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# "MAPPING AND EVALUATION OF THE CHANGES IN THE LAND USES OF SELECTED RIVER BASINS IN THE NORTHERN PROVINCE"

## - A research based on Geographical Information System.

Subajini Uthayarasa

**Abstract**

Researches on the land use patterns of an area are indispensable to the evaluation of the land development activities therein. Though such studies of land use patterns are made in various ways, the standards of such evaluation vary depending on the levels of such studies. The changes in land use refer to the identification of various differences found on the surface of the earth in the area concerned, at least within two distinct periods. Following the rehabilitation activities in the areas affected by the internal war in the Northern Province, rapid development activities have led to changes in the land use patterns too. As a result, mapping and evaluation of the changes that occurred in a large scale within a short period have become necessary. In this regard the purpose of this research is to map and evaluate the land use changes that have taken place within the three selected river basins in the north of Sri Lanka viz: The river basins of KanagarayanAru, Peraru and PaliAru. The changes in land use have been studied and evaluated with the help of GIS technology, using data obtained from such sources including participatory field work, satellite images (Geo-Eye-2016,0.5meter spatial resolution) and digital land use maps of the survey department. Through these the changes that occurred within two years (2010, 2016) have been evaluated. Though the changes in the land use patterns within the research area appear tangible, during future planning activities, it is important that due consideration is given to the availability of suitable lands, their uses, the needs of the people in such areas, their likes as well as their opinions. As such, this research, while having mapped the land uses and the changes therein, one is able to note these changes quantitatively and qualitatively. It is also expected that this study should be of guidance to future researches undertaken on the river basins of North Sri Lanka as well as on other river basins elsewhere in Sri Lanka.

**Key words** : River basin, land use, land use change, mapping, evaluation.

## Introduction

Studies on the land use patterns of an area are indispensable for the evaluation of any subsequent land development activities carried out in that area. Though such land use studies are conducted in many ways, the standard of the evaluation tends to vary depending on the levels of such researches. Here, time, expenditure and human labour, form the main deciding factors. As the evaluation of land use patterns could be obtained without much delay, through statistical techniques, these are being broadly used. The term land use, denotes all human activities on land as well as any natural or artificial land coverage (Gautam, 1999). Changes in land use, refers to the identification of variations that occur, on the surface of the earth at least during two distinct periods (Serneels et.al., 2001). The information related to the locational distribution of land use patterns and their changes are inevitably required for the planning of such matters like land resources, their usage and management (Anderson et. al, 2001). Besides, information regarding land use, is also essential to handle the available land resources efficiently. Land use information is measured through land use researches. This methodology enables gathering of suitable and correct information pertaining to how the land resources of this country are utilized and also about contemporary land use changes and land use suitability assessments which are useful in such activities like land use planning. (Ines Sant - Riveira et.al. 2008). Land use change is in fact an outcome of the inter-relationship between man and environment. Increased population and rapid urbanization etc. lead to changes in land use also, from time to time and place to place. On the bases of social, economic and political factors, these changes may take place rapidly or slowly depending on the circumstances concerned. (Serneels et. al., 2001).

Conventional methods were used at the beginning for mapping land use. However, today the researches on land use are conducted with the aid of modern geographical techniques. At present, remote sensing has become a well-developed technique for mapping land use patterns. That is to say, that remote sensing is a very powerful device that is greatly useful in the study of land use. Through remote sensing, the various satellites in the orbit of the earth, keep on photographing the surface of the earth continuously. Through the images projected by these satellites, even the worst inaccessible places like dense forests, cold regions, high mountain areas, marshy lands and deserts are photographed. As a result, continuous data at very short intervals are being collected and land use pictures are able to be renewed continuously. In addition, as communicative data are received in digital image forms, it has become possible to get very exact land use information (Anderson et.al. 2001).

Geographical information system and remote sensing are efficient and time saving techniques in mapping the modes of land uses (Ashok Kumar Sharma et.al., 2004). A variety of techniques are used to know the changes in land use

during different periods (Lambin Ehrlich, 1997). As far as Sri Lanka is concerned, changes in land use are occurring at a rapid pace. Consequently, there is also an increase in the need for land use maps. In recent times, more and more land use maps are being prepared on the basis of remote sensing images. These are used in researches concerned with land use changes and also for various development schemes. In Sri Lanka, right from the beginning, researches on land use have been going on, along with attempts to map them. From time to time the survey department of Sri Lanka has been publishing land use maps.

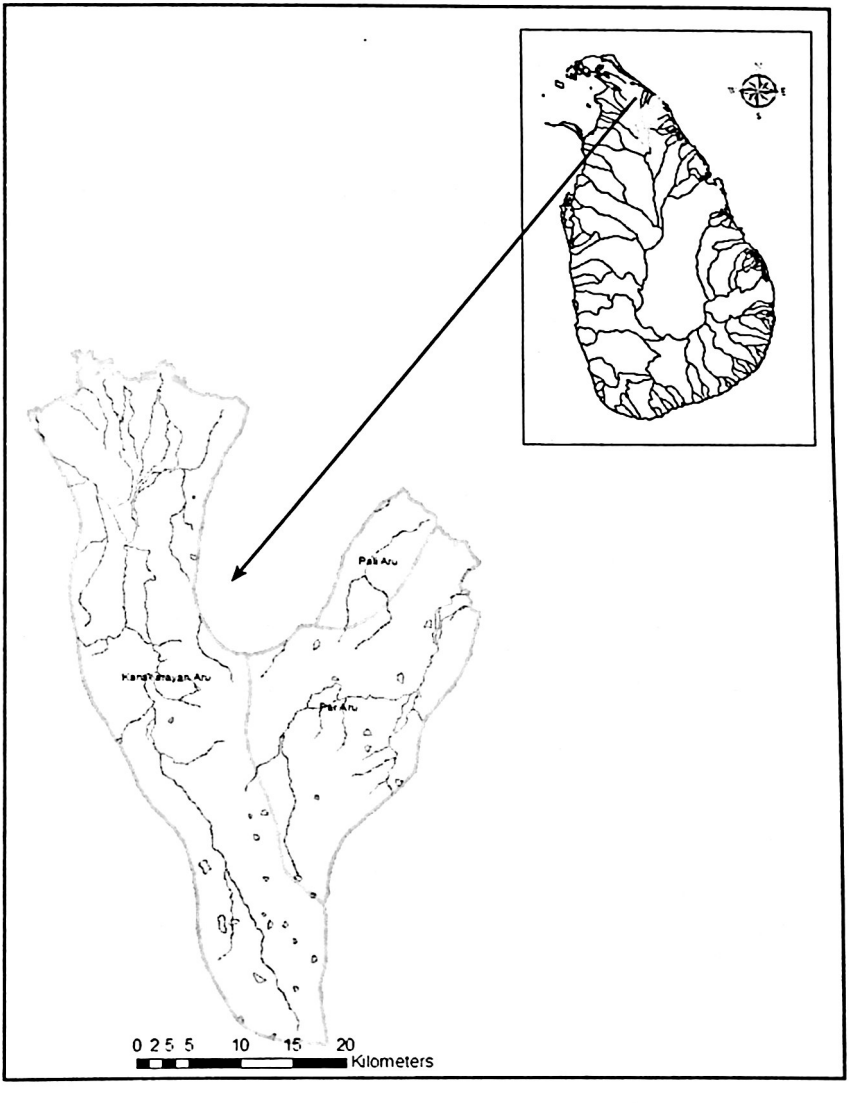
Following resettlement of people, particularly in the war affected areas of Northern Province including the districts of Kilinochchi, Mullaitheevu and Vavuniya North, development activities are going on at a rapid pace. As more and more changes are occurring within comparatively shorter periods, there arises the need for mapping and evaluating them. Thus, the purpose of this research is to map and evaluate the changes occurring within selected river basins in North Sri Lanka.

