Analyzing the effects of land use and land cover changes on paddy cultivation using Remote Sensing: A case study of Sooriyawewa, Sri Lanka

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Abstract*: Land-use and land-cover (LULC) change research is a type of environmental research that is intimately linked to socioeconomic development. At present, the LULC changes are mainly occurred due to physical developments and agricultural purposes. Paddy is the major crop and mostly grown in Sri Lanka. Hambantota district rank as fifth place in rice production in Sri Lanka. Sooriyawewa is the driest and mostly grown paddy Divisional Secretary Division (DSD) in Hambantota District, but nowadays there are so many reasons that hinder paddy cultivation. This research aims to identify the existing system for monitoring the LULC changes in paddy cultivation and applicable Remote Sensing techniques, then quantify the LULC changes over paddy cultivation in Sooriyawewa during the past four decades and finally examine the underlying causes for LULC changes over the paddy. For this research, downloaded Landsat images from 1980 to 2019 with a specified time gap and Supervised classification was used for the land cover classification for all images to detect the paddy variation in this area. Obtained net changes between 1980-2019 are Paddy, Other crops, Forests, Waterbodies, Built up areas and barren lands. According to the LULC changes between 1980-2019, there was a -15.50% decrease in paddy areas but built-up areas, other crops significantly increase 11.97%, 10.08% respectively. This is a temporal problem in this area and this study is essential for the relevant authorities for decision making, preparing urban development plans, where planned infrastructural development and supervision, land use planning, natural resource conservation and environmental sustainability.*

Keywords: *Land use and Land cover, Classification, Remote Sensing*

1. Introduction

At present, Land Use and Land Cover (LULC) changes are mainly occurring due to physical developments and agricultural purposes (US Department of Commerce, 2020). Land use implies human activities which directly involve to the site and land cover means the vegetation, water, natural surface, and man-made features of the site (Us Geological Survey, 1997).

Land cover can be identified by analyzing aerial and satellite images, but land use cannot be identified through satellite images (US Department of Commerce, 2020). Analyzing these LULC changes are very important for land surveyors and spatial planners because, land cover maps procure details to realize the current landscape properly (US Department of Commerce, 2020). To examine past changes, different years of land cover maps are needed, and this information is useful for authorities to evaluate past management decisions as well as possible effects of their current decisions before they are proceeded (US Department of Commerce, 2020). Rapid increment of population growth, limitations of the arable lands, plant

diseases, environmental changes (temperature variations, water shortages, floods) and climate changes are the main issues for food security in Asian regions (Huang et al., 2014). So, developing countries are increasing agricultural production to uplift the food supply and increase employment and income.

Rice (Oryza sativa) is one of the staple food crops of the world. Most Asian countries use rice as second in agriculture production (Dengiz and Formation, 2015). In the past, Sri Lanka is one of the prominent countries for rice production in the world and paddy is the major crop and mostly grown in Sri Lanka (doa.gov.lk. 2013). Main area of rice cultivating are Ampara, Kurunegala, Polonnaruwa, Matara, Hambantota, Baticola, Anuradhapura (Paddy Statistics, 2019). The study area of the research is Sooriyawewa Divisional Secretary Division (DSD), in Hambantota district, dry southeastern part of Sri Lanka and Hambantota district rank as fifth place in rice production in Sri Lanka (Paddy Statistics, 2019). Today paddy and Other Field Crops (OFC) are the most cultivated crops in Sooriyawewa (Perming, 2013). Yala (during the period from April to August) and Maha (during the period from September to March in the following year) is the main paddy cultivation seasons (Paddy Statistics, 2019) and Maha is the most paddy cultivation season in Sooriyawewa.
Paddy crops are cultivated as wetland crops in all the districts of Sri Lanka and nowadays, the total land allocated for paddy is estimated to be about 708,000 Hectares (Paddy Statistics, 2019). However, the whole area allocated for paddy cultivation is not being cultivated due to number of reasons such as water shortages during the seasons, prevailing unsettle conditions on the ground, etc (Paddy Statistics, 2019). Due to the covid-19 pandemic period, world discussed the importance of fresh and nutrient foods from small scale rural producers (Deuja, 2020). Also, Sri Lanka had to face some issues on the food security, unable to supply for the demand so, harvest estimation is very important for that. Crop production acts a huge role in food security and the economic development of a country. Most of the farmers here tend to convert paddy fields into alternative crops for economic benefits.

