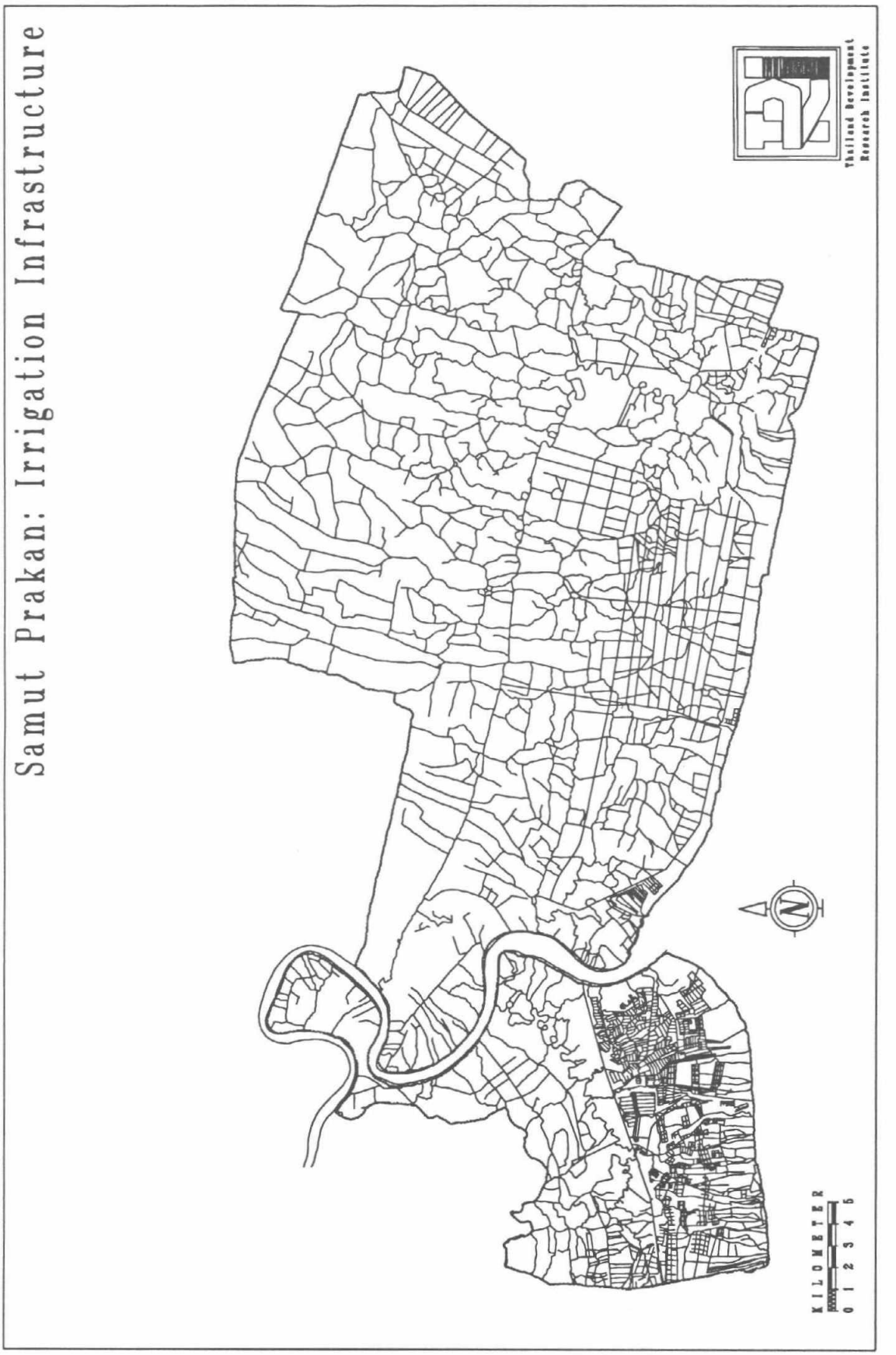
Map 24: 1989 Samut Prakan Land Use



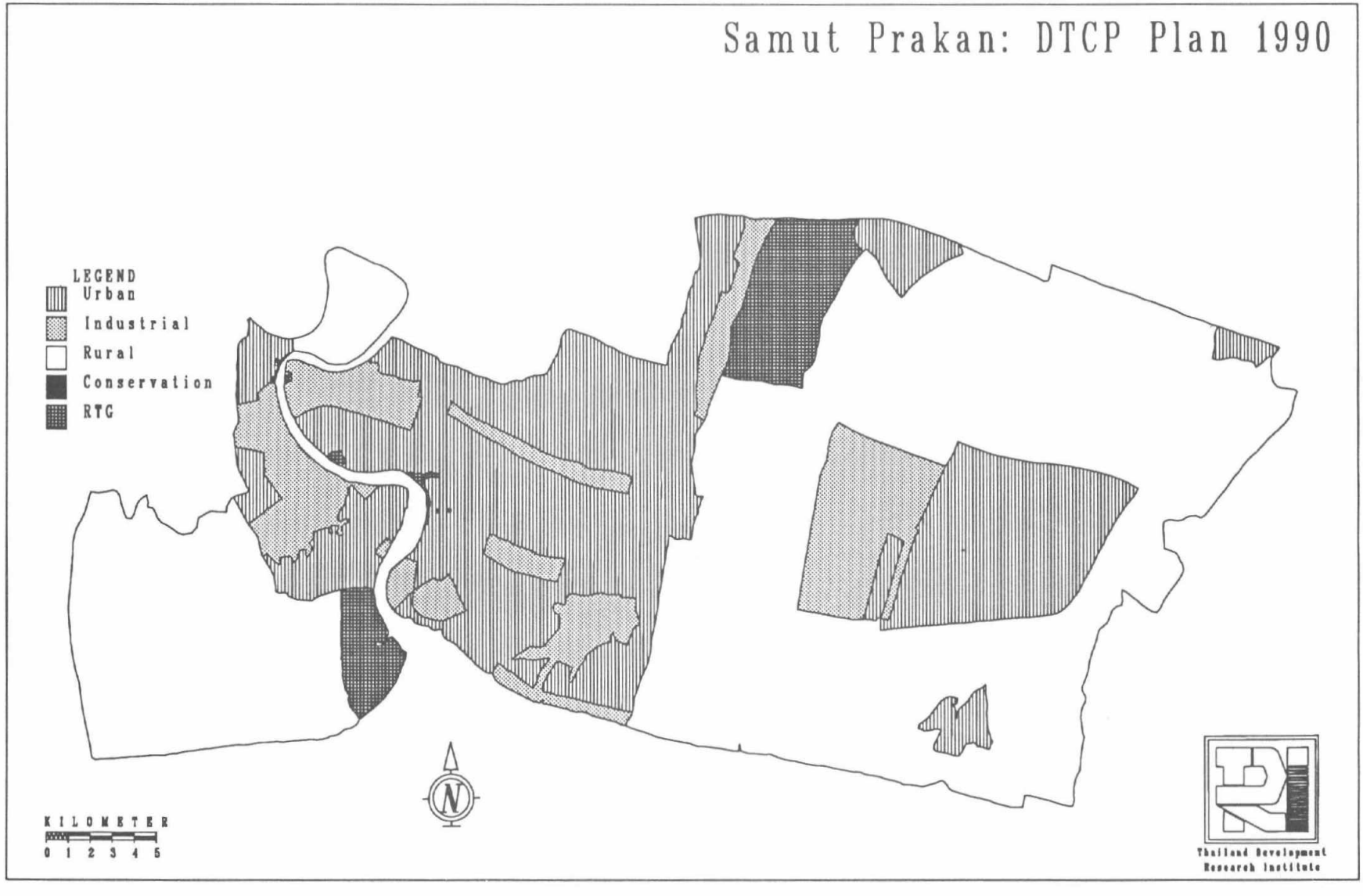
