

LULC dynamics and application of nature-based solution in high erosion prone areas of Malappuram District

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ARTICLE INFO	ABSTRACT
<p>Received : 13 December 2022 Revised : 13 February 2023 Accepted : 06 March 2023</p> <p>Available online: 26 June 2023</p> <p>Key Words: Accuracy assessment LULC Nature based solutions Soil erosion</p>	<p>Kerala State is highly vulnerable to natural disasters, mainly soil erosion due to changing climatic dynamics in the steep slope. In 2018 and 2019 flood, some districts in Kerala State were affected by significant floods due to extreme and prolonged rainfall, leads to large and small landslides. Malappuram is one of the districts that got affected in 2018 and 2019 flood. Disaster risks are augmented by a critical factor that has been silently rising in the State now, which is change in the land use pattern and practices. Hence, the Land Use and Land Cover Dynamics study was conducted in the selected watersheds (Kakkarathode – Pulikkal and Palathingal) of Malappuram district, and spotted major landslides in the area. The LULC dynamics were carried out in the different time periods like 2013, 2018 and 2020. LISS IV (5.8 m resolution) satellite images were used for the analysis and field visit, to identify the related changes. Accuracy of the classification was evaluated using error matrices and kappa statistics. The overall accuracies for 2013, 2018 and 2020 were 84.93%, 86.21% and 87.5% respectively and the corresponding Kappa values were 0.82, 0.84 and 0.85 which indicates the high accuracy of the classification. The flood has mainly affected Plantation, Paddy and Mixed Plantation which had been decreased during 2018-20 and has resulted in the emergence of more Barren land and Waste Land. LULC helps in identifying the changes in the erosion prone areas. Moreover, erosion hazardous area and its prioritization in applying the soil management and conservation practices can be effectively done using LULC change assessment. Nature based solutions such as planting trees and grasses (like shrubs, vetiver grass etc.), construction of ponds, creation of green walls and assemblage of vegetations can be adopted in the region of high-risk hazardous area depending on the categorized zone.</p>

Introduction

LULC categorises the natural and human factors on the landscape throughout a specific time period. The classification is based on recognised scientific and statistical techniques for the analysis of suitable source materials. Classified areas help users in clearly recognizing the current landscape and monitor temporal dynamics in agricultural ecosystems, water bodies (surface), forest conversions, etc. on annual basis. For determining

conservation priorities, LULC data sets reveal indicators of the threat by potential development. Other data sets include details on how humans have altered the landscape, results of an increase urban sprawl or other anthropogenic pressures. Many countries all over the world are experiencing rapid, broad changes in Land Use and Land Cover. The prompt rise in the world population that led to an escalate in anthropogenic actions, have ended in

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rapid changes in LULC, forest destruction and the conversion of generative land to urban development, all of which have major ecological consequences. Understanding and mapping LULC change has become increasingly relevant in governance of natural resource management and environmental monitoring. Land use change through the conversion of forest land to other purposes is continuing to develop at a rapid rate due to the exponential growth of the human population, which enhances the need for food and land. According to a UN survey, Global forest loss was around 129 million hectares between 1990 and 2015, reflecting a 1.3 percent annual rate of loss. Urban residents account for 55 percent of the global population and are expected to rise to 68 percent by 2050. 2.5 billion more people will reside in cities by 2050 (The Global Forest Goals Report, 2021). The impact of severe LULC changes causes various issues in environment such as; climate change, increased surface erosion, depletion of soil nutrients, loss of water quality, loss of bio diversity etc. With the advanced Remote Sensing and GIS techniques, it is possible to constantly monitor LULC changes and predict the future changes. With the help of this data proper planning can be done to diminish the impact of the LULC changes. Floods, which are one of the most dangerous natural catastrophes, are prone to any inhabited places that are generally found in tropical locations which cause damage to human lives, agriculture lands, properties and other infrastructure. Therefore, adequate knowledge of land use and land cover and the ability to accurately locate and map the flood prone areas, are required for executing proper planning and management against flood (Tiwari *et al.*, 2020). Contribution of LULC changes in August 2018 flood in Kerala was mainly due to deforestation-related changes during 1995-2005 (Ankur Dixit *et al.*, 2022). In Kerala, the built-up area significantly increased from 1988 to 2017 by 134% and from 2000 to 2017 by 265%, also increase in the average land surface temperature (LST), from 27.7 °C to 30.3 °C, was also recorded. Land cover dynamics in Kerala over different decades through MODIS data and statistical techniques, the first decade as 2001 to 2010 and second decade as 2011 to 2019, increase in the area covered by forest, urban, crop land,