At present, Sri Lanka uses traditional methods for crop monitoring. Traditional methods of crop monitoring have some issues as time-consuming, subjective, expensive, limited to some extent, large errors occur during the field observations, less efficient and less accurate (Huang et al., 2013) but, Remote Sensing is a new trend in the world for crop monitoring in the proper way and very useful for evaluating natural resources and management. Also, useful for monitoring the crop conditions, the healthiness of the crops, estimate the yields. This research focuses to identify the paddy land use changes using Remote Sensing efficiently and accurately.

This research aims to identify the existing system for monitoring the LULC changes and applicable Remote Sensing techniques, then quantify the LULC changes over paddy cultivation during the past four decades (1980-2020) in Sooriyawewa DSD and finally examine the underlying causes for LULC changes over the paddy in this study area. This analysis reveals what will be the possible changes in the study area in the past years and what are the present land use changes taking place in the area. This is a temporal problem in this area and hopes this project is essential for the relevant authorities for decision making.

2. Methodology and Experimental Design

A. Study Area

Sooriyawewa Divisional Secretariat Division (DSD) was the target area for this study. It is situated in the Southern Province of Sri Lanka, Hambantota District, bordering Sewanagala, Hambantota, Lunugamwegera and Embilipitiya DSDs and between Latitude 6° 11' 40" to 6° 24' 20" North and Longitude 80° 55' 00 " to 81° 05' 00 East.
Sooriyawewa DSD is the driest DSD in Hambantota District (Perming, 2013)

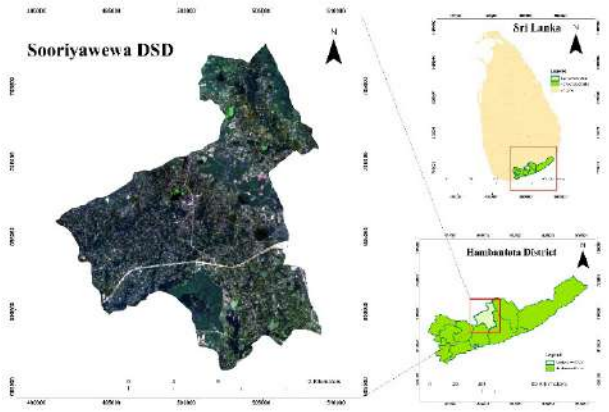

Figure 1: Study Area

Hambantota district rank as fifth place in rice production in Sri Lanka (Paddy Statistics, 2019). Today paddy and Other Field Crops (OFC), including bananas, are the most cultivated crops in Sooriyawewa (Perming, 2013). There are special features in this area for analysis. First, this area is flat, not consist with higher geological barriers for disturbing the analysis, this is a dry zone and not effect by environmental hazards such as floods, and landslides. Second, normally the area is called as a rural area, but nowadays it is changing. In near Sooriyawewa, development projects were running and the department of Census and Statistics reported the number of inhabitants increased in the past years (Perming, 2013).

Table 1: Landsat images

Satellite series	Year	Acquisition Date
LANDSAT_3	1980	1980-02-06
LANDSAT_5	1988	1988-03-02
	1992	1992-01-25
	1997	1997-02-23
	2000	2000-01-23
	2005	2005-03-17
	2010	2010-01-26
LANDSAT_8	2014	2014-01-21
	2019	2019-01-03

B. Data used

This study was conducted mainly based on quantitative analysis, and work with primary and secondary data. For this investigation, distinct Landsat images were employed on several evolution stages (Landsat 3, 5, and 8). To prevent seasonal fluctuations in this location, the images for nine distinct years were gathered with nearer acquisition dates. Maha season is from September until March the following year and chooses January to March period for downloading satellite images in each image. The Landsat images utilized in this experiment are listed in the table below.

C. Experimental Materials

1) GIS Software

All forms of geographic and spatial data are stored, managed, displayed, and analyzed using a Geographic Information System. GIS software creates visual representations of geographic data for study and presentation. The LULC categorization procedure was carried out using Arc Map 10.5 licensing software.

2) Google Earth

Google Earth is a free and open-source program. The Google Earth software was used to detect land coverings for various years and to test the accuracy of the procedure

