Role of Relief and Slope in Agricultural Land Use: A Case Study in Valapattanam River Basin in Kannur District, Kerala Using GIS and Remote Sensing

Abstract

Land is a delineable area of the earth's surface, encompassing all attributes of the biosphere immediately above or below this surface. Physical characteristics of land determine the agricultural land use. Among them, relief and slope play an important role. Aim of this study is to establish the relationship of relief and slope with agricultural land use in Valapattanam River basin in Kannur district using GIS and Remote sensing.

The Survey of India Topographic maps in 1:50000 scale were used as a base map for delineating the basin. Contours were digitized and Digital Elevation Model (DEM) was generated. Agricultural land use map was prepared using satellite digital data by digital image processing method using ERDAS IMAGINE image processing software. Agricultural land use map was intersected with the relief and slope classes in ArcGIS software. Areas were calculated and trend of agricultural land use patterns were studied. The study revealed that there is a strong correlation between Agricultural land use and relief & slope in the Valapattanam River basin.

Most of the area under paddy, coconut, mixed crops like banana and tapioca concentrated below 20m height in the coastal plain and valley regions of the basin. Rubber mostly cultivated between 100 and 300 meters with slopes between 3 to 12 degrees. Agriculture is limited up to 18 degree slope and 300 m height. Areas of more than 300m height are occupied mostly by forest.

Keywords: Remote Sensing, Topographic maps, Landsat imagery, Geographic Information System.

Introduction

Land is the basis for many life support systems. Land is a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), the near surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.) (FAO, 1995). Wise land use/land cover is an essential basis for a healthy and prosperous future of the society. Functions of land are manifold and depend upon site, situation and function. Land evaluation is part of the process of land-use planning. The essence of land evaluation is shell to compare or match the requirements of each potential land use with the characteristics of each kind of land. The result is a measure of the suitability of each kind of land use for each kind of land. Land properties vary in time and space. Land-use/ land cover is dynamic. Over the years a variety of evaluation procedures have been proposed to cope with the complexity of land and its use.

Man's agricultural activities depend on the physical environment (Singh *et al* 2006). From the very beginning researchers who worked in the field of agricultural geography were attracted to the problem of explaining how variation in environment influenced agricultural landscape (Gregor, 1970). Relief and slope have its own distinctive regional characterisation of agricultural landscape. Since relief and slope impose physical restrictions on the regional distribution of agricultural activities, the analysis of patterns of agricultural practices is essential and provides guidelines for solving developmental problems. The relationship between cropland occupancy and physical environment has not been systematically and comprehensively investigated in many regions of the world. The direct effect of terrain on agriculture operates particularly through relief and slope. They determine the pace of cultivation, farm mechanisation, the degree of accessibility, flooding of downstream areas and erosion and landslides in the upstream areas. Soil formation and its maturity are decided by the relief and slope. In the higher elevation, soil would be immature with poor nutrients, which is not suitable for agriculture; whereas in the lower reaches of streams and elevation, the soil is fertile, mature and highly suitable for agriculture. Elevation also controls the climate and suits to certain crops. Relief and slope controls the recharge of ground water and surface runoff which are related to agricultural land use.

Vink (1983) established relationship between Landscape Ecology and Land Use. FAO (1976, 1981, 1984, 1985, 1991, 1993 and 1995) brought out guidelines and methodologies for land evaluation and suitability analysis for agriculture. Noor Mohammad (1981) and Singh *et al* (2006) in their study on Agricultural Geography emphasized the role of physical parameters like relief and slope. Terrain evaluation and its use in agriculture was studied by Raju *et al* (1977), Cooke *et al* (1978), Brinkman (1998), Nagarathinam (1982) and Burrough *et al* (1986). Gautam (2002), Gautam *et al* (1983, 1985,1991 and 1996) demonstrated how satellite remote sensing could be used for land use/ land cover studies and Sukumar *et al* (2001 and 2007) made studies using satellite remote sensing data and GIS related to agriculture. Integrated studies of environmental assessment, suitability analysis on River basin wise studies were made by Chattopadhyay *et al* (1986), NRSA (1995), AnilKumar (1996), Bhagat *et al* (2006) and Bandhopadhyay (2009). In most of the GIS and Remote sensing studies, visual correlation was made by overlaying physical characteristics of the land with agricultural land use; whereas attempt was not made on agricultural land use areas with relief and slope categories in micro level. Jyothirmayi (2012) attempted to find out agricultural land use areas with physical parameters like relief, landforms, slope, aspect and soil and their sub classification levels by intersection method of geoprocessing in ArcGIS and suggested methods for sustainable agriculture by conserving land and water.

In this paper an attempt was made to see the relationship between relief and agricultural land use; and slope and agricultural land use in Valapattanam river basin in Kannur district using GIS and Remote Sensing.