## Research methodology

### The Research area

Within the five administrative district of the Northern Province of Sri Lanka. The research area spreads across the three districts of Mullaitheevu, Kilinochchi and Vavuniya. Generally research areas are formed on the basis of administrative boundaries. Conversely, this is a research area formed on the basis of natural river basins. Thus, this research area includes the three river basins viz: KanagarayanAru, Peraru and PaliAru. The research area is bounded on the north by Jaffna lagoon, on the east and north east by sea, on the south by the Vavuniya North Secretarial Division, while Poonakari and Manthai West Secretariat Divisions form the western boundary. Latitudinally the research area lies between latitudes from $80^0$ 52' 54" N. to $90^0$ 31' 18"N, while longitudinally it lies between the longitudes $80^0$ 20'41" E to $80^0$ 44'55"E. Nine secretarial divisions including Vavuniya, Vanuniya North, Puthukkudiyiruppu, Ottusuttan, Karaithuraippattu, Thunnukkai, Karaichchi, Kandavalai and Pacchilaippalli are found lying fully or partially within the research area. Likewise, 104 grama sevaka divisions are also lying fully or partially within the research area. The total extent of this is 136,511.62 hectares (1365.11 sq.km). This is two percent of the total extent of Sri Lanka. The location of the research area may be seen in figure 3.1

Fig. 1 The location of the research area




All three rivers in the dry zone have a fan- shaped structure of the study area. These are, but seasonal streams, with water flowing mainly during the rainy season. A tropical monsoon climate prevails here. The average temperature ranges from 28.C to 30 .C. Rainfall varies from 1250mm to 2000mm.

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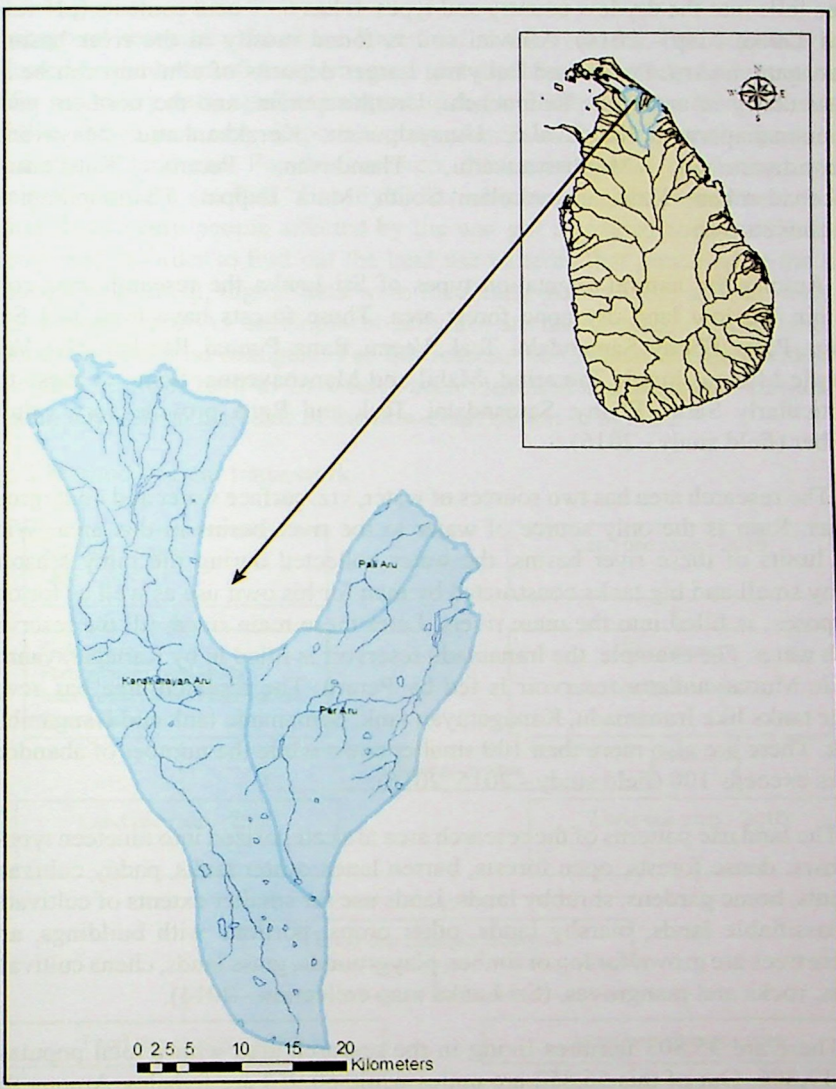


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According to Sri Lankan soil classification, the soil resource of the research area falls into the dry low country soil types. It has 6 - 7 acid contents (pH value). (Sri Lanka Map - 2014). Alluvial soil is found mostly in the river basins of KanagarayanAru, Peraru and Paliyaru. Larger deposits of alluvium can be seen particularly in areas like Kilinochchi, Urutthirapuram, and the northern part of Ramanathapuram, Kandavalai, Umayalpuram, Korakkankattu, Mayavanoor, Mavadiyamman, Mutthaiyankattu, Thanduvan, Peraru, Katsilaimadu, Tacchadamban, Kanagarayankulam South, Mara Iluppai, Tharmapuram and Putthuvettuvan.

Among the natural vegetation types of Sri Lanka the research area comes within the low land dry zone forest area. These forests have trees like Satin, Naga, Palai, Ebony, Samandalai, Teak, Veerai, Rana, Punnai, Ilanthai, Itthi, Vahai, Jungle Mango, Jungle Tamarind, Mahil and Manchavenna. Some of these trees particularly Satin, Ebony, Samandalai, Teak and Rana provide very valuable timber (field study - 2016).