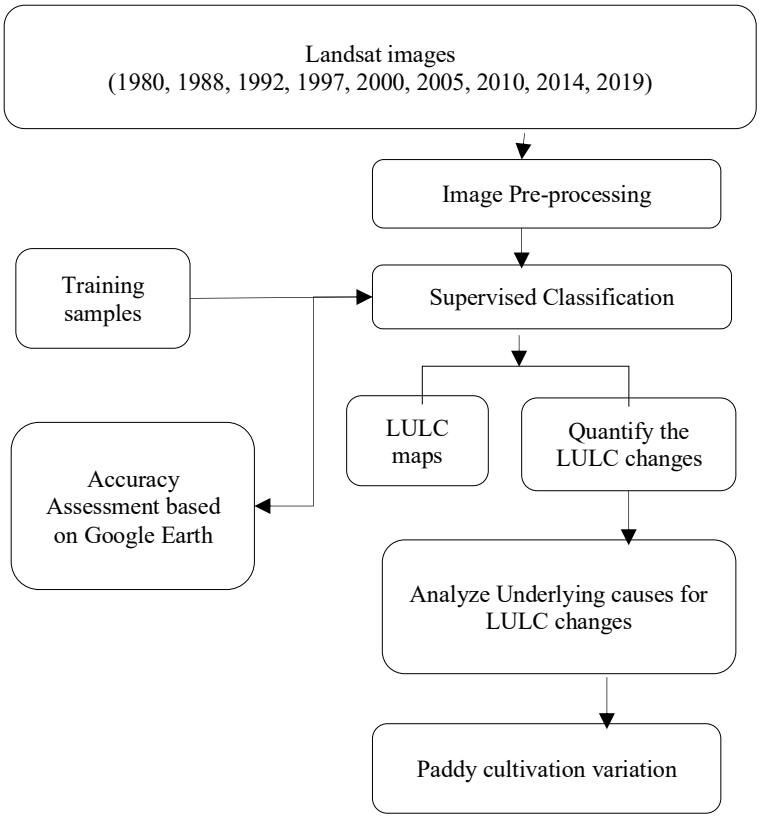

Figure 2 : Experimental Workflow

The research was conducted in three stages. First identified the existing system for monitoring the LULC changes and applicable Remote Sensing techniques. Second, quantified the LULC changes over paddy cultivation during the past four decades (1980-2020). And last, examined the underlying causes for LULC changes over the paddy cultivation in Sooriyawewa. Used past research papers to identify the existing LULC monitoring mechanism. Before the analysis, first applied single band preprocessing techniques (Radiometric calibration and atmospheric correction) to each band that use for the study.

The LULC classification is based on supervised classification. While providing training samples, supervised classification is used to recognize distinct land use classes in a particular area with maximum likelihood algorithm. Select the training samples that encompass the study area first. The experiment focused to identify paddy variation so paddy areas, other agricultural areas, forest areas, water areas, built-up areas, and barren land areas as training samples and used Google Earth to choose appropriate training sites.

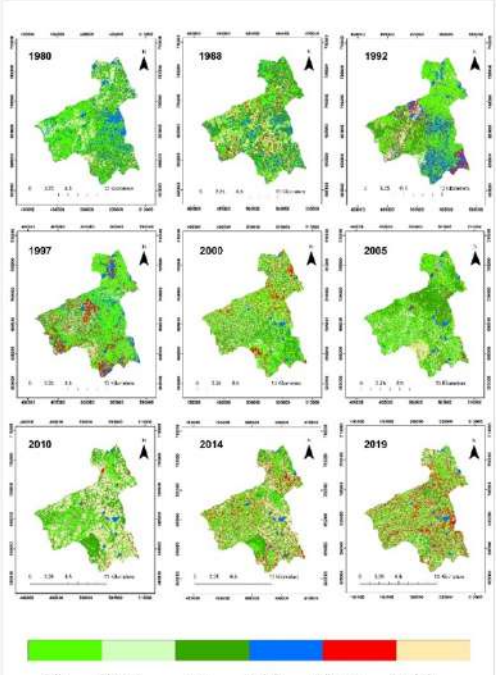

Figure 3: Supervised Classification Results

2. Results

Existing LULC monitoring systems

In the early 1950s, to show shifting patterns of land use and land cover, the researchers (Gangodawila, 1988) utilized a variety of approaches. Field inspections were utilized in addition to black and white panchromatic photographs by the researcher. To increase the accuracy of interpretation and evaluation of agricultural land, water, and resources, preliminary air photo interpretation stereoscopic pairs of images were utilized. In this (Wickramasinghe, Subasinghe and Ranwala, 2016) study, air pictures (scale 1: 40,000) from 1956 and air photos (scale 1: 20,000) from 1982 were employed. For the years 1956 through 1982, no research satellite pictures were available. As a result, aerial pictures with a scale of 1: 20,000 were utilized

at the time. From 2001 to 2010, high-quality IKONS photos (4m spatial resolution) were utilized. They georeferenced two IKONS photos and digitized them using Arc GIS 9.3 software's "on screen Digitizing" technique. Calculating the green cover change for each era and then dividing it by the number of years in that period yielded the rate of green cover change.

