Population and land use changes in the central highland Province of Dak Lak, Vietnam

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Abstract

The Province of Dak Lak in Vietnam has experienced a massive coffee plantation during the last ten years, but severe deforestation, accelerated soil erosion and reduction in soil fertility are widespread. Poor water resources management and low yields are some of the problems the new farmers face. In order to create a map basis for a land resource database, an important prerequisite for land use planning, a classification of the land use changes in the period 1979-1989 and 1994 was conducted using air photos and satellite images. Finally the land use change was analysed using a geographical information system. Though several map errors were created during the classification process, the produced maps create a basis for the development of a land use planning system that will be further developed in the years to come.

Keywords

Vietnam, land use, population changes, deforestation, GIS.

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The Province of Dak Lak in the central highlands of Vietnam has during the past two decades experienced major land use changes. Large numbers of legal and illegal settlers from the densely populated northern part of Vietnam emigrate to the Dak Lak province. This is primarily due to land shortage in the North in combination with the relatively easy access to land in the Dak Lak Province. Furthermore, the region is well suited for perennial cash crops such as coffee and rubber. The large immigration combined with incipient environmental devastation has created a rising demand for development of a rural land use policy. A first step in the policy formulation was to generate a land use inventory based on modern information technology. The article deals with the initial phase of this policy formulation, it describes a procedure where older maps, aerial photos and satellite images are used to create a recent and retrospective mapbasis that is used for analysis of land use changes in a desk top geographical information system.

The background for the land use changes in Dak Lak is related to demographic changes especially in the large agricultural region of North Vietnam. Traditionally production of rice has been, and still is, the major farming system in Vietnam. For centuries it has made up most of the agricultural production in Vietnam and the country has, despite its fast-growing population, been able to maintain a high degree of self-sufficiency. The two major rice production areas in Vietnam are the Mekong delta in the South and the Red River delta in the North. The southern area is the largest and it comprises 40,000 Km². Approximately 25% of the area is cultivated with rice, making the Mekong delta one of the most important regions for rice in the world. The Red River delta consists of the area surrounding three river the Red River (Song Koi) the White River (Son Kai) and the Black River (Song Bo). The delta is smaller than that of the Mekong. Nevertheless, it covers more than 3,000 km². and comprises 70% of the agricultural area in North Vietnam. Wetland rice covers more than 94% of the total area used for rice while dryland rice covers the rest. The annual rice production is 20 million tons of which three million tons are exported. Both deltas are densely populated with a density of 1400 inhabitants per km² against the Vietnamese average at 234 per km², and most of the 77 mio. people of Vietnam (1997) live in these areas.

In his work "Landbrug i Tonkin deltaet, Vietnam" Sofus

Christiansen (Christiansen, 1977) analysed the agricultural production and economy in the Tonkin delta (Red River delta). And it is stated that the production of rice more than other agricultural productions builds upon the hard work of former generations. It is stressed by Christiansen that the demand for agricultural land, as a result of the population growth, has created major constraints on land-tenure in the Red river delta. This demand has resulted in high land prices and the new farmer's freedom of action is limited. Instead of producing on their own land, land is leased if possible, or farmers are employed as day-laybourers. Despite the expanding rice production, a large number of small farmers, and especial day-laybourers in the Red River delta, are influenced by these constraints, and the number of people living in poverty is increasing.

The 1997 per capita income in Vietnam was US$ 380 and the primary agricultural production, of which rice is predominant, constitutes about 50% of the GNP. In order to strengthen the economy, the Vietnamese government has pushed on towards a less specialized agricultural production. Coffee and especially rubber plantations have been known since 1930 in the Dak Lak Province (Figure 1). These plantations belonged to large, private estates that were nationalized after the division of the country in 1954. New areas suited for these perennial crops were pointed out in Dak Lak, and the state established several new economic zones. Following up on this initiative the government has encouraged farmers to emigrate from the densely populated regions in the North to the sparsely populated Dak Lak Province. The large rubber and coffee state farms in Dak Lak were soon to be followed by smaller private farms. A development that has resulted in an expanding coffee and rubber production during the last 30 years in Vietnam. The development has been especially fast since the '80s. At national level the coffee production had increased to 400,000 tons in 1997 of which 200,000 were exported. The rubber latex production was 30,000 tons of which 11,000 tons were exported.