shrublands and natural vegetation, decreasing trend in savannas and grasslands (Vijith H *et al.*, 2022). The pre-flood Land Use and Land Cover mapping reveals that agriculture land was the major LULC (113.34 km²), followed by water bodies (44.44 km²), aquatic vegetation (74.83 km²), terrestrial vegetation (40.92 km²). With respect to post flood land use/ land cover changes, major part of agricultural land, terrestrial vegetation and others LULC classes were primarily affected and decreased (63.86 km², 31.21 km², 5.36 km² respectively). On the conflicting, majority of said LULC classes were covered by sand deposits (i.e. 22.76 km²) determining the ecosystem process of lake environment (Tauseef Ahamad *et al.*, 2017). Substantial reduction in forest, agriculture and shrubs for the period of 10 years, leads to high flood risk (Sugianto *et al.*, 2022). Kerala's flood of 2018 was one of the biggest natural disasters of the century. This flood had a detrimental impact on Kerala's economy, as well as the lives and livelihoods of those who reside in the impacted areas. Over 483 people were died and thousands of homes were damaged. Malappuram district was one among the severely affected district in Kerala by 2018 flood. Therefore, a study regarding the LULC impact on flood in the selected watershed was taken.

Material and Methods

Study area

Kakkarathode-Pulikkal and Palathingal watersheds are located in Eranad Taluk of Malappuram district in Kerala which belongs to the southern part of India. Kakkarathode-Pulikkal watershed lies between latitude 11° 03' 23" to 11° 05' 47" N and longitude 76° 08' 42" to 76° 10' 51" E and Kakkarathode - Palathingal watershed lies between latitude 11° 02' 07" to 11° 04' 38" N and longitude 76° 09' 04" to 76° 11' 47" E. Kakkarathode-Pulikkal and Palathingal watersheds are having an area of 500 ha and 730 ha and the total area of Kakkarathode watershed is 1230 ha. As per the 2011 census, the population of this area is about 4000. Physio graphically, the watershed comes under high land region with an elevation ranges from + 40 m to + 609 m from MSL. The maximum elevation of the watershed is 609m. The study area map is shown in Figure 1.