The research area has two sources of water, viz: surface water and underground water. Rain is the only source of water to the river basins in this area. Within the limits of these river basins, the water collected during the rainy season in many small and big tanks constructed by man for his own use as well as for other purposes, is filled into the main rivers. Later these main rivers fill the reservoirs with water. For example, the Iranamadu reservoir is filled in by Kanagarayanriver while Muttaiyankattu reservoir is fed by Peraru. The research area has several large tanks like Iranamadu, Kanagarayan tank, Semamadu tank and Kangambikai tank. There are also more than 100 smaller tanks while the number of abandoned tanks exceeds 100 (field study - 2015, 2016).

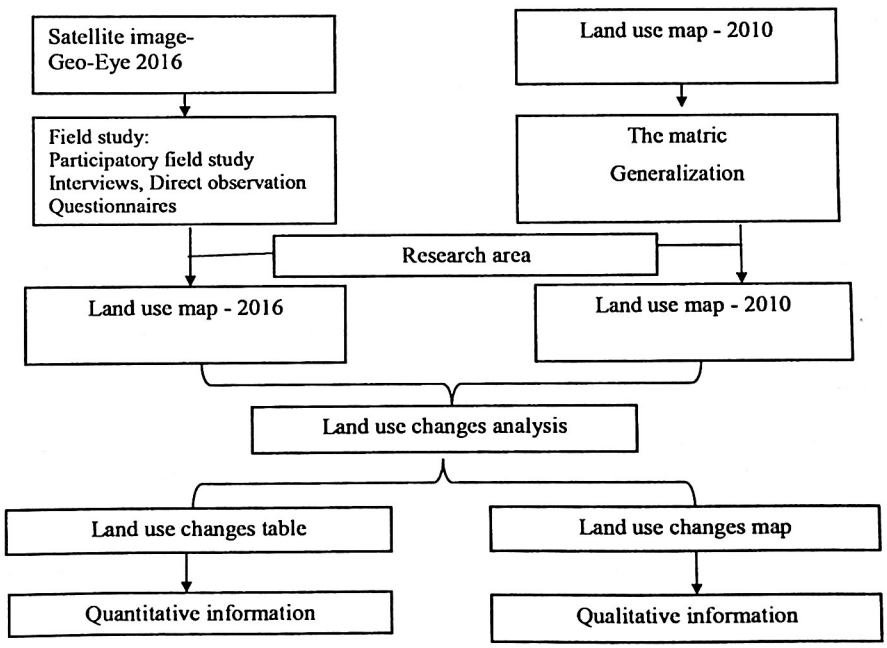
The land use patterns of the research area are categorized into nineteen types as follows: dense forests, open forests, barren lands, water tanks, paddy cultivation extents, home gardens, shrubby lands, lands use for smaller extents of cultivation, unclassifiable lands, marshy lands, other crops, portions with buildings, areas where trees are grown for log or timber, playgrounds, grass lands, chena cultivation areas, rocks and mangroves. (Sri Lanka map collection - 2014).

There are 35,803 families living in the research area with a total population of 117,806. Out of this 56,852 are males while 60,954 are females. Among them 95 percent of the families have agriculture as their chief occupation (Field study 2016). This is supported by the favourable soil and water resources found in this area.

## Data, methods of data collection and analysis

Primary and secondary data have been used in this research. Primary data were collected on the bases of questionnaires, participatory field study, and interviews. As for secondary data, satellite images and digital land use maps have been used. Satellite image is a very important data source in determining the periodical variations of land use. For this research, 0.5 meter spatial resolution images obtained from the satellite "Geo-Eye" have been used. The research area is a region from where people affected by the war got displaced and resettled after some years. In order to find out the land use patterns that prevailed at the time of such resettlement, digital data were metrically generalized, and the map for 2010 was prepared. As development activities are taking place rapidly, land use patterns also keep on changing. For this reason, the land use changes within the short interval from 2010 to 2016 have been identified and mapped. Analysis has been undertaken on the basis of the flow chart shown in figure 2.

Fig. 2 Methodological framework




The land use maps obtained from satellite images were visually interpreted and thereafter any unclear features in the land use were renovated and identified. On the basis of the confusion matrix based on GIS the extents transformed from one particular land use to another type of land use, and the extent of land use

into one particular type of land from another, each land use for the years 2010 and 2016 have been calculated. This is indicative of the changes that took place between the two years. The diagonal indicates the land use extents that had not been subject to any land use changes. Through the confusion matrix, maps and tables have been obtained showing how the land use changes had taken place quantitatively and qualitatively. Each land use change has been calculated in hectares and percentages.

## Results and discussion

### Land use patterns to 2010 and 2016

The land use patterns for the years 2010 and 2016 have been mapped in this research. Table 1 explains how the land use existed during each of the years 2010 and 2016. This can also be observed in figures 3 (2010) and 4 (2016).

Forests have been more dominant in the land use patterns of the research area during the year 2010. There had been various types of forests including dense forest, open forests and forests cut down for timber. 48.27% of the research area was under forests. Paddy cultivation had spread for over 15.66% of the research area, following which shrub lands occupy 9.08% of the area. These three categories occupy much of the land use patterns in the research area, while the other types of land use are as indicated below: home gardens 7.78%, tanks 5.45%, less cultivated areas 4.92% and barren lands 3.21%. From these the aspects of land use in 2010 could be known.

An observation of the land use patterns in 2016, show that much extents had been devoted for forests, paddy cultivation, shrub lands and home gardens, which respectively represent 46.88%, 15.23%, 11.07% and 7.39% of the total land use. The other land use patterns may be observed in table 1 and figure 4.

### Land use changes 2010 - 2016

The term 'land use change' refers to how the land use aspects of a particular period, are changed during a later period. This can be studied by comparing the land use aspects of two different periods. Thus, the changes that occurred between the years 2010 and 2016 can be observed in figure 5. In other words, figure 5 shows what types of land use changes had taken place within a period of six years, i.e. in 2016 due to the rapid development. Activities that followed the resettlement processes that had taken place since 2010.

At the same time the changes in land use patterns between the said two years are more clearly illustrated in confusion matrix table 2.