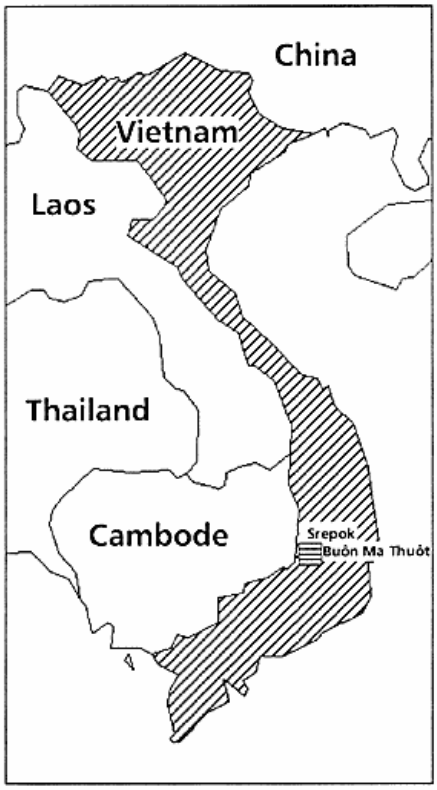

Figure 1: The Srepok basin in Dak Lak.

The Dak Lak Province

The Dak Lak Province is situated in the highlands of the central part of Vietnam. It is one of the largest and most remote provinces in the country and comprises 194 communes. It is situated in the centre of the South Central Highlands. The total area is 19,800 km² and the topography generally consists of undulating hills. More elevated areas exist in the central and northen part of the region where hills rise to 600-800 m. Elevations in the southern and eastern part decrease to 400-500 m and to 250-350 m in the west. In the southwestern part of the province, the Truong Song Mountains have peeks of 2,450 m. A large basalt plateau of 700,000 ha divides the area into three major regions. The area North West of the basalt plateau is dominated by basement shale at 200-350 m. While a small alluvium zone along the Kron Ana river is situated between the basalt and large mountain and granite area towards the East and South.

Weathering of the basalt has created a clay loam that is highly fertile being red-brown where well drained, and black in poorly drained areas. In general, the area is well drained and provides good conditions for cultivation of coffee and rubber. The favourable conditions make this region the focus area for agricultural and economic development in Dak Lak. The basement shale areas are dominated by rather fertile clayey ferrosoils.

Several rivers and streams drain the plateau, the largest being the Krong Ana and Krong Buk rivers in the East and South, while the Srepok river runs to the West of the pla-

teau. The rivers are normally cut deep into the ground where they act as efficient drains. The flows of the large rivers are not controlled, but a few minor rivers are regulated by hydraulic structures that are built along the river branches. They are connected to small or larger reservoirs which are used for irrigation and drinking water normally diverted by gravity.

Agriculture

Farming is the main activity in Dak Lak, and 70% of the labour force are employed in this sector, mainly in the coffee industry. There is a long tradition for coffee in the region, but at a rather small scale. In 1979 coffee plantations covered only 14,500 hectares. The area was doubled to 32,600 hectares during the period between 1979-1989. But the real increase has taken place since 1989. At present 80,000 hectares are mature, see Table 1, while new plantations occupy more than 138,000 hectares.

The rubber plantations that averaged 5,000 hectares in the period 1979-1989 rose to 18,000 hectares in 1994 and they are still expanding. In 1997 they constituted 30,000 hectares.

A number of different farming systems exist in the province. The information here on the farming systems is mainly based upon field work in Dak Lak and on interviews with extension workers at the Swap office in Buon Ma Thout. They comprise shifting cultivation practised by ethnic minority groups in the mountain areas, and more intensive and modern production methods in the lowland and in upland areas on flat or sloping terrain. The major agricultural categories are low-input subsistence farming and high-input improved and market oriented systems that use both fertilizer and pesticides. Since the latter relates to large land use changes, they are the focus of this article.