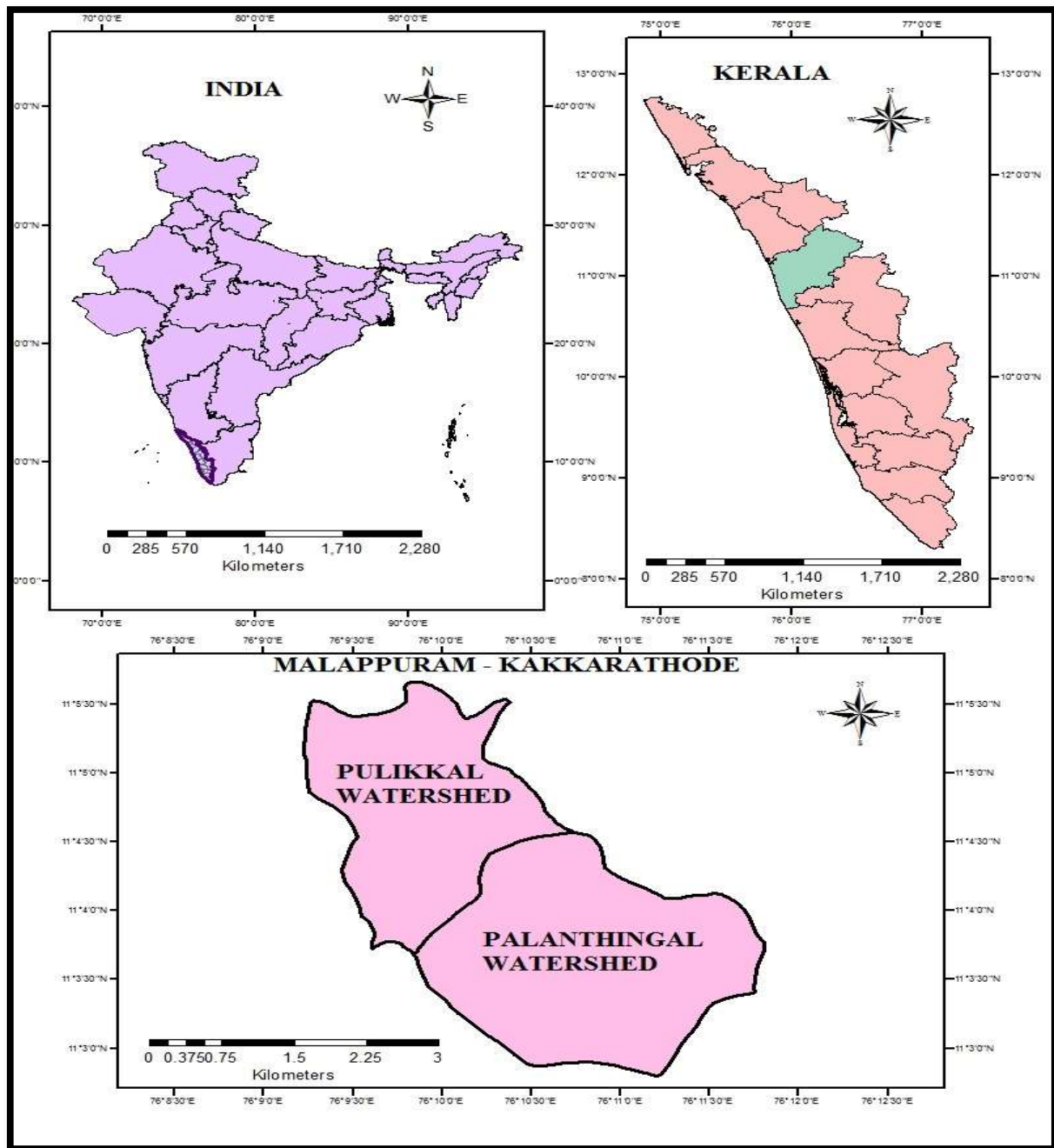


Figure 1: Study Area; Kakkarathode- Pulikkal and Palathingal watershed

Major cultivations in the watersheds include rubber plantation, coconut, banana, paddy, cashew, coffee, arecanut and vegetables. Rubber and coconut are the predominant crops in the high land. The coconut & arecanut in the area is being converted to Rubber. Plantain and vegetables are also cultivated in the low laying valley. Banana and Tapioca are

the annual crop grown in this area during the monsoon season. The watershed has a humid tropical climate with an average annual rainfall of 2800 mm. The mean max. and min. temperatures are 36°C and 22°C respectively. The southwest monsoon accounts for over 70% of total rainfall, which occurs mostly in the months of June, July,

and August. Pre-monsoon showers provide about 5-10 percent of total rainfall in April and May. And the remaining quantity occurs during the North East Monsoon in September and October. From December to April, there is a five-month dry period. The Kakkarathode -Palathingal watershed is a drainage area of a fourth order stream, which is a tributary of the Kadalundi river. The main drain of the watershed area is Kakkarathode which originate from Nenmini Mala area as Nenmini Church Vala thodu and flows towards western direction. Chemtheliyam para Vala thodu, Chathampara-Pattalipara thodu, Kallrutti -Mannathipara thodu, Mullarangad -Pachollaparathodu and Enchipullu thodu are the main sub drains which originates from Pandallur Mala and join to the main drain Kakkarathode. Then the main drain of Kakkarathode flows towards western direction and joins to Kadalundi puzha at Pulikkal-Pandallur. Drainage map showing their stream order is given in Figure 2.