Table 1: Land use patterns – 2010, 2016

| | Land use | 2010 | | 2016 | | Difference | |
|---|---|---|---|---|---|---|---|
| | | Area (Ha) | % | Area (Ha) | % | Area (Ha) | % |
| 01 | Built up area | 168.19 | 0.12 | 336.43 | 0.24 | +171.24 | +0.12 |
| 02 | Barren land | 4,388.11 | 3.21 | 4,042.57 | 2.96 | -345.54 | -0.25 |
| 03 | Chena | 51.98 | 0.04 | 88.68 | 0.07 | +36.70 | +0.03 |
| 04 | Dense forest | 47,024.68 | 34.45 | 43,722.12 | 32.03 | -3,302.56 | -2.42 |
| 05 | Open forest | 17,729.81 | 12.99 | 19,271.00 | 14.12 | +1,541.19 | +1.13 |
| 06 | Forest plantation | 1,131.43 | 0.83 | 1,015.23 | 0.73 | -116.20 | -0.10 |
| 07 | Grassland | 119.26 | 0.09 | 119.26 | 0.09 | 0.00 | 0.00 |
| 08 | Homesteads/Garden | 10,614.04 | 7.78 | 10,091.13 | 7.39 | -522.91 | -0.39 |
| 09 | Hydro | 7,439.92 | 5.45 | 7,452.15 | 5.46 | +12.23 | +0.01 |
| 10 | Mangrove | 6.12 | 0.01 | 6.12 | 0.01 | 0.00 | 0.00 |
| 11 | Marsh | 2,177.24 | 1.60 | 1,993.76 | 1.46 | -183.48 | -0.14 |
| 12 | Other cultivation | 2,100.79 | 1.54 | 2,265.92 | 1.66 | +165.13 | +0.12 |
| 13 | Paddy | 21,380.97 | 15.66 | 20,784.67 | 15.23 | -632.30 | -0.43 |
| 14 | Playground | 27.52 | 0.02 | 27.52 | 0.02 | 0.00 | 0.00 |
| 15 | Rock | 45.87 | 0.03 | 45.87 | 0.03 | 0.00 | 0.00 |
| 16 | Sand | 314.97 | 0.23 | 314.97 | 0.23 | 0.00 | 0.00 |
| 17 | Scrub land | 12,405.98 | 9.08 | 15,106.12 | 11.07 | +2,700.14 | +1.99 |
| 18 | Sparsely used cropland | 6,718.25 | 4.92 | 6,978.17 | 5.11 | +259.00 | +0.19 |
| 19 | Unclassified | 2,666.51 | 1.95 | 2,846.92 | 2.09 | +180.41 | +0.14 |
| | Total | 136,511.62 | 100.00 | 136,511.62 | 100.00 | | |