The main perennial cash crop cultivation is part of the improved farming system and is primarily located in the upland areas on sloping well drained basaltic soils. The main crops are coffee, rubber, cashews and pepper, but also maize is an important cash crop. Besides these crops beans and other vegetables can be harvested three times a year (Figure 2). The average farm size is approximately 1 hectare per person of working age. Coffee is typically grown by individual farmers on both private and state farms and coffee farms of 1-5 hectares are common. The farm size is associated with the farmer's capacity to invest in plantation and irrigation systems and there is a trend towards still larger farms. The primary coffee production is intensive and is carried out with high inputs of fertilizer and pesticides. Normally the coffee plantation has to be irrigated and fertilized 4 times during a growing season. The first harvest is gathered after 4 years. Due to the high coffee prices, the investment in plant fertiliser etc. are returned after only 5-6 years. By combining coffee plantation with cash crops such as maize and beans, many families have within 2-3 years experienced a substantial increase in their income. Compared with their past in North Vietnam the increased welfare is conspicuous. The first sign is typically that the prevailing roof of palm leaves

Crops	*Area (ha)*		*Yield*	*Productivity*
	Total	*Mature*	*(Ton/ha)*	*(Ton)*
Coffee	138,000	80,000	2.00	160,000
Rubber	30,000	15,000	1.00	15,000
Cashew	10,000	8,000	2.00	16,000
Wetland Rice	40,000		46.00	184,000
Upland Rice	28,000		1.50	42,000
Maize	20,000		5.00	100,000
Beans	30,000		1.00	30,000

Table 1: *Main crops and production in Dak Lak Province 1997. Source: Annual Agricultural Report 1997, Department of Agriculture & Rural Development of Dak Lak Province, Vietnam.*

Figure 2: *New settlements in Dak Lak. The forest has been replaced with vegetables.*

is changed to tiles. Another clear evidence is the small motorbikes that many families in the coffee districts are able to buy. A typical motorbike imported second-hand from Thailand or Japan costs approximately US$ 600-700.

Forest

Although the agricultural sector is fast growing, forest is still seen in the mountains and remote areas. In 1994 it constituted 58 % of the land cover. It can be divided into four major types, evergreen dipterocarp forest, deciduous dipterocarp forest, pine forest and various forms of secondary forest and plantations. Evergreen broad-leaved forest and deciduous dipterocarp forest comprise more than 70% of the total forest cover. The forest is protected by legislation, and several restrictions have recently been imposed on commercial logging due to forest degradation in the area. These restrictions have reduced the logging considerably, but illegal logging is still prominent (FIPI 1997 A). Despite the large deforestation, plantations are nearly unknown in the district and constitute approximately 1% (1994) of the total forest cover.

Population

Dak Lak has a heterogeneous population of 1.3 mill (1997) of which 10-15 % is living in the cities. It consists of 36 ethnic groups, the largest being 65% Kinh, 10% Ede, 5% M'nong. The immigration into the province started in 1954 after the peace accord in Geneva. The country was divided along the 17th latitude and a large group of Kinh immigrants came to Dak Lak as refugees from North Vietnam. This immigration was to some extent continued during the war against USA. After the war the Vietnamese government established several new economic zones, and people from the North were moved into these areas of which most were situated in the lowland area. This immigration had several purposes. It was used as means to increase the agricultural production, to relieve the population pressure in the north, and finally it was intended to stabilize the Dak Lak province politically. The province was dominated by ethnic minority groups which, to a large extent, were either protestant or catholic. Perhaps even more important was that several of these groups had participated in the war against the North. Since the middle of the '80s the immigration has risen considerably. While the ethnic minority groups in 1954 constituted more than 2/3 of the population, recent surveys have shown that they now constitute less than 1/5 (Cowi-Krüger, 1997). Lately, the government policy has, to some extent, been changed in order to protect the environment. Some communes dominated by ethnic groups in mountain areas are now closed for new settlers. But the immigration into Dak Lak is still considerable, and the population more than tripled in the 20-year period from 1977 to 1997 from 382,000 to 1,3 mio. In 1997 the population density was 66 inhabitants per km², which was low compared with the Vietnamese average. However, due to the composition of the population, which is younger than the Vietnamese average, the province is expected to have a large population increase in the years to come. Predictions in 1993 estimated the yearly population increase to be 7% of which 3% is natural growth (Cowi-Krüger, 1997).