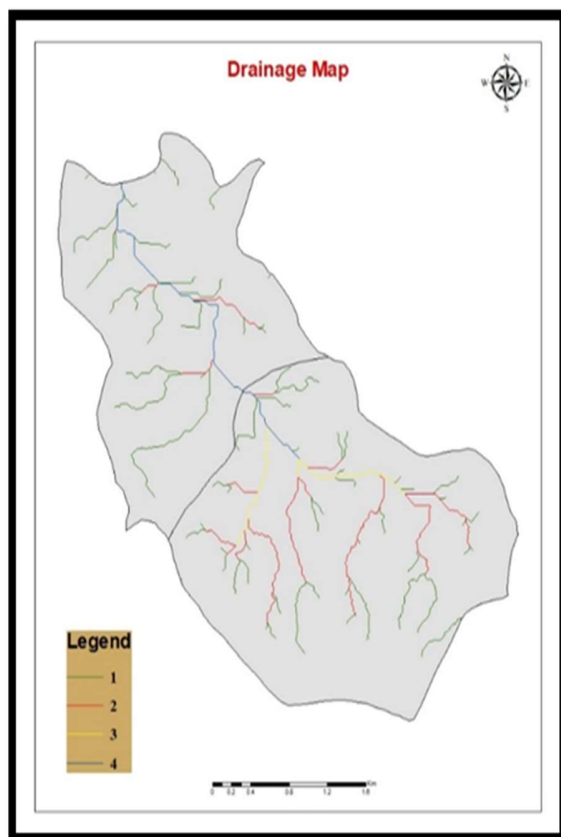


Figure 2: Drainage map of the watershed

Slope characteristics of Kakkarathode watersheds

The major landslides observed in the watersheds are about 40° slope terrains. The slope map indicates that the slope ranges from 16.17 to 1.64% rise from the general slope (Figure 3).

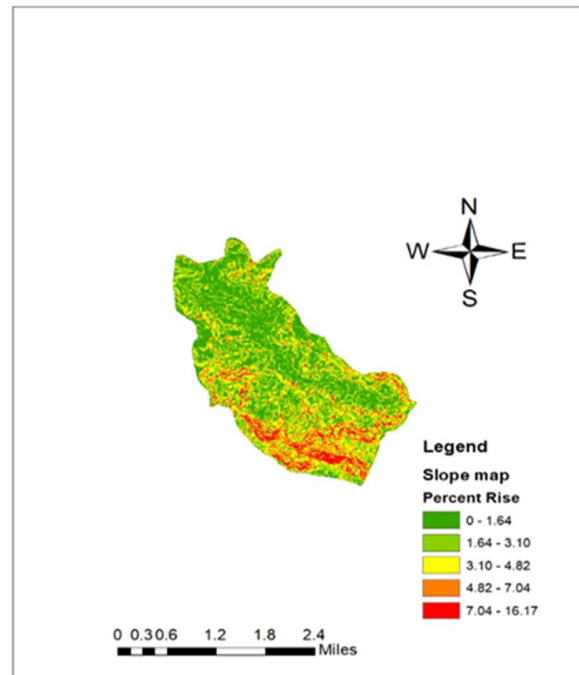


Figure 3: Slope map of the watershed

Data acquisition

LISS-IV satellite images of Kakkarathode - Pulikkal and Palathingal watersheds were acquired for the years 2013, 2018 & 2019 from National Remote Sensing Centre (NRSC), Department of Space, Govt. of India, Hyderabad, Andhra Pradesh with following specification as shown in Table 1.

Table 1: Details of Satellite Images.

Satellite	Sensor	Spatial resolution (m)	Date of Acquisition	Bands
IRS-P6	LISS-IV	5.8	02.02.2013	III
IRS-P6	LISS-IV	5.8	20.03.2018	III
IRS-P6	LISS-IV	5.8	11.02.2020	III

Software and platforms

The standard method of image processing was used, followed by ground truth collection. ERDAS Imagine version 14 and ArcGIS version 10.5 were used to create thematic maps from digital satellite data. For mapping vegetation and secondary

information such as elevation (rise) and landforms, digital image processing (traditional method) was used, which included the use of image elements such as shape, position, tone, pattern, texture, association, and so on. Following the preparation of these interpretation elements, an interpretation key was prepared. Acquired data should be pre-processed to eliminate the errors. Pre-processing includes Geometric correction, Sub-setting etc. It is important to geometrically correct the data in order to perform change detection analysis. After obtaining the various data, they are likely to have varied projections, thus the next step is to project it, such that, all spatial data sets will be associated with a single coordinate system. In this study, the LISS IV imagery was geo-referenced to the UTM Zone 43N coordinate system. Universal Transverse Mercator (UTM) projection, Zone 43N, Spheroid WGS84 and WGS84 Datum was used as the primary coordinate system here.

Procedure used for LULC classification

ERDAS Imagine (Version 14), ArcGIS (Version 10.5) and Google Earth were used for classification process. After defining an area of interest (AOI), which is referred to as training classes, the supervised classification was done. The training sites were selected based on areas that were distinctly evident in each of the image sources. To reflect a specific class, more than one training sample was used. The training locations were chosen based on LISS-IV imagery and Google Earth. Following the digitization of the training site (Area of Interest), is the stage to establish statistical characterizations of each piece of data. In ERDAS Imagine 2014, these are known as Signatures editors. The SIG files are created and contain a wide range of information on the land cover classes. After specified training classes, the maximum likelihood classification (MCL) algorithm was used and finally calculated the area for the classified fields. Visual interpretation was used to solve the issue of mixed pixels. The results obtained using the supervised algorithm was substantially improved by using visual analysis reference data and local knowledge. Ground truthing is done for further improving the accuracy of the study. The accuracy of classification was determined by comparing collected reference points and classification results statistically using error matrices. The whole procedure is shown in Fig 4.