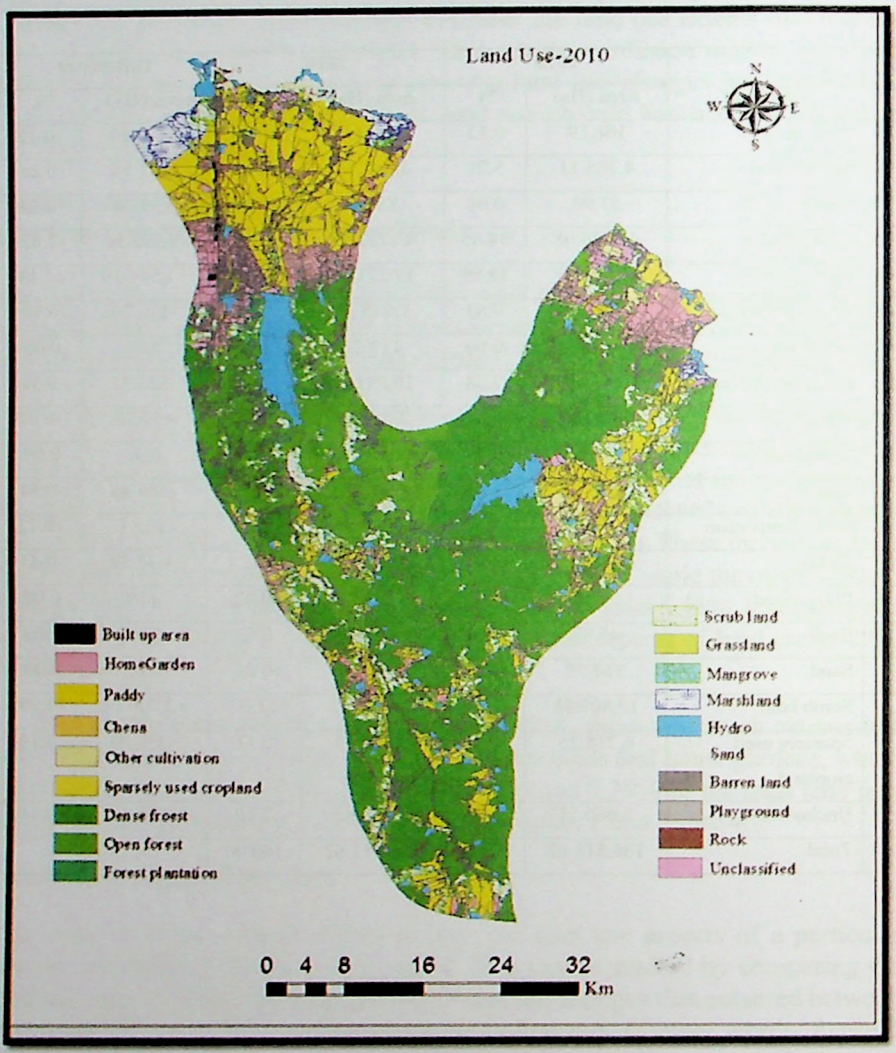



**Fig. 3: Land use patterns- 2010**

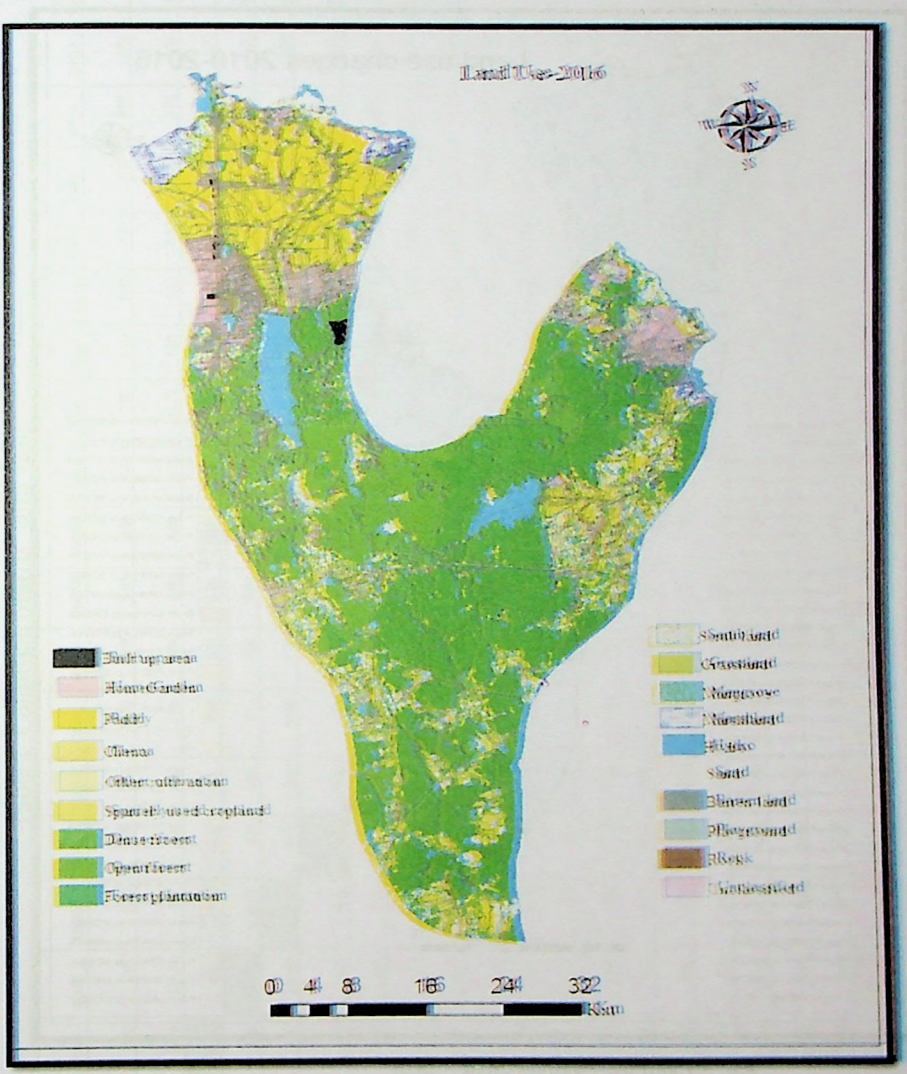



**Fig. 4: Land use patterns- 2016**

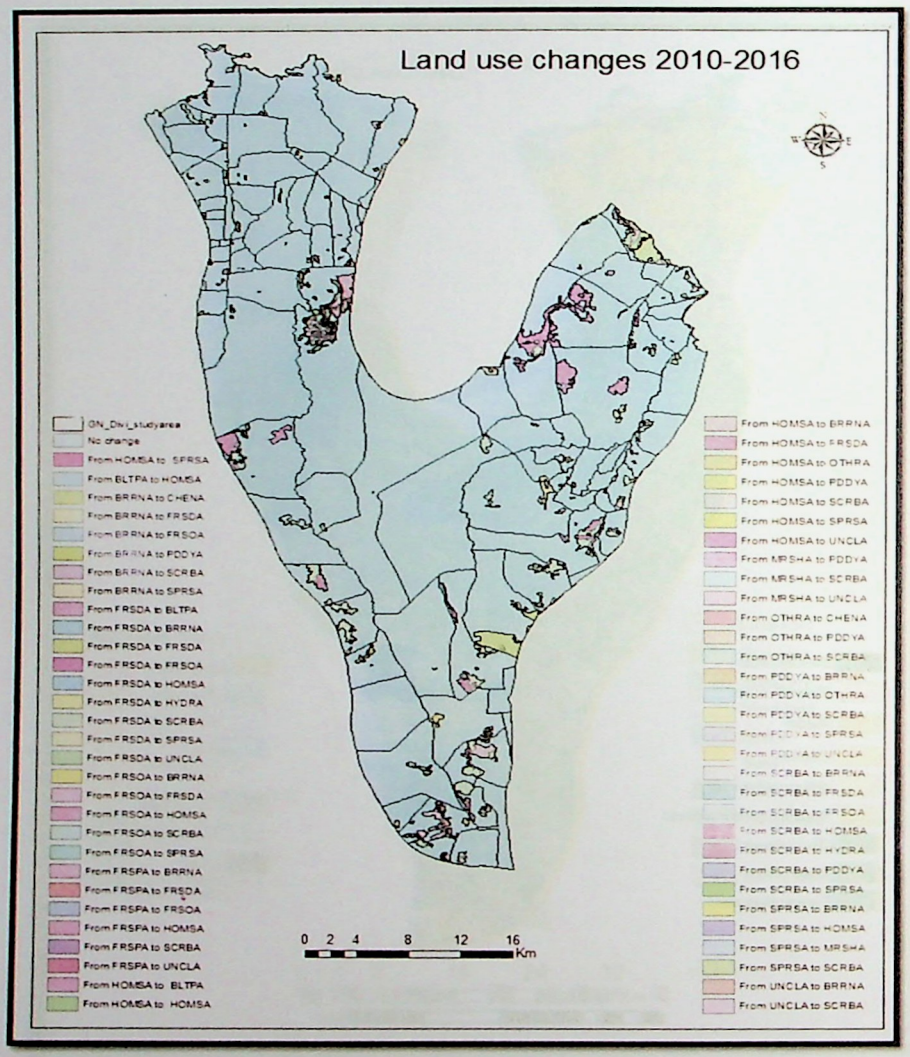



**Fig. 5 Land use changes 2010 – 2016**

## Table 2 Confusion Matrix 2010 -2016

| LU_TP_CL_1 | BLTPA | BRRNA | CHENA | FRSDA | FRSOA | FRSPA | GRSLA | HOMSA | HYDRA | MNGRA | MRSHA | OTHRA | PDDYA | PLGDA | ROCKA | SANDA | SCRBA | SPRSA | UNCLA | total2010 (ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BLTPA | 146.78 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 21.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 168.19 |
| BRRNA | 0.00 | 3908.02 | 15.29 | 149.84 | 9.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.29 | 0.00 | 0.00 | 0.00 | 287.44 | 3.06 | 0.00 | 4388.11 |
| CHENA | 0.00 | 0.00 | 51.98 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 51.98 |
| FRSDA | 192.65 | 12.23 | 0.00 | 42758.88 | 2152.77 | 0.00 | 0.00 | 6.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1865.33 | 33.64 | 3.06 | 47024.68 |
| FRSOA | 0.00 | 0.00 | 0.00 | 256.87 | 17084.59 | 0.00 | 0.00 | 30.58 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 357.78 | 0.00 | 0.00 | 17729.81 |
| FRSPA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1015.23 | 0.00 | 6.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 91.74 | 0.00 | 18.35 | 1131.43 |
| GRSLA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 119.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 119.26 |
| HOMSA | 0.00 | 39.75 | 0.00 | 27.52 | 0.00 | 0.00 | 0.00 | 10008.57 | 0.00 | 0.00 | 0.00 | 162.07 | 88.68 | 0.00 | 0.00 | 0.00 | 36.70 | 155.95 | 94.80 | 10614.04 |
| HYDRA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7439.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7439.92 |
| MNGRA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.12 |
| MRSHA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1990.71 | 0.00 | 3.06 | 0.00 | 0.00 | 0.00 | 162.07 | 0.00 | 21.41 | 2177.24 |
| OTHRA | 0.00 | 0.00 | 21.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2061.04 | 3.06 | 0.00 | 0.00 | 0.00 | 15.29 | 0.00 | 0.00 | 2100.79 |
| PDDYA | 0.00 | 58.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 42.81 | 20653.18 | 0.00 | 0.00 | 0.00 | 88.68 | 486.21 | 51.98 | 21380.97 |
| PLGDA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 27.52 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 27.52 |
| ROCKA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 45.87 | 0.00 | 0.00 | 0.00 | 0.00 | 45.87 |
| SANDA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 314.97 | 0.00 | 0.00 | 0.00 | 314.97 |
| SCRBA | 0.00 | 6.12 | 0.00 | 529.02 | 24.46 | 0.00 | 0.00 | 3.06 | 12.23 | 0.00 | 0.00 | 0.00 | 18.35 | 0.00 | 0.00 | 0.00 | 11800.51 | 12.23 | 0.00 | 12405.98 |
| SPRSA | 0.00 | 18.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.29 | 0.00 | 0.00 | 3.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 394.47 | 6287.08 | 0.00 | 6718.25 |
| UNCLA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.06 | 0.00 | 0.00 | 0.00 | 6.12 | 0.00 | 2657.33 | 2666.51 |
| total2016 (ha) | 339.43 | 4042.57 | 88.68 | 43722.12 | 19271.00 | 1015.23 | 119.26 | 10091.13 | 7452.15 | 6.12 | 1993.76 | 2265.92 | 20784.67 | 27.52 | 45.87 | 314.97 | 15106.12 | 6978.17 | 2846.92 | 136511.62 |

The observation of the changes between two years on the basis of table 2 indicates that while certain land uses have been added into other types of land uses, the extent of certain other land use patterns has been reduced. However, the land use patterns in the main diagonal of the table have not changed. However, when the figures away from the diagonal are read horizontally, it indicates how many hectares of a particular land use has changed into another pattern of land use or rather how many hectares of land each land use has been altogether lost. At the same time when read vertically from the diagonal, it indicates what other land uses have been amalgamated into a particular type of land use.