Development of a rural management policy

Even though Dak Lak has experienced a large immigration during the last 30 years, the availability of land is not yet a problem. There is, however, an increasing need for a land management policy. Soil conservation and water management programmes are also required to optimize land and water use. Problems related to the large migration have made both the Agricultural and the Forest Ministry aware for the need of a land use planning system for the province. The Srepok Water Action Plan was initiated in 1993 by the Government of Vietnam, The Mekong River Commission, The Vietnam National Mekong Commission, and the Peoples Committee of Dak Lak with support from Danida. The project was mainly carried out by the National Institute for Agricultural Planning and Projections (NIAPP), the Forest Inventory and Planning Institute (FIPI), the Dak Lak Water Resources Services (WRS) and the Dak Lak Agriculture and Forestry Services (AFS) in a joint venture cooperation with the Danish companies Cowi and Krüger. Part of this project was the establishment of a land resource database including mapping of the land use in the period 1979-1995. The mapping was followed by an analysis of the land use changes using a Geographical Information System (GIS). The work should be seen as the first step in creating guidelines for the land use planning of the Dak Lak province.

Methodology

The major land use changes that the region has experienced during the last 20 years have made the existing maps obsolete. A land resources database, including a new map

basis for land use planning, were needed in order to minimize environmental degradation. The main contents of the database are information on relevant water resources, land resources, and land use information, including procedures for analysis, monotoring, and evaluation. The map basis is composed of new digital maps for 1979, 1989 and 1995 that enable processing and display of data using a simple desk top GIS.

The method applied follows a rather traditional top-down approach inspired by guidelines from FAO (FAO, 1993). The method has been developed by FAO during the last 20 years, and it implies a set of basic maps that can be used in a rural land management plan. The guidelines for land use planning are in this case improved by the use of modern geo-information technology. The underlying paradigm for the geoinformation approach is the "Double crisp" model because the classes in attribute space are supposedly completely definable and non-overlapping (Burrough, 1997). This definition indicates that the boundaries between different map objects have been adjusted in a map generalisation process. Slivers, small polygons less than 8 hectares and overlaps between polygons, have been removed using a delineation process in which boundaries between different map objects were defined, creating well defined polygon boundaries and homogeneous polygons. This map generalisation results in a pattern where spatial elements are easy to interpret due to the well-defined classes in each datalayer. Each attribute in the database relates to discrete and uniform parts of the landscape. The method is developed for conventional land evaluation, in which the method identifies land use conditions that are described by a limited set of attributes.

The geo-information needs of the "Double crisp" model that was implemented are simple, which is why it was chosen. It is regarded as a first step in the introduction of modern information technology. By interpretation of older maps, aerial photos, and satellite imagery objects are delineated and digitized in a Geographical Information System (GIS). A set of three digital maps was created from 1979, 1989 and 1994/95 followed by an analysis of the land use changes. This work was carried out at the Vietnamese institutions NIAAP and FIPI in cooperation with Cowi and Krüger.

The land use mapping procedure included 4 basic steps:

- The preparation of older maps, photos and satellite images for digitalisation
- Photo-interpretation
- Field check
- Digitizing, correction and computerised analysis

A major task was the classification of forest, it was defined as vegetation dominated by woody vegetation, with a tree height above 5 meters. The legend was established by analyses of the dominating species, combined with a percentage classification of the multi-storey forest width. The forest was defined as closed forest when the forest cover was above 70 % and as medium open forest if the coverage was more than 40 %. A coverage above 20 % was defined as open forest. The remaining area may consist of bush, grassland or agricultural land or a mosaic of all three classes (Cowi-Krüger, 1996).