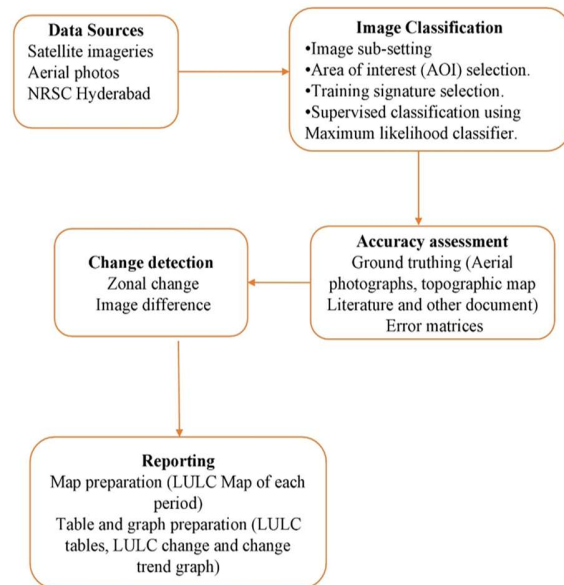


Figure 4: LULC classification chart

Accuracy assessment

In order to assess how accurately a classification represents reality, it is compared to either a high resolution image or ground truth data. The main goal of accuracy evaluation is to identify the sampling methods used to divide pixels into the appropriate land cover groups. In this study, accuracy assessment was done with ArcGIS by random sampling method. Each LULC class had at least five sample sites, and each of these points was verified in the field or using higher resolution images (Google Earth), where locations were unapproachable. If sample point taken for LULC map matches with the ground truthing data it is considered as 1 and if they miss-match, it will be counted as 0. An Error matrix is generated based on this analysis - overall accuracy, producer's accuracy, user's accuracy (FA Islami *et al.*, 2022) as well as Kappa coefficient were calculated.

1. **Overall accuracy** is the measure of ratio of the number of sample points which are correctly classified to the total number of sample point. (FA Islami *et al.*, 2022)

$$\text{The overall accuracy} = \frac{\text{No. of correctly classified points}}{\text{Total no. of points}}$$

2. **User's accuracy** define to the ratio of number of correctly classified points in every class to the total number of samples in that particular class, ie, it's a measure of how many no. of the samples of a similar class matched correctly (FA Islami *et al.*, 2022).

$$\text{User's accuracy} = \frac{\text{No. of samples that are correctly classified in a given category}}{\text{Total no. of Samples in that category}}$$

3. **Producer's Accuracy** is a compute of how much of land in each LULC class was classified correctly (FA Islami *et al.*, 2022)

$$\text{Producer accuracy} = \frac{\text{No. of samples that are correctly classified in a particular category}}{\text{Total no. of samples that are classified to that particular category}}$$

The Kappa coefficient is the difference between true agreements or correctly categorized points (major diagonal) and chance agreements. It defines the accuracy of the entire classification. So it is crucial to do kappa statistics in order to know the extent of accuracy of any LULC study. Table. 2 shows the Kappa Statistics general way of choosing the strength of agreement. The equation used for the calculation as: (Sophia *et al.*, 2017)

$$K = \frac{N \sum_{k=1}^r x_{kk} - \sum_{k=1}^r (x_{k+} \cdot x_{+k})}{N^2 - \sum_{k=1}^r (x_{k+} \cdot x_{+k})}$$

Where,

r = Number of classes

N = Total number of Pixels

x_{kk} = total pixels in row "k" and column "k"

x_{k+} = total samples in a row "k,"

x_{+k} = total samples in column "k"

Table 2. Kappa Statistics

SN	Kappa statistics	Strength of agreement
1	<0.00	Poor
2	0.00 - 0.20	Slight
3	0.21 - 0.40	Fair
4	0.41 - 0.60	Moderate
5	0.61 - 0.80	Good
6	0.81 - 1.00	Very Good