Map 25: Samut Prakan Vacant Land 1989



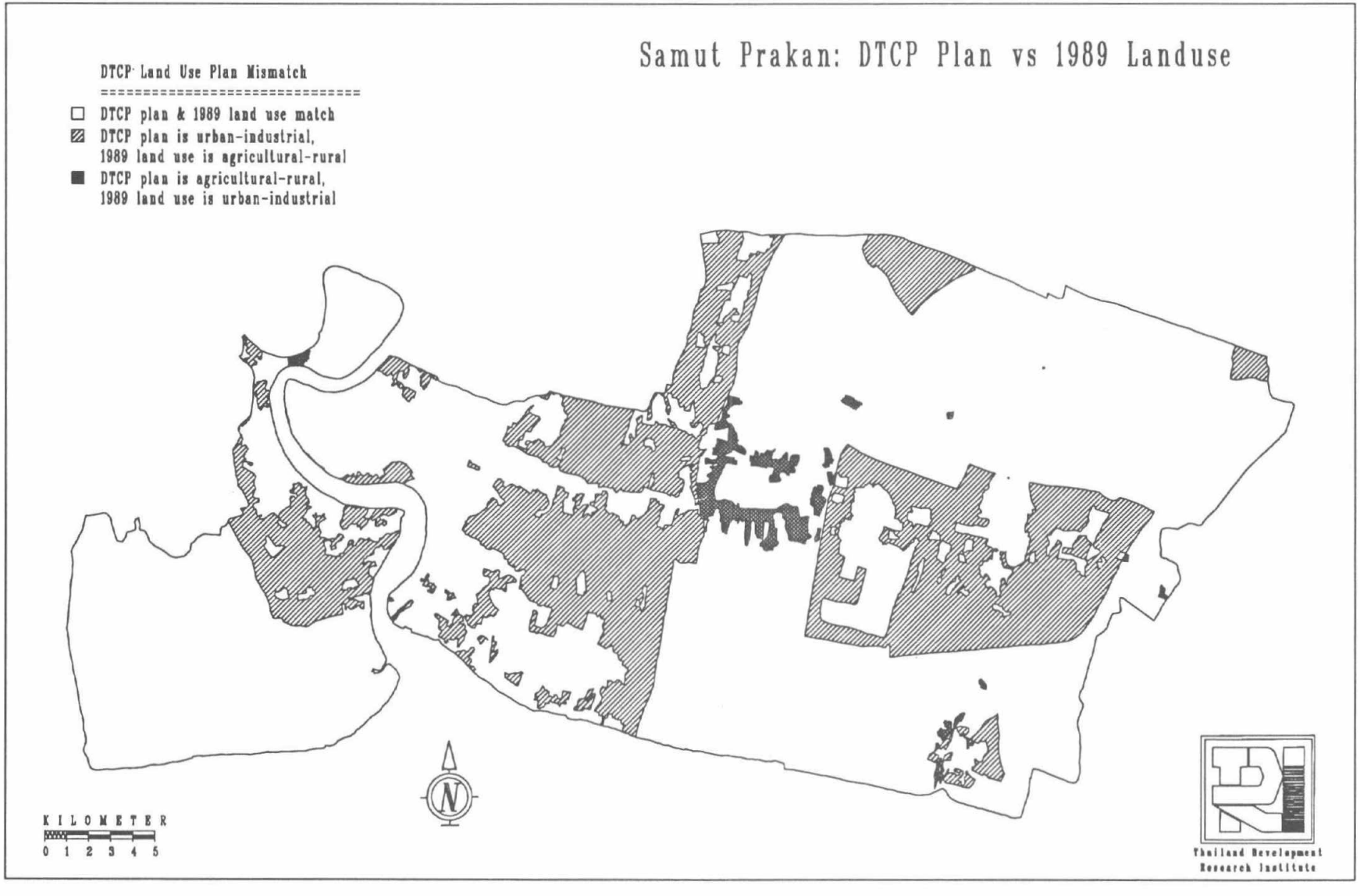
Map 26: Samut Prakan GPP