Crop monitoring in many countries relies on traditional data gathering approaches such as field visits and reports to estimate crop and yield (Sawasawa, 2003). These reports are frequently subjective, expensive, time-consuming, and prone to substantial inaccuracies due to incomplete ground observations, resulting in poor crop monitoring evaluation (yield estimation, area estimation). Until now, Sri Lanka only uses traditional data collecting methods for paddy monitoring.

3. LULC change analysis

The past patterns (1980–2019) of LULC variations were estimated from Landsat images using Maximum Likelihood classification, presented in Fig.3. The Maximum Likelihood classification obtained the overall classification accuracy more than 80% for each year

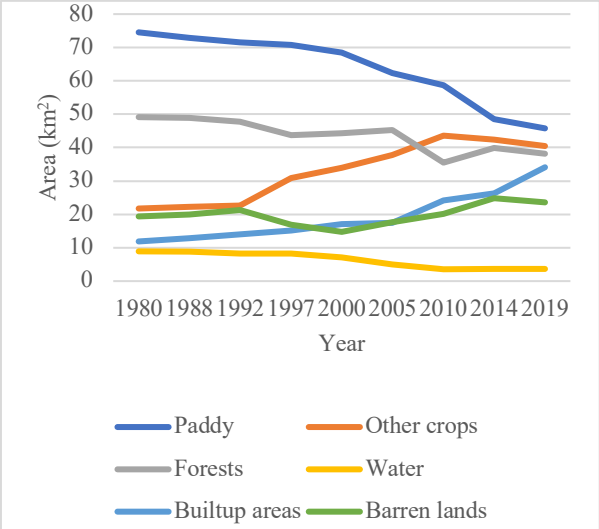

Figure 4: LULC changes between 1980 to 2019

The primary goal of this research was to discover changes in paddy areas. Diagram 4 depicts how paddy fields have evolved over the last four decades. Paddy areas have been declining since 1980, but there has been a significant drop since 2000. As well as other crops, this area cultivates a variety of crop kinds (banana, pomegranate, papaya, etc.). Other agricultural areas have expanded dramatically since 1992. The research area has low forest covering due to increasing urban development. In all directions of the research region, the decline of highly green areas was documented. However, in 2005, there was a substantial decrease. Since ancient times, water sources have been the lifeblood of human society in dozens of ways. The major challenge confronting the worldwide tourist sector is water. Instead of conserving water sources, people are encroaching on them, causing pollution and uncontrolled development plans, as well as urban growth. The declining phenomena of the previous four decades have had a direct impact on this area's agriculture, particularly rice production. Rapid, uncontrolled urban expansion shattered the natural equilibrium, making the region more unsuitable for life and agriculture. Since 2010, the government has concentrated on the Hambantota region, and

several development projects have been launched in the Hambantota District. The primary projects are Mattala International Airport, Sooriyawewa International Cricket Stadium, and the Southern Expressway. As a result, this area is growing in terms of administrative, commercial, recreational, infrastructural, telecommunications, and transportation amenities. Urbanization is accelerating for a variety of causes. Rural-urban migration, increased career possibilities, improved quality of life, and natural growth are all examples of natural growth. Although considerable urban growth is occurring in all directions in the area. All of these amenities make this study location more appealing to residents than to other people. Furthermore, the dispersion of these amenities is transforming the region into a hotspot for urban growth by attracting a rising number of business and administrative operations. In the past, these places were overlooked by rural residents, but today, individuals are drawn to these areas in search of better job prospects and a higher quality of life. The aesthetic and ecological qualities of bare lands, which are mostly unoccupied urban areas and open spaces, give environmental, social, and economic benefits to residents. The changes in bare lands during the

categorization were driven by substantial rural-urban migration and a lack of focus on conserving open areas. The extent of bare lands changed from 1980 to 2019, as seen in Fig.

4. Causes for the LULC changes

1) Water shortages

The drier parts of Sri Lanka are sometimes susceptible to water shortages due to the spatially and seasonally uneven distribution of water. The Government of Sri Lanka is aware of water management issues. The policies stress the need of conserving water. However, the work may not be simple to carry out. Although much money has been spent on restoring irrigation projects, this does not prevent individuals from using water without authorization, a subject that the farmers questioned in Sooriyawewa were concerned about.

According to several studies, Sri Lanka is experiencing a general trend of decreasing precipitation rather than increasing it (Droogers, 2004; Peiris 2006). Peiris speculates that deforestation during the last decade may be to blame for the shift, as the forest no longer regulates the hydrological cycle to the same level. They also talked about the changing monsoon patterns. Peiris (2006) also expresses concern about how agriculture that replaces forests contributes to biodiversity loss, soil salinity, and erosion, to mention a few risks when irrigation and chemical compounds are used.