Results and Discussion

The data analysis is based on the comparison of LULC classes for three different periods during 13 years period. Land Use Land Cover maps: for the years 2013, 2018 and 2020 were prepared by supervised classification of LISS IV satellite images with the help of ancillary information as well as ground truthing. A total of 8 LULC classes were identified namely; Agricultural land, paddy,

mixed plantation (converted paddy), Water Body, Plantation, Built-up Land, Waste Land and Barren Land. Area distribution of various LULC classes in different study period has been summarized in Table 3. Visual analysis is the primary step in viewing an image and is the easiest way to distinguish different land covers and modify data about the specific region through a human interpreter. The visual assessment will provide a broad overview of LULC transition pattern over a 13-year cycle. The false colour (Figure 5) composite images were created using LISS IV satellite images. Natural and false colour composites are an effective method for visually extracting information from LISS IV satellite images and it can help in generating a general overview of LULC change pattern in the selected watershed for the study. Texture, size, shape and patterns of the imagery are the key factors while identifying change in LULC through visual interpretation (Padmanava Dash *et al.*, 2016).

Training Areas

LULC classes have presented in the watershed and illustrative the training samples for every class, supervised classification used for generating the LULC map from a satellite image. Training samples are typically derived through first-hand experience, fieldwork, or through visual interpretation of other facilities, such as high-resolution photos from Google Earth and satellite imagery (Lu and Weng 2007). Training samples can be gathered from various sources such as in-place data, aerial photos, topographic maps etc. It is crucial and advisable that ground truth data should be taken simultaneously with data acquisition or at least before environmental situation changes, to achieve a high accuracy and to keep the results of LULC changes over time. Aerial photos, visual interpretation and in-field knowledge were used in this study to collect training samples and ground truth" data which is needed for classification as well as accuracy calculation. A minimum of 20 training pixels have been taken for each class defined, using LISS IV satellite imagery for 2013, 2018 and 2020. With its speed, precision, and affordability, collecting ground truth data from aerial photographs has a clear advantage over traditional survey processes.