Difference 1982-1987



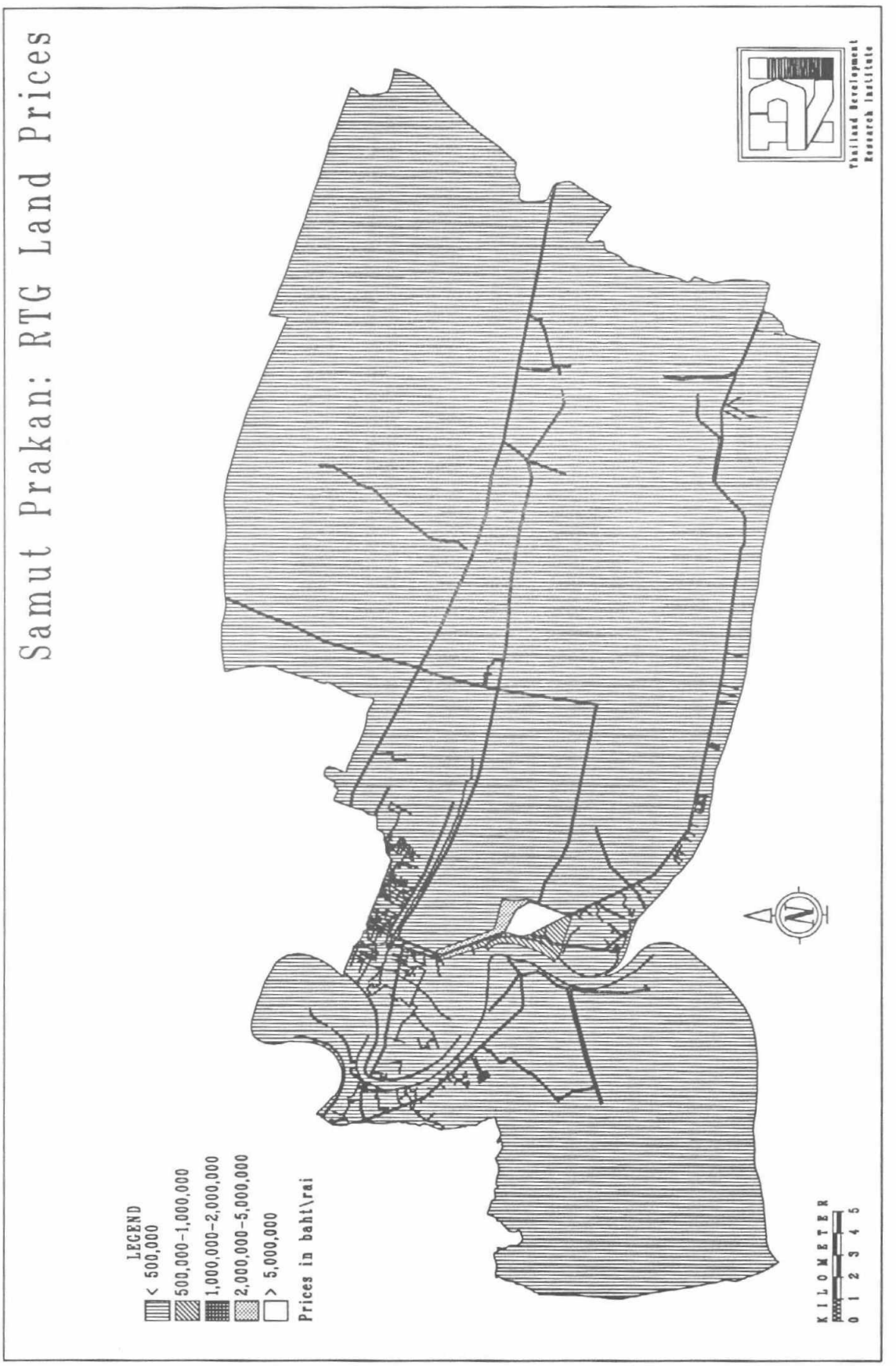
Map 27: Samut Prakan Irrigation Infrastructure