2) Alternative crop cultivations

Banana, watermelon, papaw, pomegranate, and passion fruit are the most prevalent alternative crops in Sooriyawewa DSD, and a study conducted in Hambantota in 2015-2016 found that farmers chose to produce bananas in paddy areas for economic gain (Kumarage and Arunakumara, 2019). Chena cultivation in the Hambantota district begins in October when the Maha rains fall. Farmers start forest firing, also known as 'Nikini Paaluwa,' during the dry season in August (Kumarage and Arunakumara, 2019). Water scarcity, economic factors, animal damage, and, most importantly, a lack of government assistance, which includes fertilizer and seed subsidies, are the key causes for the increase in other crops.

Another significant issue raised by farmers is marketing, which is influenced by political actions as well as market demand (Perming, 2013). The producers said that because banana prices fluctuate on the market, the harvest is best timed to coincide with the months when market prices are at their maximum. In Sri Lanka, the fruit season runs from April to June, which means that the banana faces market competition and is thus sold at a reduced price. As a result, the market price rises when production is low. Paddy had a predetermined minimum price at the time the interviews were done, but this was not always the case.

Paddy production has a high starting cost, thus farmers must invest a significant amount of money. Floods, droughts, pest and disease outbreaks, and price variations are all considered risk factors in the paddy industry, thus farmers face a slew of financial challenges if their harvest is lost. Alternate crop production is regarded as one of the greatest solutions accessible to both personal and commercial farmers in the Sooriyawewa area.

3) Construction activities near Sooriywewa

During the period 2005-2015, one of the Government of Sri Lanka's top goals was to upgrade infrastructure and start numerous new projects in the Hambantota District. The Hambantota International Port, the Mahinda Rajapaksa International Airport in Mattala, the Mahinda Rajapaksa International Cricket Stadium in Sooriyawewa, the Southern Expressway, and the Magam Ruhunupura International Convention Centre were among the major projects that began during this time. These construction activities mainly caused the LULC changes in Sooriyawewa DSD.

4. Discussion and Conclusion

This study used Landsat satellite images to monitor and predict the LULC changes in Sooriyawewa DSD, Sri Lanka. The study denoted LULC changes in paddy cultivation from 1980 to 2019. The main objective of this research was to analyze the paddy area changes but there most noticeable changes in waterbodies, built-up areas and other crops. According to the LULC changes between 1980-2019, there was a -15.50% decrease in paddy areas and built-up areas, and other crops significantly increase 11.97%, 10.08% respectively.

As studied in the past years, there is a trend to convert paddy fields into alternative crops, especially, banana crops in Hambantota area (Hirimburegama, Dias and Hirimburegama). When this situation will continue in the future, there is a red alert for the staple crop of Sri Lanka. If the rice is not sufficient for the population growth, it may be exported from another country and it is highly affected the economy of the country. Hambantota district is a rapid development area since 2010, so land management for proper cultivation is very important.

Traditional methods of crop monitoring have associated issues and Remote Sensing technology is beneficial for evaluating natural resources and management. Also, useful for monitoring the crop conditions, the healthiness of the crops, estimate the yields. Most research on crop monitoring is based on Remote Sensing technologies and these studies can be done at regional and national levels and the results are useful for planning agricultural production (Unal, 2020).

In this project, identified what are the existing system for monitoring the LULC changes and applicable Remote Sensing techniques, then quantify the LULC changes over paddy cultivation during the past four decades

(1980-2020) and finally examined the underlying causes for LULC changes over the paddy. Paddy and natural resources are converting into Built-up areas creating significant impacts on the environment by reducing ecosystem services, the amount of land used for food production, increase heat waves, and health-related problems. To minimize these adverse consequences, the inclusion of a sustainable land use management plan to estimate microscale change detection in different directions is needed for Sooriyawewa by imposing restrictions on the conversion of natural resources to built-up areas. The methods and findings of this study will be helpful for concerned authorities, policymakers, government officials, and urban planners who can utilize the microlevel directional approach in Local Area Planning (LAP) to make the city liveable by plantation, conserving waterbodies, and planned urban infrastructural development in making Sooriyawewa area planned, inclusive, and environmentally sustainable. This is a temporal problem in this area and hopes this project is essential for the relevant authorities for decision making

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Abbrevations and Symbols

CA - Cellular Automata

DSD - Divisional Secretary Division

GIS – Geographical Information Science

LAP - Local Area Planning

LULC - Land use and Land Cover

OFC - Other Field Crops

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