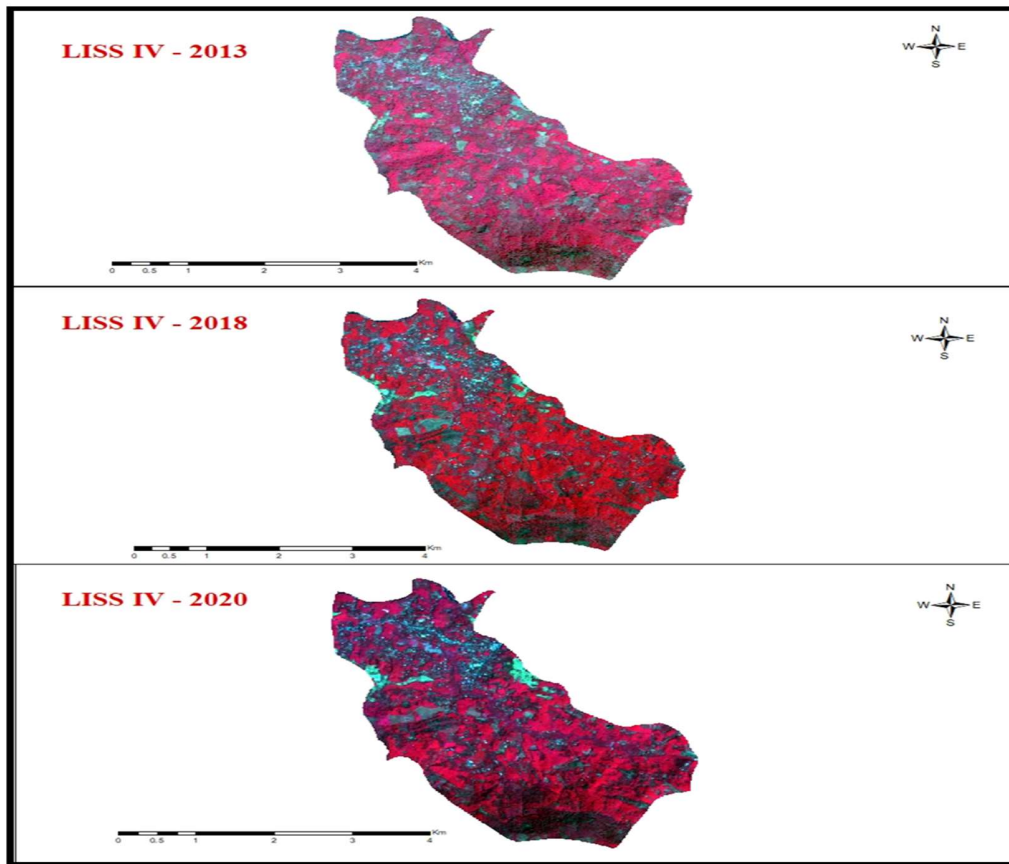


Figure 5: LISS IV False colour composite of 2013, 2018 and 2020

LULC Classification

Land Use Land Cover Analysis of 2013

LULC map of 2013 has shown that Plantation (49.75%) was the most dominant class occupied in the study area which was followed by Agricultural land (32.4%) and least area was covered by Water body (0.4%). Mixed plantation (Converted paddy) comprised an area of 95.97 ha (7.8%) where different crops such as banana, tapioca, Areca nut, various vegetables etc. Converted paddy - It was once used to cultivate paddy, which was then converted into various other plantations mainly due to lack of profit. Built-up area (1.05%), Waste Land (1.9%) and Barren land (6.27%) were the other LULC classes occupied.

Land Use Land Cover Analysis of 2018

Analysis of 2018 LULC image has revealed that Plantation and agricultural land constitutes around 80% of the total area. Here also Plantation was the

most dominant class covering 55.5% of the total study area. Agricultural land was at the second position with 24.36% followed by mixed plantation (7.4%), barren land (7.28%), waste land (2.24%), built-up area (2.5%), and paddy (0.38%). Water body comprised only 0.35% which was the least in 2018.

Land Use Land Cover Analysis of 2020

As in 2013 & 2018, Similarly Plantation is major dominant and occupied 49.46% in 2020 and agricultural land retained its second position, occupied 22.12% of the study area. Barren land showed a remarkable hike in its area when compared to the previous study periods which was due to the flood occurred in 2018. Barren land was covered by 15% and finally 6.79%, 3.04%, 2.81%, 0.42% and 0.36% of the study area were covered by mixed plantation, waste land, Built-up area, water body and paddy respectively. LULC details are shown in Fig 6 & 7.

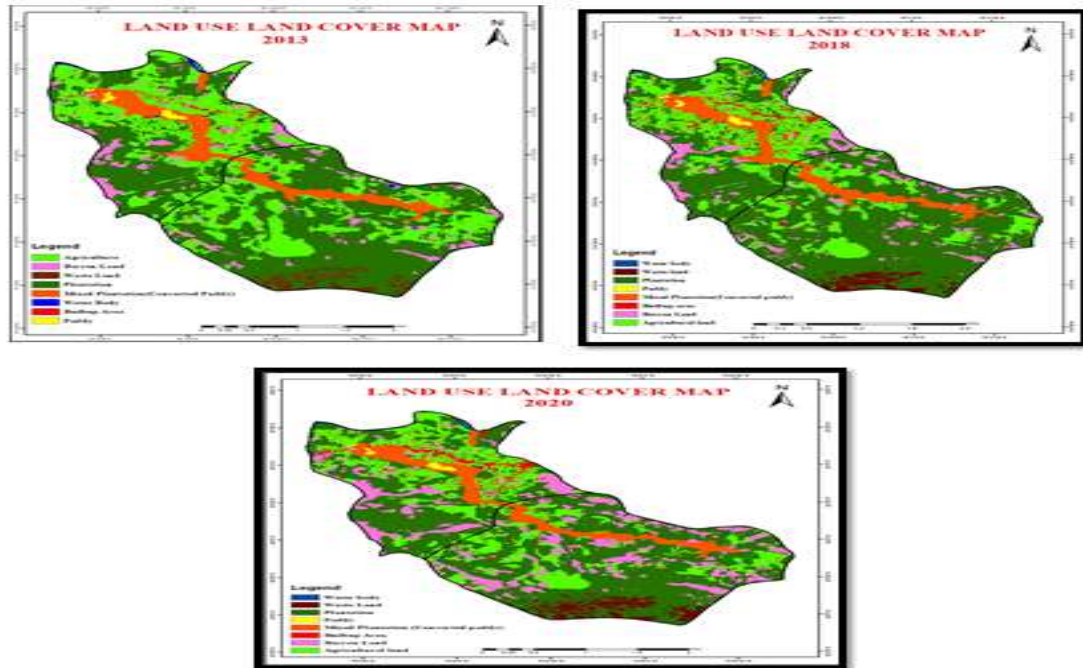


Fig 6. Kakkarathode – Pulikkal and Palathingal watersheds LULC map of 2013, 2018 and 2020