A photo-interpretation key was established based on spectral signatures. Each class comprises a characterisation for land use classes and forest land which afterwards was checked in the field. The images were classified by use of the photo-interpretation key and transferred to a transparency. The smallest mapping unit was 8 hectares.

The 1979 land use maps are based upon two separate set of maps prepared in the scale 1:100,000. One included themes of agricultural land use, the second the forest classification. The agricultural land use was based on

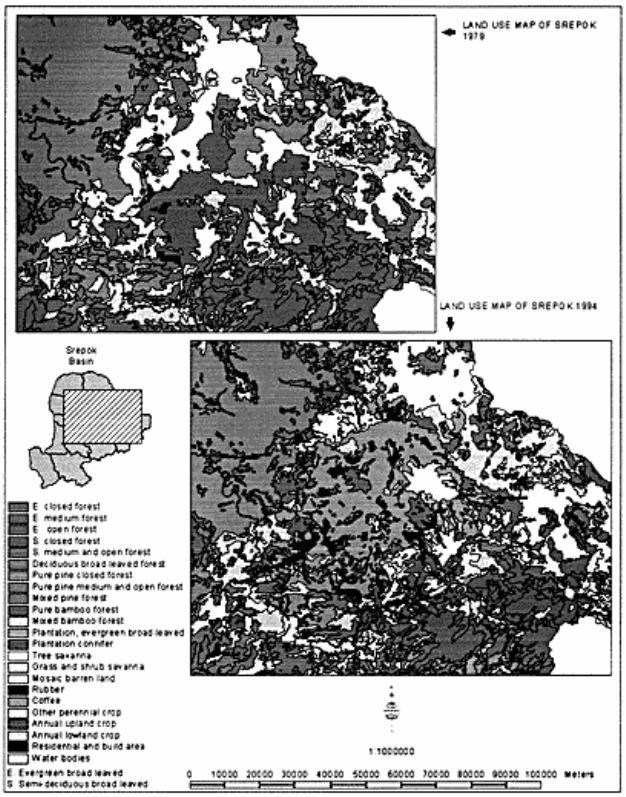

Figure 3: Landuse changes in the Srepok Basin 1979-1994.

intensive field work where map features were transferred to a topographic map from 1965. The forest map was established by manual interpretation of satellite imagery from 1973 and 1976 followed by field work.

The 1989 map was likewise based on two different maps, one of agricultural land use and of vegetation cover which were merged into a single map. The original maps were based on visual interpretation of enlarged colour composite prints of Landsat MSS and SPOT satellite imagery and field work. Satellite images of band 3-2-1 were used in the scale 1:100,000.

The transparency for 1979 and 1989 was then digitized and the digitized lines were corrected and overlapping features removed.

The 1994/95 land use map (Figure 3) was based on visual interpretation of printed Landsat TM imagery and ground truth was checked by fieldwork. In addition to the satellite imagery, additional map data such as local forest, land use, ecological and topological maps were included. The legend on the 1994/95 map was made identical to the legend used for the 1979 and 1989 maps.

The produced maps were combined with information on soils, terrain, and landforms in a land resource database, forming the basis for the implementation of a regional planning procedure. By use of a simple desk top GIS, land use changes in the period 1979-1994/95 could be envisaged by use of standard routines and queries. (Figure 3).

Errors and uncertainties

The use of the paradigm of the "Double crisp" model creates several errors due to its simplicity. Most important in this case is that spatial and temporal variation within areas of land delineated are ignored due to the scale of 1:100,000. Furthermore, spatial and temporal variation may exist at several scales and not just at the level of resolution determinated by the survey (Burrough,1997). The magnitude of the errors was estimated during the spring of 1997 when a field check of the 1994/95 map was carried out. These observations and ground truth controls revealed large classification errors, especially in difficult and mountainous terrains that were sparsely populated and difficult to access. In general, the map retained a high quality in populated areas along the major roads. This difference in quality was explained by interviews regarding the original field check procedure. They revealed that several transects were established, but the verification transects all followed the major roads. It was concluded that detailed use of the map had to be followed by field check when possible. Also, area calculations based upon the two historical maps are encumbered with some degree of uncertainty. Scale error originating from the transfer from paper to digital maps was not estimated. Further, the incorporation of statistical data in the two historical maps is problematic as no documentation exists to what extent the maps have been modified in order to correspond to official agricultural statistics (Cowi-Krüger, 1997). These uncertainties must be seen in the light of the new technology that was introduced to the Vietnamese institutions that carried out the work.