Study area

Valapattanam River is one of the important rivers in north Kerala. Out of the 44 rivers of Kerala, seven west-flowing rivers are in Kannur district and Valapattanam River is the longest among them. It is the ninth longest river in the State and by the quantum of water resources, it gains fourth place. The Valapattanam basin extend between latitudes 11º 49'30" N and 12º 13' 50" North and longitudes 75º 58' 55" E and 75º 17' 22" East (Fig. 1). The length of the river is 110.50 Km with a catchment area of 1907 Sq km of which approximately 1321Sq km of area falls within the territory of Kerala State and the remaining in the Karnataka State. The river covers about 43.45% of Kannur district. Important tributaries of Valapattanam River are Bavali, Aralam, Veni or Vallithodu, Iritty, Sreekandapuram rivers, and Kattampallipuzha.

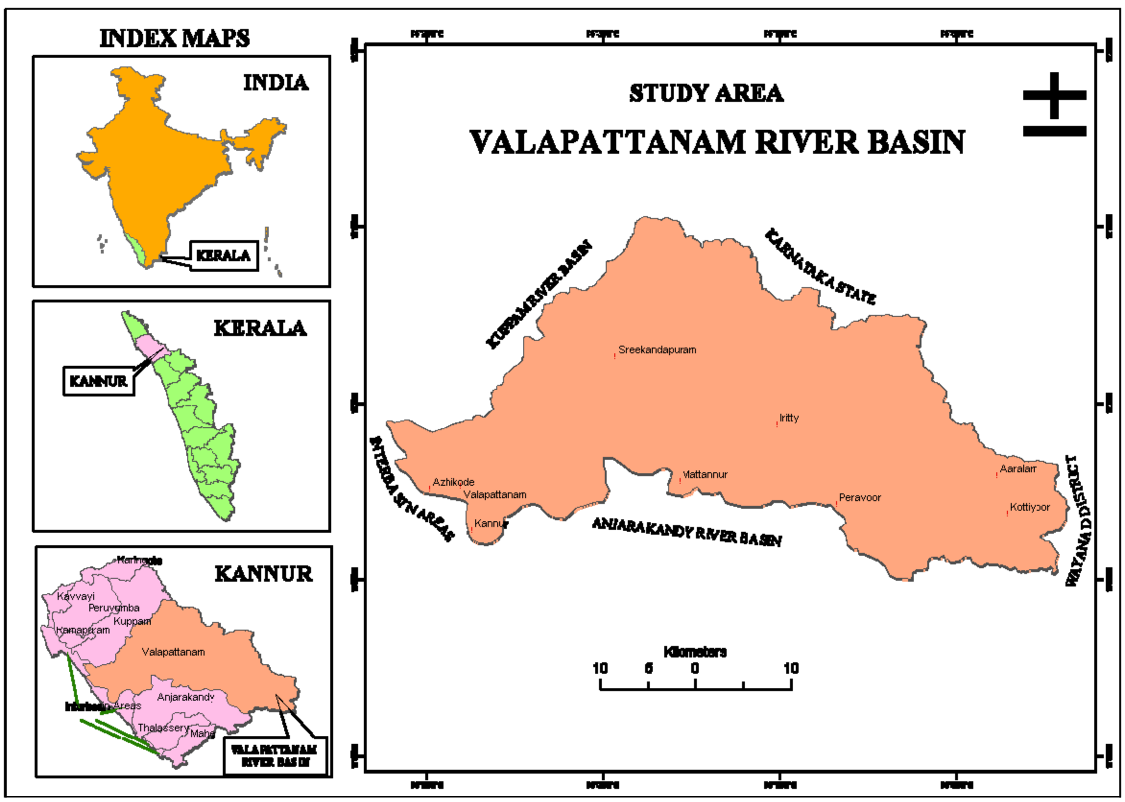


Fig.1 Location of Valapattanam River basin

Materials and methodology

The Survey of India Topographic maps in 1:50000 scale were used as a base map for delineating the basin. Contours were digitized and DEM was created. Based on the contours a relief map was prepared (Fig.2). Using DEM slope map was prepared (Fig.3). ArcGIS software was used for the integration and analysis. Spatial Analyst module was used for deriving slope map. Using Landsat imagery of ETM 2006 data and Google maps agricultural land use map was prepared using satellite digital data by digital image processing method with ERDAS IMAGINE image processing software (Fig.4). Relief map was classified into 8 categories. Slope map was classified into 7 categories. Relief and slope map categories were intersected with agricultural land use categories (Fig.5 to 19) and areas were calculated by geoprocessing method in the GIS environment. To show the relationship trend graphs were prepared. Correlation coefficients were also made to establish the relationships.

Analysis and Discussion

Relief

Relief is the difference between the highest and lowest elevations in an area. A relief map shows the topography of the area (Fig.2). A relief shows changes in elevation over a given area of land. It is the expression of the interaction of several different phenomena and processes within the earth's crust and on its surface. Relief has strong influence on the processes such as climate, hydrology etc. It is also a well known fact that both natural and accelerated processes of soil erosion are largely dependent upon the nature of local relief. Relief is therefore intimately connected with many of the other elements of landscape resources. Agricultural land use is strongly influenced by the size and shape of the relief forms. The distribution of area under different elevations is given in the Table 1.