Whereas the built up areas which occupied 168.191 hectares in 2010, increased to 339.43 hectares, during both periods no change occurred within an extent of 146.78 hectares. An extent of 21.41 hectares out of the 169.19 hectares of built up areas in 2010 has been converted to home gardens. This change has taken place mostly in the Grama sevaka divisions of Thirunagar South and Puthukkudiyiruppu. At the same time in 2016, 192.65 hectares of dense forests, have come under builtup areas. This change has taken place in Ambagamamgrama officer division. Since the research area is a resettled region, the increase in building activities particularly along road sides, can also be seen through the land use changes map. As this area is developing fast, building activities are going on at a rapid pace. The aforesaid reasons were the cause for the increase in building activities during the period from 2010 to 2016.

The barren lands which occupied 4388.11 hectares in 2010, decreased to 4042.57 hectares in 2016, while no changes occurred in an extent of 3908.02 hectares. The 4388.11 hectares of barren lands in 2010, has transformed respectively into 15.29 hectares of chena cultivation, 149.84 hectares of dense forests, 9.17 hectares of open forests, 15.29 of paddy cultivation, 287.44 hectares of shrub land, and 3.06 hectares of cultivation in small scale. Most of these changes have taken place around the grama officer divisions Vannerikkulam, Ambagamam, Thirumuruhandy, Ambalavanpokkanai and ArumuhatthanPuthukkulam. At the same time, in 2016, 12.23 hectares of dense forests, 39.75 hectares of home gardens, 58.10 hectares of paddy cultivation lands, 6.12 hectares of shrub lands and 18.33 hectares of small scale cultivation have crept into barren lands. Most of these changes have taken place in the grama officer divisions Ponnagar, Rathnapuram, Barathipuram, Vattakkacchi, Mannakandal and Aanandapuram. Shortage of water is the main cause for the lands of paddy cultivation, home gardens and the lands of small scale cultivation to be converted into barren lands.

While in 2010 51.98 hectares of the lands of chena cultivation land was remaining unchanged, in 2016 21.41 hectares of other cultivated crops had crept into it. As a result the extent of chena cultivation in 2016, increased to 88.08. For this too, lack of water was the main cause. Chena cultivation is an activity that depends fully on the availability of rainfall.

While observing the land use changes of dense forests, the extent of 47,024.68 in 2010 was found to be 43,722.12 hectare in 2016, and there was no change in the extent of 42,758.88 hectares during both periods. The 47,024.68 hectares of dense forests, have changed respectively into 192.65 hectares of built up area, 12.23 hectares of barren land, 2152.77 hectares of open forests, 6.12 hectares of home gardens, 1865.33 hectares of shrub land, 33.64 hectares of small scale cultivation land, and 3.06 hectares of unclassifiable land. The main reason for these changes is the rapid development programmes that followed the resettlement in this area. Most of these changes have taken place in the grama sevaka divisions of Ambagamam, Mankalam, Kanagarayankulam north and Puliyankulam south. At the same time, in 2016, 149.84 hectares of barren lands, 256.87 hectares of open forests, 27.52 home gardens and 529.02 hectares of shrub lands have got converted into dense forests. Such changes have occurred in the grama sevaka divisions of keppapilavu, AmbalavanPokkanai, Panrikkeythakulam, Ambagamam, Udayarkattu south, Kombavil and Sinnadamban.

Out of the total land use in 2010, 17729.81 hectares were open forests. Out of this, while 17,084.59 hectares remained unchanged, an extent of 256.87 hectares changed into home gardens while 357.78 hectares changed into shrub lands. A greater part of these changes have taken place in the grama sevaka divisions of Puthukkudiyiruppu east, Umayalpuram, Thirunagar south, Arumuhatthan and Puthukkulam. The extent of open forests has increased in 2016. That is to say that changes have taken place in the use of open forests during the period between 2010 and 2016. During this period 2152.77 from dense forests, 9.17 hectares from barren lands, and 24.46 hectares from shrub lands had mingled into the open forest category. The cutting down of the huge trees in the dense forests may have led to the reduction in the density of these forests which eventually became open forests. At the same time a few large trees around shrub lands may have grown bigger to form open forests. Most of such changes have taken place in the Grama sevaka divisions of Sinnadamban, Mannakandal, Panikkankulam, Vallipunam and Mayavanoor.