Map 28: Samut Prakan 1990 DTCP Plan

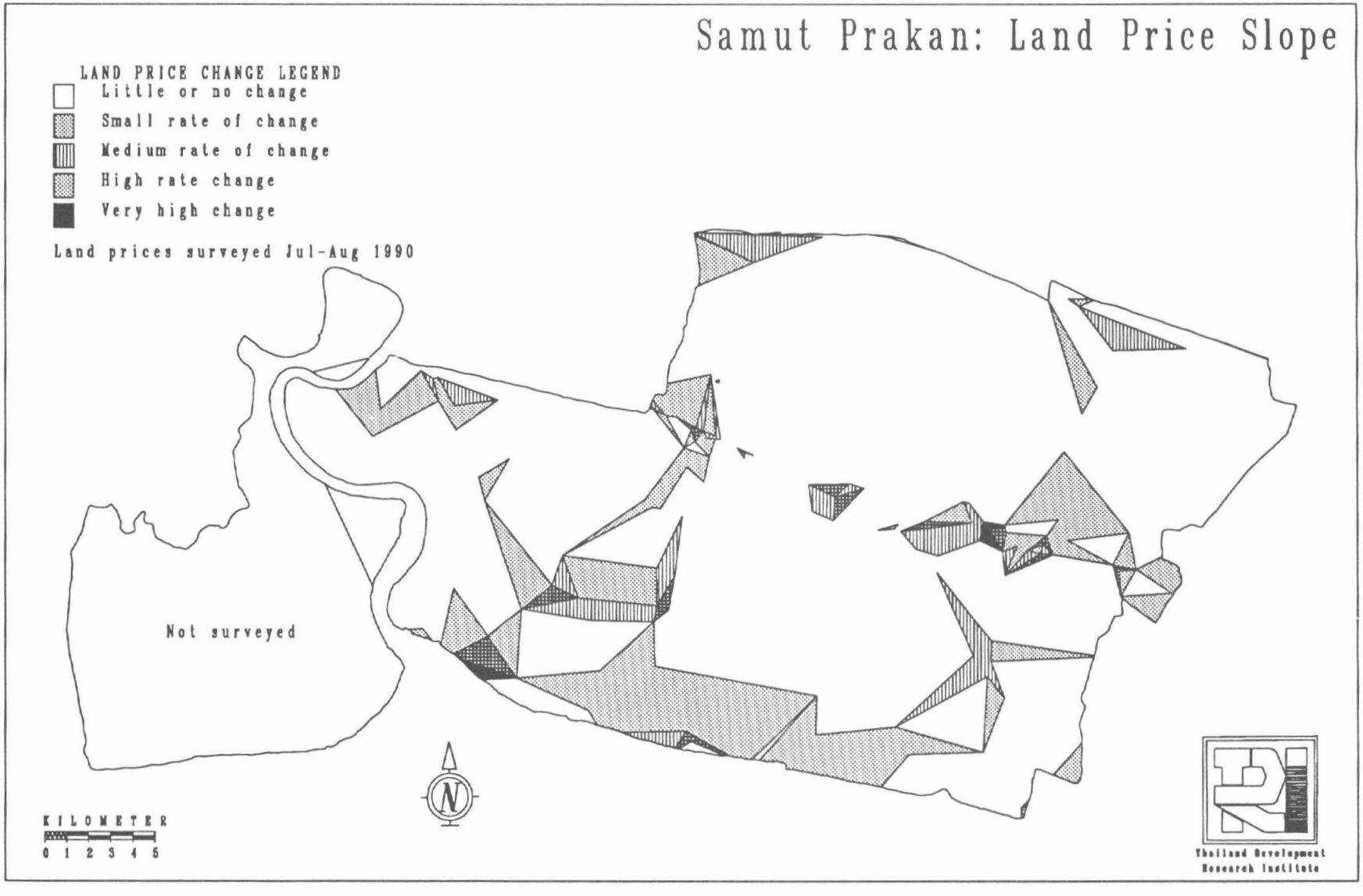


Map 29: 1989 Land Use versus DTCP Plan

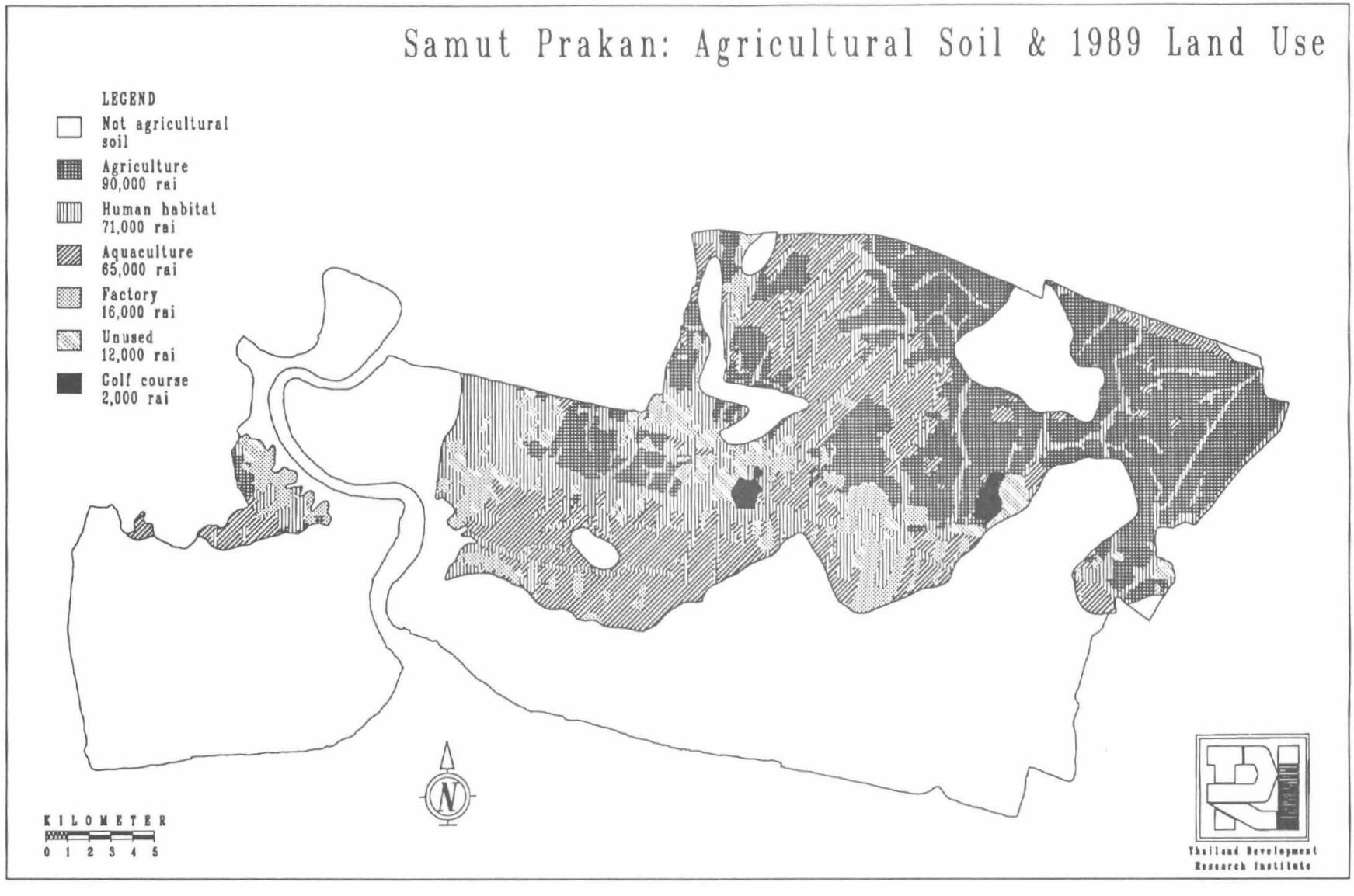


Map 30: Samut Prakan RTG Land Prices

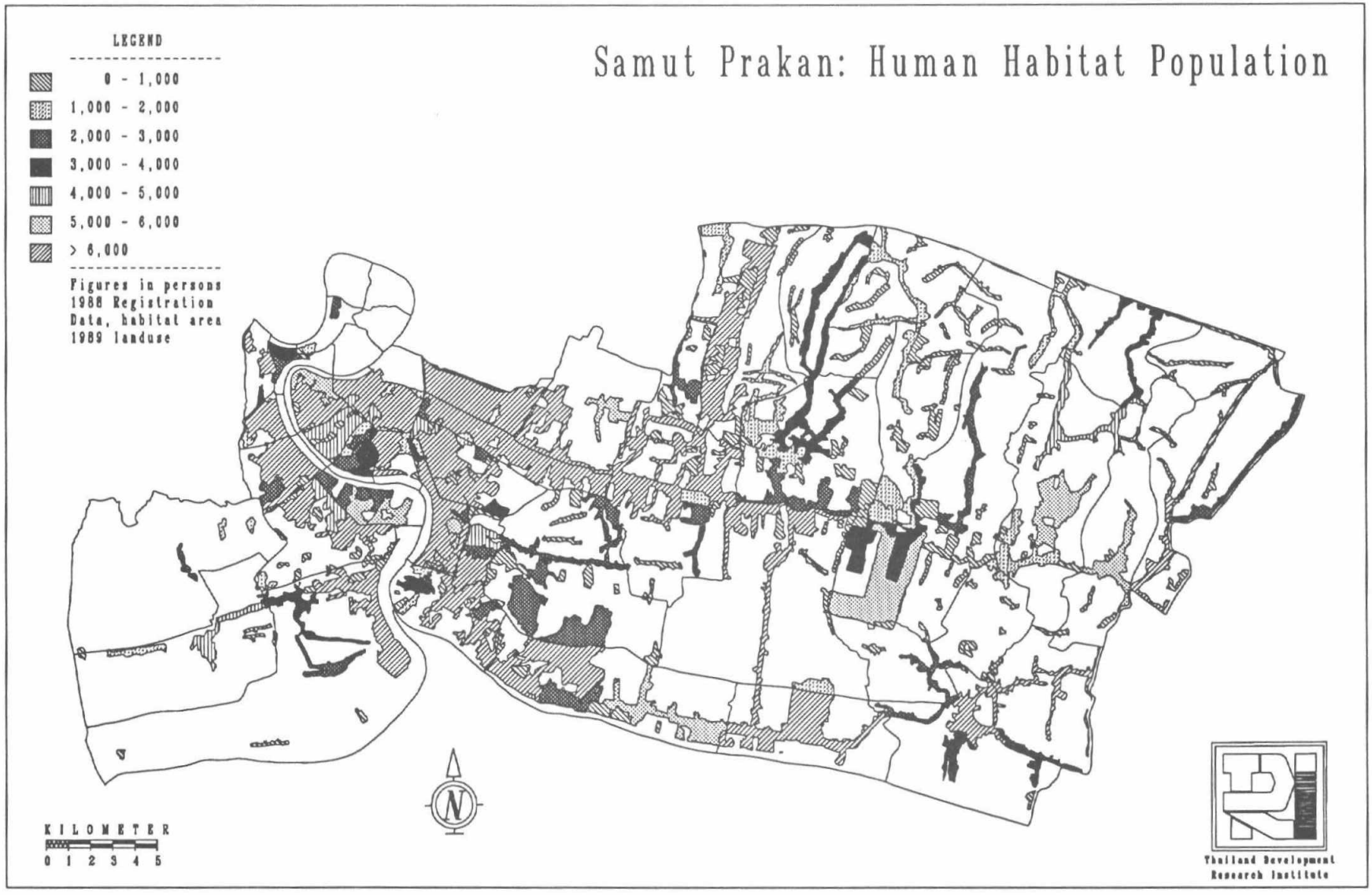
Map 31: 1990 Surveyed Land Prices



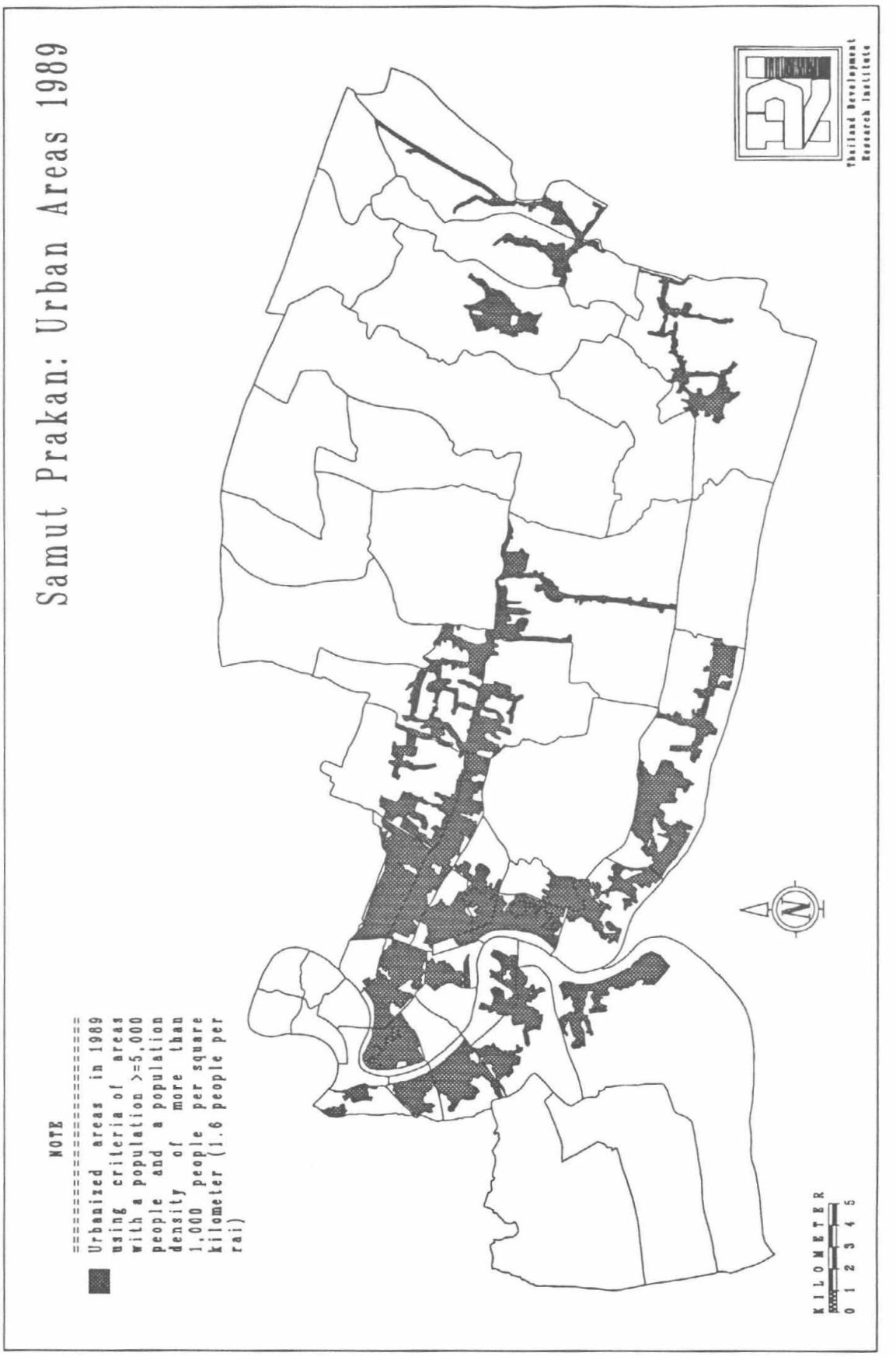
Map 32: Land Price Slope



Map 33: Agricultural Soil vs 1989 Land Use



Map 34: Samut Prakan 1988 Population



Map 35: Samut Prakan Urban Areas

Chapter 5
Conclusion

The ability to collect and analyze geographic information is becoming of paramount importance to the well-being of human societies. A society's ability