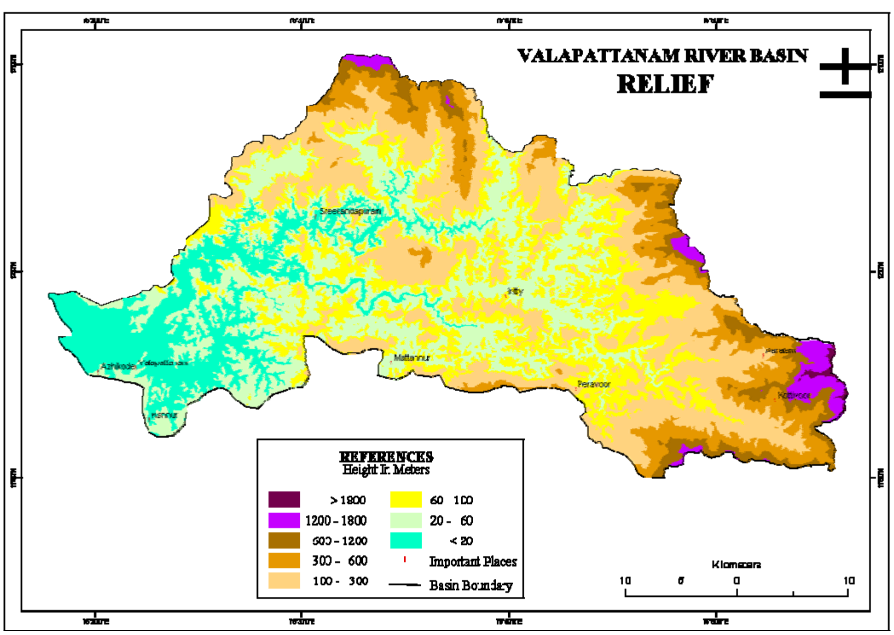


Fig.2 Relief of Valapattanam River basin

About 25 percent of the basin has an elevation between 100 and 300 meters. Elevation of about 20 to 60 meters occupies 24.3 percent of the total basin area and 20.3 percent area is occupied between 60 to 100 meters elevation. Major portion of the district is covered between 20 meters and 300 meters elevation. They are mostly in the midland regions of the district.

Table.1 -Valapattanam River basin: Relief

Sl.No.	Height above mean sea level memean in metre	Area (sq.km)	Percent to the basin area
1	Below 20	169.3	13.0
2	20-60	317.4	24.3
3	60-100	264.8	20.3
4	100-300	331.1	25.4
5	300-600	139.5	10.7
6	600-1200	54.3	4.2
7	1200-1800	25.8	2.0
8	Above 1800	3.1	0.2

Slope

Many physical attributes vary along a natural slope. Seven categories of slope are recognized in the Valapattanam basin based on the degree of steepness. Based on the relief and slope, landforms of the area were identified. Plateau edges and high mountain region have steep slopes in the eastern part of the river basin. Many physical and biological processes acting on the landscape are highly correlated with topographic position: a hilltop, valley bottom, exposed ridge, flat plain, upper or lower slope, and so on. Physical processes include soil erosion and deposition. Relief and slope controls hydrological balance of the river basin. Slope in the River basin varies from flat to more than 30 degrees (Fig: 3). More than 50 percent of the basin has very gentle slope of less than 3 degree slope angle.