Figure 4: Deforestation followed by a new coffee plantation in Dak Lak.

Discussion of the land use changes

The population changes in Dak Lak during the nearly 20-year investigation period has been comprehensive. As one of several consequences the residential and built area has spread into the country side and this area has been enlarged from 0.07 % of the area in 1979 to 2.5 % in 1994, mainly established along the bigger roads. The population change is reflected in major changes of the land use pattern and clearly illustrated by the maps in Figure 3.

The land use map analysis illustrates a shift from forest and tree savanna into perennial crops of which coffee dominates by 6% (1994). It also indicates that the land use changes have been most pronounced on the fertile basaltic soils especially around the Province capital Boun Ma Thout. The relatively easy change of tree savanna and annual upland crop areas into coffee plantations being one reason, another

is that the poor infrastructure causes the new coffee farmers to focus on potential farmland close to the Province capital Buen Ma Thout when possible. As a consequence, all available land was occupied around the Province capital during the period 1989 and 1994 and mainly turned into coffee plantations. New settlers now move into forest areas further away from Boun Ma Thout, this change of behaviour has led to an increase of the environmental deterioration. Furthermore accelerated afforestation and degradation of primary forest are seen where new settlers move in, cutting down forest for farmland, firewood, and building materials as illustrated in Figure 2 and 4. The analysis indicates that the primary forest is transformed into tree savanna or grass and scrub savanna, which can be seen as intermediate stages towards a transition into farmland. Contemporary with the removal of primary forest, the remaining forest becomes smaller and more fragmented. On a national level the forest cover has been reduced from 14.3 mio. hectares in 1943 to 9.3 mill hectares in 1995 (FIPI 1997). The same trend is seen in Dak Lak. The forest that covered 75 % in 1979 was reduced to 58 % in 1994 (Table 2).

The clearing of land and removal of forests are executed despite natural conditions due to ignorance and lacking knowledge (Ngoc 1998). Due to rising population pressure mainly along the major roads, even steep slopes are deforested and land cropped with vegetables. Depending on the soil type, this often gives rise to erosion. The lowland farmers from the north have nearly no knowledge of farming methods in a hilly terrain. Even simple measures to avoid erosion are generally not adopted mainly due to a poor extension service. As a result of the erosion, large areas have been destroyed as farm land.

The land use changes are caused by a massive planned immigration into Dak Lak, as mentioned above, in accordance with the governmental objective of rural development. This immigration has been followed by an equally massive spontaneous immigration. Reliable information on the sizes of these figures is difficult to obtain. The most recent information is a report on "Illegal immigration into Dak Lak in the period 1976-1996" produced by the office of immigrants and settlements in the Dept. of Agricultural and Rural Development. This report, based on interviews in the districts, numbers the spontaneous immigrants to 349,500 persons compared with 313,700 planned immigrants in the same period. The accuracy of these figures is unknown, but they do illustrate that the spontaneous immigration is considerable. The massive immigration into Dak Lak can be explained by the poor living conditions, of low income groups in the North, combined with constraints regarding the security of land tenure. Such conditions associated with the possibility of prospering by growing coffee, have led to immigration into Dak Lak. Lately, the Government has strengthened the immigration control and in 1997 plans were revealed regarding removal of illegal settlers. Despite these arrangements, immigration into the province is expected to continue. This fact, combined with a high yearly population increase, stresses the need for land use planning which is not fulfilled by the basic land use mapping performed in this project.