to manage its resource base is becoming more and more dependent on its proficiency in managing its information.

Today's environmental and natural resource issues are multi-dimensional, they can no longer be investigated within the limited context of one field. A multi-disciplinary approach is now required if we are to solve the problems now facing us. Much of the important natural resources and environmental information is spatial data. Geographic Information Systems are a powerful technology capable of helping to analyze the complex relationships existing among natural resource and environmental systems using data and expertise from a variety of sources. It is a technology capable of integration at a level never before attainable.

This paper has provided a short primer as a way of introducing GIS technology and some of the more important issues pertaining to its use. From the previous discussions, technical issues are not seen as limiting the spread of this important new technology. Institutional issues do, however, pose some serious problems and need to be carefully considered. The major issues involving GIS are:

- **organizational changes** occurring as a result of implementing a GIS. A GIS does not operate in a vacuum, it must reside in the proper institutional setting to thrive. The institutional environment must carefully considered before trying to implement the GIS.
- **responsibility issues** relating to the use and release of spatial information including the content of spatial information, its context, its data format and problems resulting from the combination of data sets within a GIS. Thai society holds several professions legally responsible for the information it provides, medical doctors for example. Should this accountability be applied to GIS centers as well? Can users of spatial information expect the same high level of confidence from GIS centers as do from surgeons?