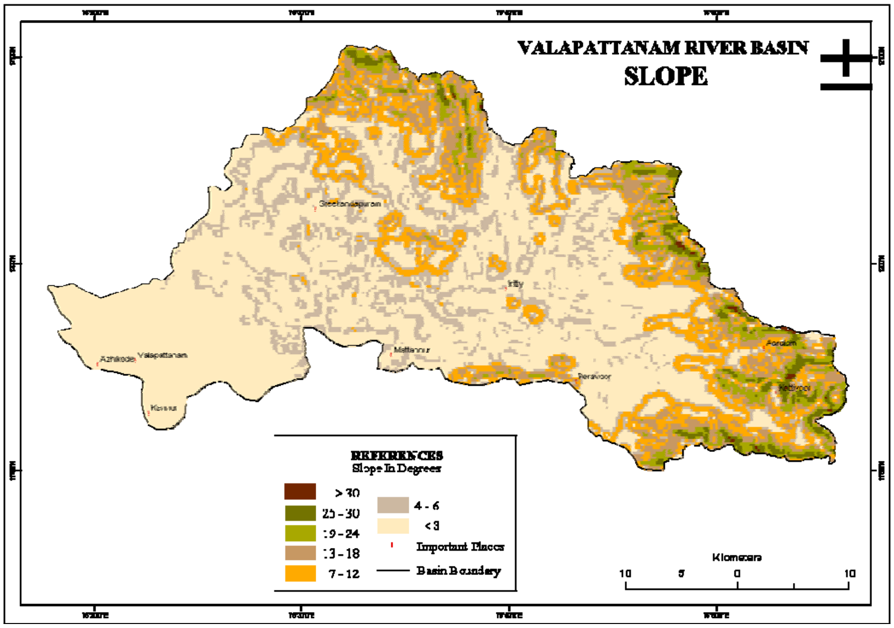


Fig.3 Slope of the Valapattanam River Basin

About 20 percent has 3to 6 degree of slope angle. The next category is the 6 to 12 degree slope which constitutes 14 percent. Slope angle of 12 to 18 occupies almost 10 percent and higher slope angles or steep slope constitute limited area of less than 5 percent of the total basin area (Table 2). High slope area follows high relief along the hill and plateau margins of the basin.

Table.2 -Valapattanam River basin: Slope

Sl.No	Slope	Area(sq.km)	Percent to the basin area
1	>30	3.6	0.3
2	24-30	29.5	2.3
3	18-24	61.7	4.7
4	12-18	119.6	9.2
5	6-12	179.6	13.8
6	3-6	218.5	16.8
7	<3	694.5	53.3

Land Use/Land Cover

Valapattanam river basin is richly endowed with agricultural resources. Most of the area comes under agricultural land use. Coconut is the dominant crop in the basin followed by rubber, cashew, arecanut, paddy and other crops. Land use/ land cover of Valapattanam River basin is shown in Fig 4.

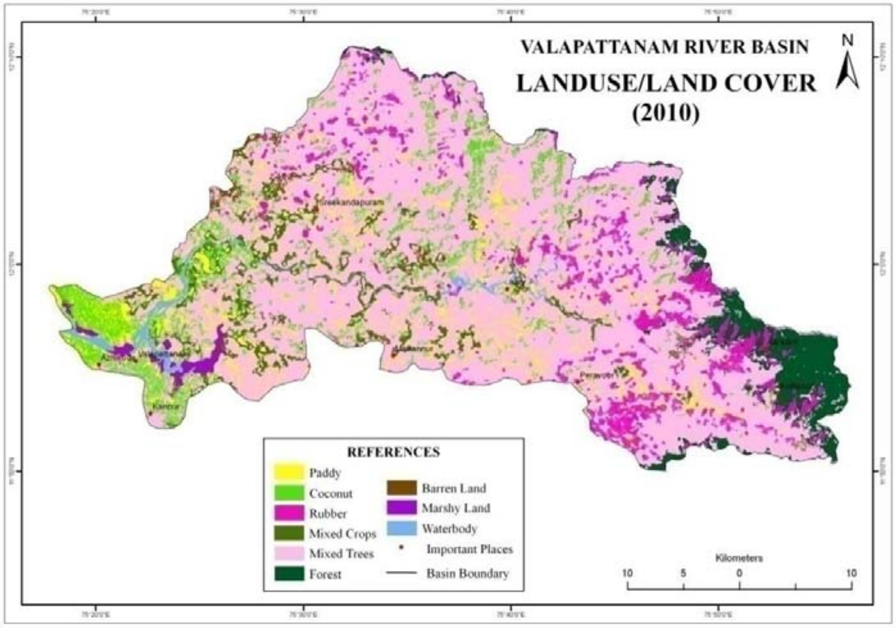


Fig.4 Land use/ land cover of Valapattanam River Basin

Mixed trees include cashew, pepper, mango, and jack fruit. Mixed crops include banana, plantain, tapioca and other crops. Area under different land use/ land cover is given in the Table.3. The upper reaches of the Valapattanam River basin are extensively cultivated with plantation cash crops like coffee, and rubber. Tapioca, cashew and pepper occupy the midland regions. At the lower elevations of the river valleys, tapioca, coconut and other tree crops are interspersed with paddy cultivation. The lowland coastal area is dominated by coconut and partly by cashew and paddy. The diversity of tree crops is markedly high at the lowland – midland junction. Conversion of forest area for developmental activity includes plantations in the uplands.

Table.3 – Area and Percentage under Land use/Land cover

Sl.No	Land use/land cover	Area in sq.km	Percentage to the total area
1	Paddy	90.5	6.93
2	Coconut	98.18	7.51
3	Mixed crops	68.09	5.21
4	Mixed trees	825.09	63.13
5	Rubber	90.13	6.9
6	Forest	79.26	6.06
7	Barren land	20.2	1.55
8	Marshy land	11.73	0.9
9	Water body	23.74	1.82