The area where trees were grown for logs or timber, had an extent of 1131.43 hectares in 2010. While 1015.23 hectares remained unchanged, 6.12 hectares changed into home gardens, 91.74 hectares into shrub lands while 18.35 hectares fell into the category of unclassifiable land use. The activities of the people after their resettlement and the changes that occurred in areas where trees were grown for logs and timber may be understood as shown below.

| **Activities** | **Changes** |
|---|---|
| Showing interest in home gardening | Development of home gardens. |
| Cutting down trees for miscellaneous purposes | Formation of shrub lands. |
| Unplanned urgent establishment of settlements | Development of Unclassifiable lands |

Such changes have occurred in the grama sevaka divisions of Kathaliyar Sammankulam, Karuvelankandal, Ottusuttan and Putthuvettuvan. In 2016 the extent of area where trees are grown for logs, has decreased to a mere 1015.23 hectares. The reason is that while this area has mostly been utilized for the various land uses mentioned above other land uses had not been brought into this.

In the land use patterns of the research area, the extent of grass lands found in 2010 remained same in 2016 too. That is to say that the 119.26 hectares of grass land that existed in 2010, was again found to be 119.26 hectares in 2016. This shows that while grass lands have not been converted to other land uses, there has not been any intrusion of other land uses into grass lands. These are not permanent grass lands. Grass is found during rainy seasons and they dry up to be grassless areas during dry seasons.

According to the land use patterns of 2010, home gardening occupied 10614.04 hectares. Whilst 10008.57 remained unchanged, elsewhere the following changes have taken place: 39.75 hectares barren lands; 27.52 hectares dense forest; 162.07 hectares other crop cultivation; 88.68 hectares small scale cultivation; and 94.80 hectares unclassifiable land use. Most of these changes have taken place in the grama sevaka divisions of Ambagamam, Mankulam, Katsilaimadu, Karuvelankandal and Puliyankulam south. At the same time, the following extents of land use have got included into the home garden extent in 2016 : 21.41 hectares of built up land, 6.12 hectares of dense forests, 30.58 hectares of open forests, 6.12 hectares of timber areas, 3.06 hectares of shrub land and 15.29 hectares of small scale cultivation areas. These changes have taken place in the gramasevaka divisions of Vivekanandanagar, Ananthapuram, Thondamannagar, Uthayanagar east and Kanagambikaikulam. Since the research area is a resettled region, people are more and more engaged in home gardens with the view to increase their income. In Mutthaiyankattu and Karuvelankandal areas, home gardens are often closely attached to settlements. At the same time, as land was fragmented in order to obtain housing schemes, it has led to the decrease of home garden extent in 2016, rather than in 2010.

In 2010, the land use patterns indicate that 7439.92 hectares were occupied by water bodies including small and big tanks. In 2016, this area is seen increased to 7452.15. During this period 12.23 hectares of shrub lands have mingled with water bodies. During the occurrence of heavy rainfall, when the cubic measure of water increases, the nearby land extent tend to become water spots. In the grama sevaka divisions of ArumuhatthanPuthukkulam and Koolamurippu such tendency has led nearby shrub lands to become small water bodies. That is how the extent of water bodies is seen to have increased by 12.23 hectares, in 2016, rather than it was in 2010. No changes have taken place in the extent of mangroves which occupied 6.12 hectares in 2010 as well as in 2016. At the same time the land

use map for 2010 shows the extent of marshy land as 2177.24 hectares. Though 1990.71 hectares of marshes had not undergone any changes, 3.06 hectares of marshes went under paddy cultivation while 162.07 hectares and another 21.41 hectares respectively became strub lands and unclassifiable lands. Such changes have occurred mostly in the grama sevaka divisions of KathaliyarSmmalankulam, Manthuvil, Ratnapuram, Vivekanandanagar, Vattakkacchi, Mayavanoor and Kandavalai. In the land use pattern of 2016, there were 1993.76 hectares of marshes. During this period 3.06 hectares of land for small scale cultivation has come under marshy land. This change took place in the grama sevaka division of KunchuParanthan. When the water decreases in water bodies, they eventually become marshy. This situation can be noticed in Umayalpuram area.

While the extent of 2016.04 hectares of other crops in 2010, remained unchanged, the following changes have subsequently taken place, i.e. 3.06 hectares into paddy cultivation, 15.29 hectares into shrub land, and 21.41 hectares into chena cultivation lands. In other words, 2100.79 hectares of land were under other crops cultivation in 2010. During this period most changes had occurred in the grama sevaka divisions of Karuvelankandal, Ananthapuram, Thirumurukandy, Murasumottai and Puliyampokkanai. In 2016, the extent of other erops cultivation increased upto 2265.92 hectares. During this period 162.07 hectares of home gardens and 42.81 hectares of paddy cultivation got added into other crops cultivation extents. Consequently in 2016, it could be observed that the extent of other crops' cultivation had increased in 2016 by 165.13 hectares, than in 2010. This increase had taken place in the grama sevaka divisions of Ottusuttan, Mutthuvinayakapuram and Kulavisuttan.

An observation of the extent of land use under paddy cultivation shows that 21,380.97 hectares had been under paddy cultivation. While 20,653.18hectares remained unchanged, the following hectares of land have changed as indicated below:58.10 hectares -Barren lands, 42.81 hectares -Other crops, 88.68 hectares -Shrub lands, 486.21 hectares - Small scale crops, 51.98 hectares -Unclassifiable

Insufficiency of water is the main cause for these changes. Most of these changes have occurred in the grama sevaka divisions of Ambagamam, Umayalpuram and PeriyaItthimadu. The area under paddy cultivation came down to 20,784.67. The main cause for this reduction was the renovation activities that took place during this period at the Iranamadu reservoir. In fact, most of the land of paddy cultivation in the research area depended on irrigation from Iranamadu reservoir. Yet, during this period 15.29 hectares of barren land, 88.68 hectares of home gardens, 3.06 hectares of marshy land, 3.06 hectares of other crop cultivation lands, 18.35 hectares of shrub lands and 3.06 hectares of unclassifiable land had been brought under paddy cultivation. Much of this paddy cultivation is rain fed. Most of these changes have taken place in the grama sevaka divisions of Pandaravanni, Mannakulam, Panikkankulam and Mayavanoor.

One of the land use patterns of the research is the playground. This is found without any changes in its extent of 27.52 hectares, throughout the period from 2010 to 2016. Similarly, the rocky areas also have remained unchanged during both years. They have remained in the same extent of 45.87 hectares during the years 2010 and 2016. Sandy areas too have been found stretching within an extent of 314.97 hectares, without any change.