Conclusions

Though several errors have been recognized in the elaborated maps, the transfer of historical and new maps to digital format has enabled analyses that were not possible using traditional maps. But the work has indicated that it is crucial to maintain

Items	*1979*		*1989*		*1995*	
	ha	*%*	*ha*	*%*	*ha*	*%*
Forest	*1,708,901*	*75,1*	*1.475,994*	*64,9*	*1,334,487*	*58,7*
Perennial crop	*21,150*	*0,9*	*40,120*	*1,8*	*118,850*	*5,2*
Annual upland crop	*57,000*	*2,5*	*105,000*	*4,6*	*148,550*	*6,5*
Lowland crop	*15,200*	*0,7*	*21,360*	*0,9*	*23,920*	*1,1*
Shrub and grass land	*440,679*	*19,4*	*577,056*	*25,4*	*573,763*	*25,2*
Others	*31,670*	*1,4*	*55,070*	*2,4*	*75,030*	*3,3*
Total survey Area	***2,274,600***	***100***	***2,274,600***	***100***	***2,274,600***	***100***

Table 2: Land changes in Dak Lak 1979-95. Source:Cowi-Krüger (1997).

an exact definition of attribute classes for the investigated period. The combination of the digital maps and a simple desktop GIS has made quantitative land use change analysis possible and illustrated the large land use changes that have taken place since 1979. It has shown that large areas of primary forest are threatened and that forest is still being removed despite different environmental protections. And it has underlined that there is a need for a land use planning system. The chosen desktop GIS was able to perform comprehensive analyses, and well suited for management and of the database. The simplification through "the double crisp method" was necessary due to the many discrete attribute classes, but its evident that more detailed mapping have to be conducted for analysis on commune level.

The procedure used in the Dak Lak project is more or less comparable with the FAO guide line for Land Evaluation, (FAO 1976). This framework has been applied in rural development and assessment studies all over the world, but many projects have remained in the study phase without any practical impact (Kutter et. al., 1997). To secure a successful implementation and continued development a number of government institutions in Dak Lak have been organized in the Water and Environmental coordination committee. This committee has frequent meetings and acts as an inter institutional body in order to coordinate planning measures, etc. The land resource database established in this project has shown to be an important tool for the committee in the development of a rural land use plan for the Dak Lak Province.

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References

Annual Agricultural Report (1997): Department of Agriculture & Rural Development of Dak Lak Province Vietnam, Buon Ma Thout, Vietnam.

Burrough, P. A. (1997): Geo-information need and affects of scale. Geo-Information for sustainable land mangement, *ITC journal* 1997-3/4: 235-236.

Christiansen, S. (1977): Landbrug i Tonkindeltaet, Vietnam. Geografforlaget, Brenderup.

Cowi-Krüger *(1996):*Watershed changes in Upper Srepok Basin and Dak Lak. *Working paper No. 17. Buon Ma Thout. Vietnam.*

Cowi-Krüger (1997): Action plan for Water Resources Development Phase III Upper Sepok Basin Vietnam. *Working paper No. 28. Buon Ma Thout. Vietnam.*

Dept. of Agricultural and Rural development (1996): Illegal immigration into Dak Lak in the period 1976-1996. The office of immigrants and settlements. Dak Lak. Vietnam.

FAO (1993): Guidelines for land use planning. *Development series* 1. FAO Rome.

FAO (1976): A Framework for Land Evaluation. *FAO Soils Bull.* 23. Rome.

FIPI (1997): Vietnamese forest data. Forest Inventory and Planning Institute. Hanoi.

FIPI (1997 A): *Personal information.* Forest Inventory and Planning Institute. Hanoi.

Kutter, A., Nachtergale, F. O. & Verheye, W. H. (1997): The new FAO approach to land use planning and management, and its application in Sierre Leone. Geo-Information for sustainable land mangement, *ITC journal* 1997-3/4: 278-283.

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Dept. of Agricultural and Rural development (1996): Illegal immigration into Dak Lak in the period 1976-1996. The office of immigrants and settlements. Dak Lak. Vietnam.

FAO (1993): Guidelines for land use planning. *Development series* 1. FAO Rome.

FAO (1976): A Framework for Land Evaluation. *FAO Soils Bull.* 23. Rome.

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