Relief & Slope and Area under Agricultural Land Use

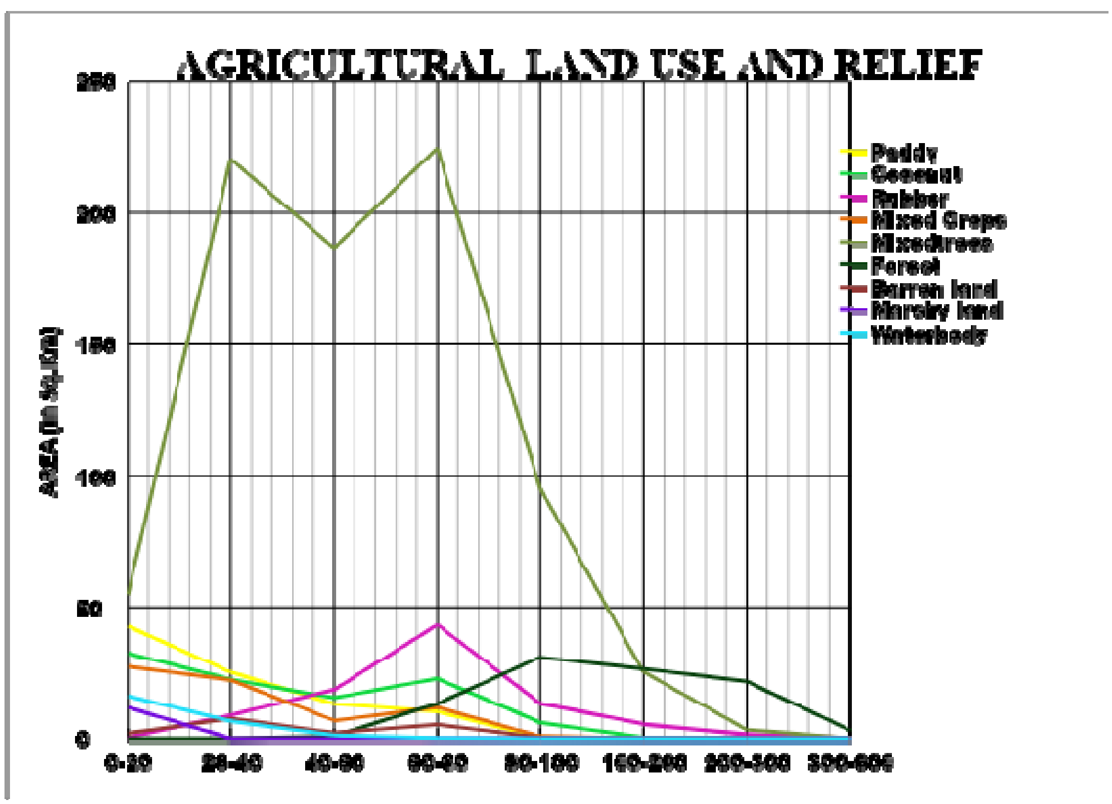
Relief ranges from zero to above 1800 meters in the basin. Area under paddy is high in the low land region of the basin below 20 meters and less than 3 degree slope with 46.7 per cent. It gradually decreases in area with increase in height and steep slopes towards east. Low land comprises of coastal plain and valleys with fertile alluvial soil. Water body and marshy areas also found in the low land region.

Area under rubber is low in the lowland region; it is high in the midland region where the slope is more than 18 degrees slope and height ranging from 100 to 300 meters with 43.1 per cent and decrease towards highland where the height is more than 300 meters. Thirty three percent of coconut found below 20 meters and 0 to 3 degree slope.

Twenty seven per cent of mixed crops found more below 20 m height in the coastal plain and valleys and 78.9 per cent below 3 degree slope areas. Similarly 27.7 per cent of mixed trees are found more in the midland region compared to low and high land region between 100 and 300 meters and 48.02 per cent found in less than 3 degree slope.

Forest area is showing increasing trend from midland to high land. Barren lands are confined to midland region.

Graph: 1 shows the relation between agricultural land use and different height categories and figures 5 to 12 shows the intersected maps showing the agricultural land use in different relief categories.