An observation of the shrub lands reveals that though it had an extent of 12,405.98 hectares in 2010, while 11,800.51 hectares had remained unchanged the changes indicated as per table below have taken place :

| | | |
|---|---|---|
| 6.12 hectares | - | Barren lands |
| 529.02 hectares | - | Dense forests |
| 24.46 hectares | - | Open forests |
| 3.06 hectares | - | Home gardens |
| 12.23 hectares | - | Paddy lands |
| 12.23 hectares | - | Small scale cultivation |

A greater part of these changes have taken place in the grama sevaka divisions of Semamadu, Sinnadamban, Ambagamam, AmbalavaaPokkanai, Vallipunam, KathaliyarSammalankulam, MannakulamPeriyaIttimadu and Ratnapuram. In these areas, the people after their resettlements have brought in changes in their land use as a matter of improving their economic activities. That is how, a large extent of shrub lands have been converted to other land uses. At the same time, in 2016 the extent of shrub lands was found increased to 15,106.12 hectares. During this period 287.44 hectares of barren lands, 1,865.33 hectares of dense forests, 357.78 hectares of open forests, 91.74 hectares of forest area for logs and timber, 36.70 hectares of home gardents, 162.07 hectares of marshy land, 15.29 hectares of other crop cultivation, 88.68 hectares of paddy cultivation area, 397.47 hectares of small scale crop cultivation land and 6.12 hectares of unclassified land have all been brought under the land use pattern of shrub lands. Particularly, large extents of lands have been converted into shrub lands. The main reason for this situation is that the above land uses had not been properly adhered to when the war was going on. In other words, this was a result of improper land use patterns. For example the lands normally utilized for paddy cultivation, home gardening or small scale cultivation, were left unused for want of irrigation and financial support, which eventually made the lands to be abandoned into shrub lands. At the same time, the destruction of dense, open and timber forests by security forces for their safety and other requirements also made those areas turn into shrub lands. Such changes have mostly taken place in the grama sevaka divisions of Ambagamam, Mankulam, Urutthirapuram north, Puthukkudiyiruppu west, Mara Iluppai, Sinnadamban, Vedivaitthakallu, Kanagarayankulam north, Keppapilavu

and Mannakandal. The results of the research point out that in 2016 the extents of shrub land have increased more by 2700.14 hectares than in 2010.

In 2010, small scale crop cultivation had been prevalent over an extent of 6,718.25 hectares. While 6,287.08 hectares remained unchanged, the following extent of land had undergone changes as indicated below:

| **Extents** | **Land use changes into** |
|---|---|
| 18.35 hectares | Barren lands |
| 15.29 hectares | Home gardens |
| 3.06 hectares | Marshy lands |
| 394.47 hectares | shrub lands |

Most of these changes have taken place in the grama sevaka divisions of Kunchuparanthan, Ananthapuliyankulam, Ananthapuram, Thirunagar south and Thattuvankotty. During the year 2010 the extent of small scale crop cultivation was found to be 6,978.17 hectares. Into this the following extents had been added :

| **Extents** | **Added land uses** |
|---|---|
| 3.06 hectares | barren lands |
| 33.64 hectares | Dense forests |
| 155.95 hectares | Home gardens |
| 486.21 hectares | Paddy cultivation |
| 12.23 hectares | Shrub lands |

A greater part of these changes had taken place in the grama sevaka divisions of Kanagarayankulam south. Ottusuttan, Vallipunam, Mayavanoor, Ambalnagar, Parathipuram and Ganesapuram. Though the areas under small scale crop cultivation in 2010 had been converted to other land uses, as various other land uses had crept into small scale crop cultivation, the extent of this type of land use has increased by 259.92 hectares in 2016 than what it was in 2010.

In 2010 the extent of unclassified or unclassifiable land was 2,666.51 hectares. Out of this, while 2,567.33 hectares remained unchanged, 3.06 hectares have been converted to paddy cultivation and 6.12 hectares to shrub lands. Such changes have occurred mainly in the grama sevaka divisions of Ponnagar, ManavalanPattamurippu, Anandapuliyakulam, Mahilankulam and Arumuhathan Puthukkulam. At the same time, when the land use patterns of 2016 were looked into, it is found that the extent of unclassifiable land was 2,846.92 hectares. Into this land use, 3.06 hectares of dense forests, 18.35 hectares of land for logs and timber, 94.80 hectares of home garden lands, 21.41 hectares of marshy land and 51.98

hectares of paddy cultivation lands have mingled. Changes of this type have taken place mostly in the grama sevaka divisions of Ambagamam, Anandapuliyankulam, Mannakandal, Vallipuram, Kombavil, Ambalavanpokkania, Thiruvayaru west Ratnapuram and Vattakkacchi. The results of the research show that the extent of this land use in 2010 had increased by 180.41 hectares in 2016. The main reason for this situation is that people, soon after their resettlement have used their lands in unsuitable ways in their attempts to revive their lost economy. Particularly the use of paddy lands as home garden areas, and the conversion of home garden areas into settlements make it difficult to accommodate them into any particular land use. As such they have been taken into a land use known as unclassifiable lands. The increase in the extent of unclassifiable lands may also be attributed to the toils of the people inorder to increase their income, as well to bring available lands under maximum use.

**Conclusion**

This research under the title "Mapping and evaluation of land use changes based on selected river basins of north Sri Lanka", ventures to explain the various changes that took place in the research area during the period from 2010 to 2016. In this regard the maps that show the results of the land use patterns and land use changes are of great importance. The grama sevaka divisions in the selected river basins are developing at a very rapid pace. Particularly, building activities are taking place very fast after resettlement. The highest number of buildings have been erected in the grama sevaka divisions including Kilinochchi, a part of Ambagamam, Thirumurukandy, Vivekanandanagar and PeriyaParanthan. Particularly along the areas adjoining to the main roads one can see the rise of business institutions and service centres amidst crowded settlements. Since the roads have been repaired, traffic movements go on very smoothly. Areas which were formerly under home gardens and forests, now appear transformed into areas crowded with buildings and also occupied with the cultivation of other crops. Though land use changes are thus going on in the research area, yet further attention has to be paid to some other aspects. Especially when lands are utilized for settlement purposes, it must be ascertained that such lands are of lesser importance for other land uses. For example, the areas in proximity to the A9 highway are fast changing into settlements. This is the need of the hour. Such changes are acceptable as these are in keeping with the rapid increase in population. However, the changes taking place in forest areas do not appear to be tangible. They can possibly disturb the equilibrium in the natural environment. Hence, it is important to pay attention towards land use changes in the areas of settlement, agriculture and forests. This means that if at all land use changes in the research area must appear tangible, land use patterns must essentially be born in mind when future plans are undertaken. Hence, this research while having mapped and illustrated the land use patterns and their changes, it has become possible to learn the changes both quantitatively and

qualitatively. In addition, this research is expected to be of guidance in any future studies related to river basins in the north of Sri Lanka and elsewhere.

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