- **GIS errors** resulting from the collection, input storage, manipulation and output of spatial information. End-users of GIS supplied information or analyses may not have the technical background to understand all the subtleties of this issue. Serious consequences will eventually result from this lack of understanding, especially if left in the dark by GIS technologists.

The heart and soul of a GIS is its **database**. Without a comprehensive spatial database, a GIS is useless. A GIS's principal assets is its database. Lord Chorley has pointed out that GIS is about spatial data analysis and adding value to spatial information. It is not about making maps. This fact is not very well understood yet by many of the users and potential users of GIS in Thailand.

The integration of physical and socioeconomic data is becoming more important as our world becomes more crowded and our resources become ever scarcer. GIS technology can act as an excellent integrator of seemingly unrelated data sets, due to the fact that most socioeconomic and physical data are united in space, they are geographic information.

It has been pointed out that remote sensing is an extremely valuable adjunct to GIS. Remote sensing is capable of providing up-to-date information as input into a GIS database. The use of remote sensing must, however, be placed in the proper context. It cannot be applied to every situation, every time. Global Positioning Systems are another type of satellite-based spatial data gathering technology that is rapidly gaining wide usage. It can provide automatic and highly accurate, locational data almost any place on the face of the earth. Its application in Thailand can aid in the demarcation of forest boundaries, national parks, cadastral surveying, infrastructure updating, search and rescue operations, etc.

At present, there are almost 25 organizations applying GIS in Thailand, where only three years ago there were none. GIS is a rapidly growing technology, that is gaining wide acceptance in Thailand. There are four GIS issues of importance in the Thai context:

- **remote sensing and its links to GIS**, efforts must be made to place more image analysis equipment in the hands of the RTG line agencies. Remote sensing must be placed in the proper institutional setting, given adequate support, and above assigned a clear and attainable goal.
- **responsibility issues**, it is suggested that each GIS agency have a *GIS Information Officer* to oversee the political, technical, legal, and economic aspects of using GIS generated data or analyses.

- **institutional issues**, including staffing, education and the political implications of a GIS. These are seen as frustrating the development of spatial databases. To date, there are very few extensive GIS databases built in Thailand. As data is so important to a successful GIS, it is suggested that private agencies be contracted to create spatial databases for RTG line agencies.
- **freedom of information**, perhaps the most crucial of all GIS issues in Thailand. GIS is most advanced in the United States, where freedom of information laws guarantee public access to government collected information. The free flow of information is extremely important to the future development of GIS in Thailand.

These issues if left un-addressed will almost certainly create problems in the long term for users of GIS technology in Thailand.

Appendix 1

TDRI's GIS Projects

The following is a list of the GIS project's undertaken by TDRI.

- TDRI with the financial support from Asian Development Bank (ADB) and DLD conducted the **Seminar on Land Use Planning**. The consensus was that the value of GIS must be tested in Thailand through the conduct of pilot studies.
- TDRI, commissioned by Prince of Songkla University, conducted a study on the application of GIS for the Songkhla Lake Basin. Pilot studies on the application of GIS for agricultural land use planning and for rubber replantation were undertaken. A survey on the needs of potential users of GIS in 27 governmental agencies was also conducted. The findings confirm the potential of using GIS as a tool for natural resources management.
- Land Use Planning in Chiang Mai Province, for DLD (14 million rai).
- Siting Intensive Shrimp Aquaculture Areas in Songkhla Province, for the Governor's Office, (7 million rai).
- Siting Suitable Land for Fast-growing Tree Plantations in Eastern Provinces, internal project of TDRI (5.5 million rai).
- Land Reform Project Identification in Chantaburi, Agricultural Land Reform Office, (6 million rai).
- Siting Hazardous Waste Disposal Sites in Ratchaburi, Industrial Works Department (3.5 million rai).
- A contract study was undertaken under from a multinational food processing company, to identify potential sites for large-scale agricultural plantations within a radius of 200 kms of the existing and planned ports in Bangkok and the Eastern Seaboard. This study has verified the potential of GIS as a self-sustainable unit at TDRI to serve both the government and the private sector (27 million rai).
- Land use changes in Phu Wiang watershed 1954-1988 in cooperation with FAO (180,000 rai).
- TDRI organized the First National Seminar on GIS with more than 200 participants, in November 1989. This seminar had served as the forum for interested users of GIS to learn from each other's experience, and also to foster a consensus on national policy on GIS. As a result, a network of GIS users is taking shape.
- Thai-Austraila Highland Agricultural and Social Development contracted TDRI to create a Management Information System for its project areas (2 million rai).
- Assist TDRI urban working group in Seventh National Plan project.