Graph: 1 shows trend of area of agricultural land use against relief categories

Valapattanam River Basin - Relief and Area under Agricultural Land Use

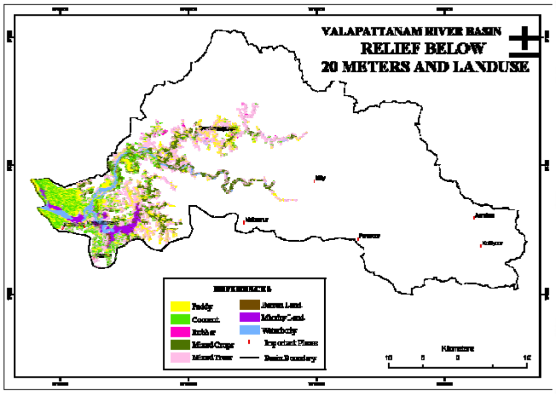


Fig.5 Relief below 20 m. and Land Use

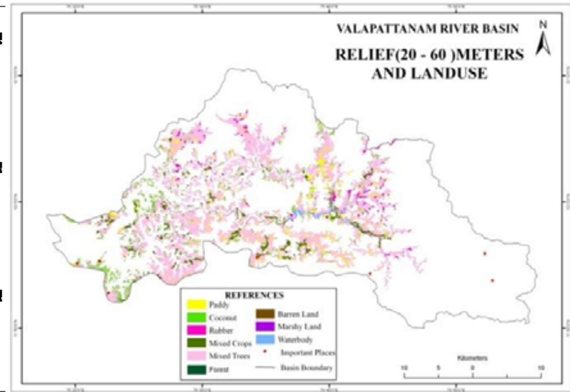


Fig.6 Relief 20-60 m. and Land Use

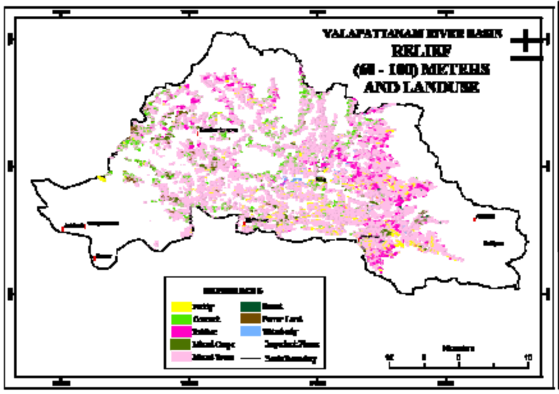


Fig.7 Relief 60-100 m. and Land Use

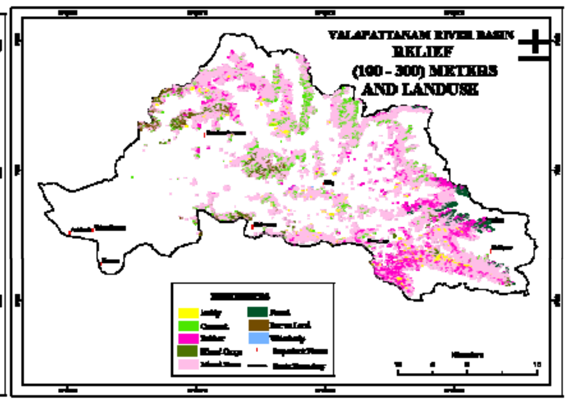


Fig.8 Relief 100-300 m. and Land Use

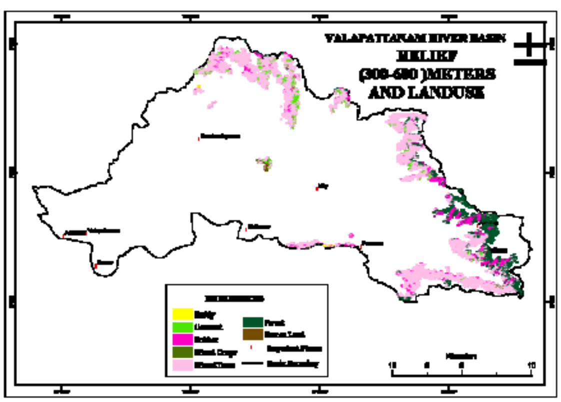


Fig.9 Relief 300-600 m. and Land Use

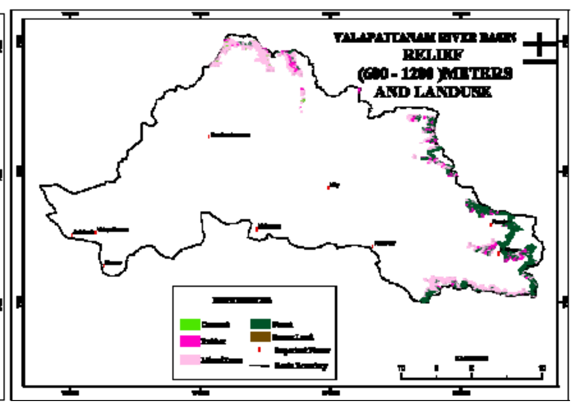
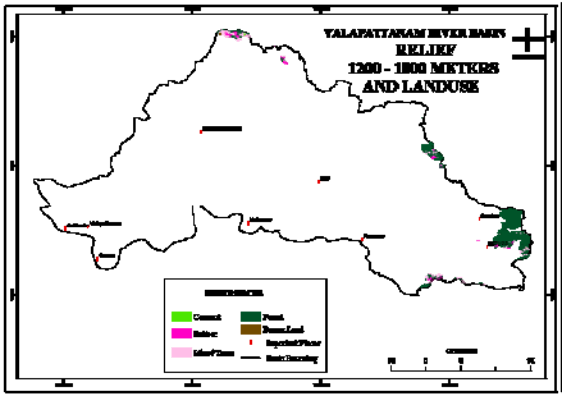


Fig.10 Relief 600-1200 m. and Land Use



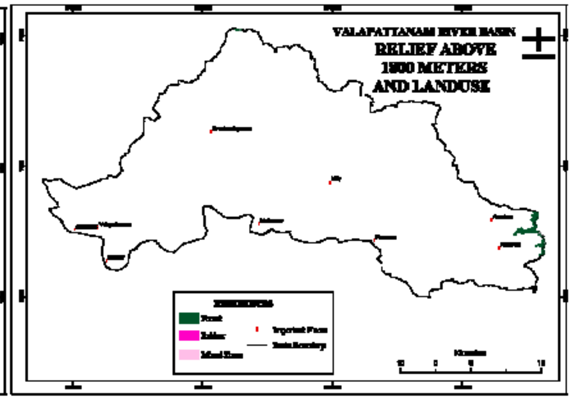
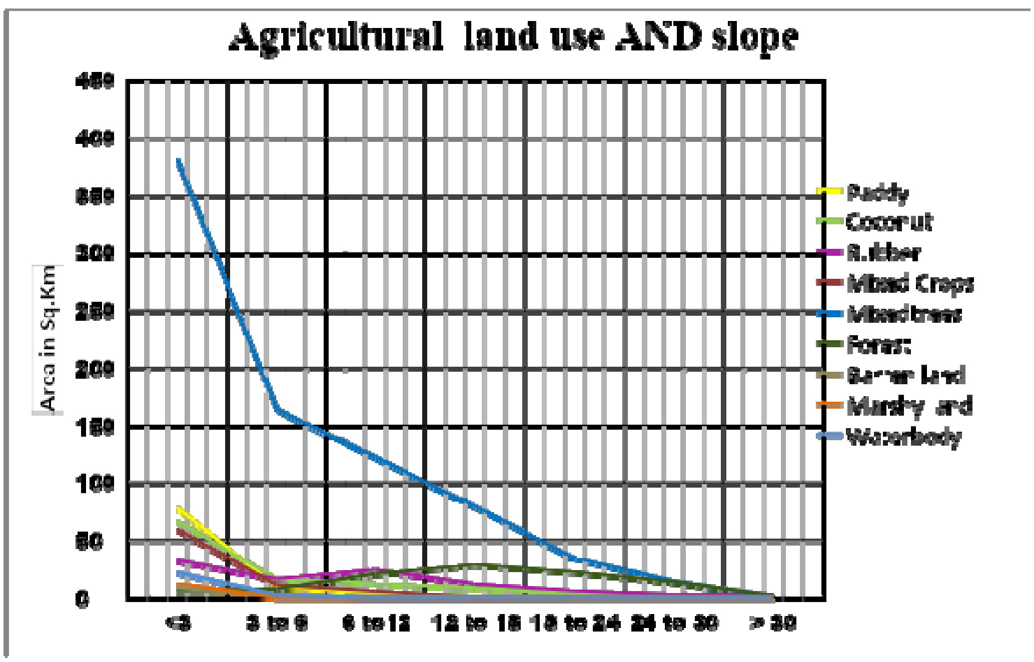


Fig.11 Relief 1200-1800 m. and Land Use

Fig.12 Relief above 1800 m. and Land Use

Agricultural land use and Slope

The correlation between agriculture land use and slope categories were derived from the intersection (figure 13 to 19) and the area calculated is depicted in Graph: 2



Graph: 2 shows trend of area of agricultural land use against slope categories

Valapattanam River Basin - Slope And Area Under Agricultural Land Use

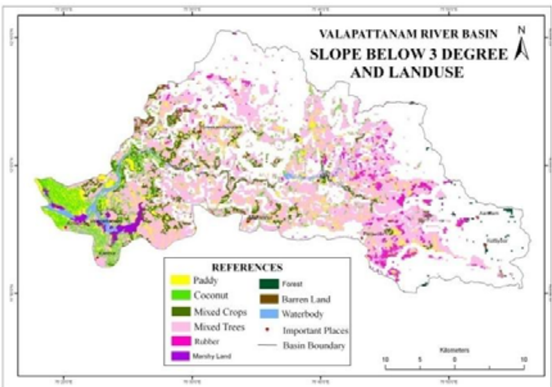


Fig.13 Slope below 3^0 and Land Use

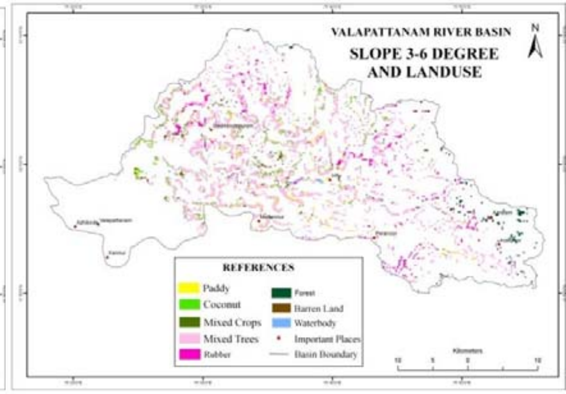


Fig.14 Slope 3^0-6^0 and Land Use

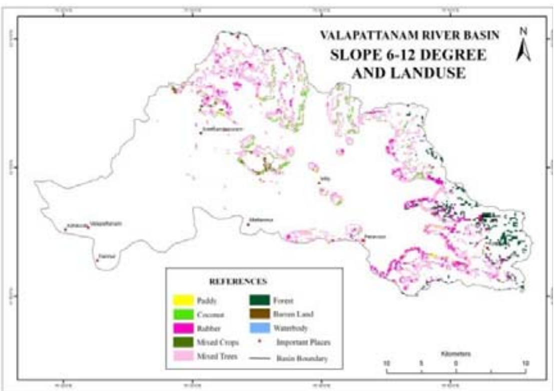


Fig.15 Slope 6^0-12^0 and Land Use

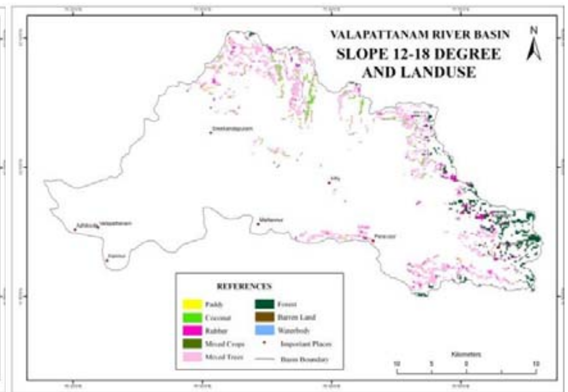


Fig.16 Slope 12^0-18^0 and Land Use

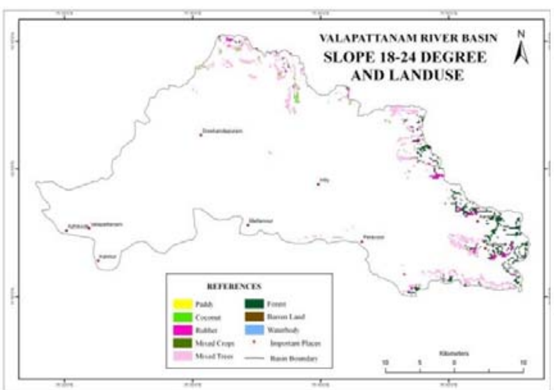


Fig.17 Slope 18^0-24^0 and Land Use

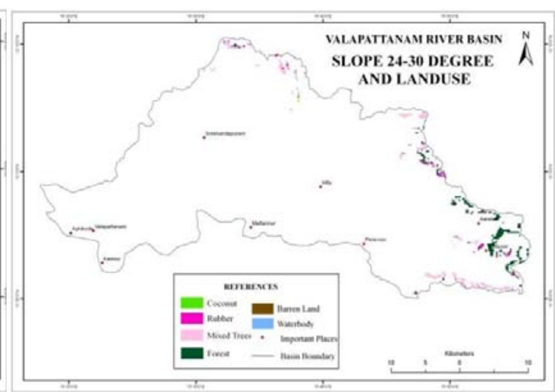
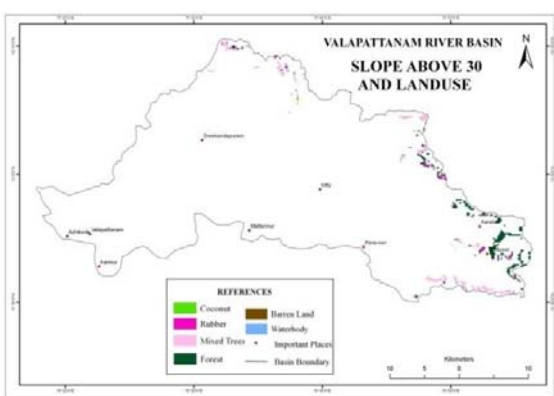


Fig.18 Slope 24^0-30^0 and Land Use



Conclusion

From the study it is found that relief and slope have control over the distribution pattern of agricultural land use in the Valapattanam River basin. Forty three percent of paddy area is found below 20m height and less than three degrees slope in the coastal plain and valley region because of the deposition of alluvial soil by the streams and rivers. Thirty three per cent of coconut area also follows the same trend in the basin. Mixed crops occupy 79 per cent below 3 degree slope and 27.3 per cent below 20m height. This is generally seen in the paddy areas because of economic factor. Twenty eight per cent of mixed trees found between 100 and 300 m height with 48 per cent terraced slope less than 3 degrees. Forty three per cent of rubber area found between 100 and 300 meters height and more than 18 degrees slope because rubber needs well drained soil condition.

The two graphs derived from the analysis explicitly shows strong correlation between Agricultural land use and relief & slope in the Valapattanam River basin. Agricultural land use data were delineated from the satellite remote sensing data and after intersecting with relief and slope categories, areas were calculated in GIS environment. This study reveals the advantage of using Satellite Remote sensing data and Geographical Information system over the conventional method of deriving data and calculating areas.

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