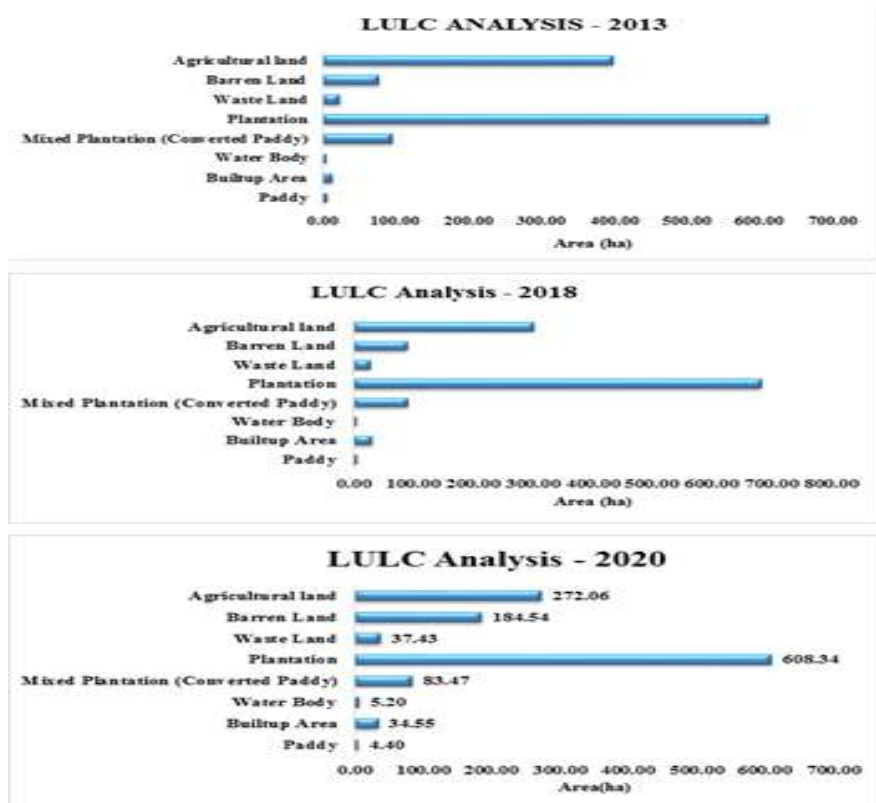


Figure 7: Area covered by different LULC classes during 2013, 2018 and 2020

Accuracy assessment

Accuracy assessment was performed using random sampling for all the 3 study periods. The overall classification accuracy and Kappa value were greater than 81% and 0.81 respectively which implies strong agreement. The overall accuracies for 2013, 2018 and 2020 were 84.93%, 86.21% and 87.5% respectively. Kappa values were 0.82, 0.84 and 0.85. According to (Vuillez *et al.*, 2018), an

accuracy value of at least 85% is considered as effective classification. Thus, this classification satisfies the maximum accuracy. Mixed plantation and paddy were found to have 100% producer and user accuracy, which showed the best accuracy among all LULC classes. It could be because these classes might have better spectral discrimination.

Table 3: Area covered by each LULC groups in different study periods

LULC Class	2013		2018		2020	
	Area(ha)	% of Area	Area(ha)	% of Area	Area(ha)	% of Area
Paddy	5.16	0.42	4.69	0.38	4.40	0.36
Built up Area	12.93	1.05	30.72	2.50	34.55	2.81
Water Body	4.93	0.40	4.34	0.35	5.20	0.42
Mixed Plantation (Converted Paddy)	95.97	7.80	90.97	7.40	83.47	6.79
Plantation	611.88	49.75	682.64	55.50	608.34	49.46
Waste Land	23.43	1.90	27.54	2.24	37.43	3.04
Barren Land	77.12	6.27	89.49	7.28	184.54	15.00
Agricultural land	398.57	32.40	299.60	24.36	272.06	22.12
Total	1230.00	100.00	1230.00	100.00	1230.00	100.00

Table 4: Accuracy assessment of LULC classification

LULC Classes	2013		2018		2020	
	User Accuracy	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy	Producer Accuracy
Paddy	100	100	100	100	100	100
Built-up Area	72.72	88.89	62.5	83.33	75	90
Water Body	71.43	100	85.71	100	100	100
Mixed Plantation (Converted Paddy)	100	100	100	100	100	100
Plantation	92.31	63.16	88.89	72.72	76.92	76.92
Waste land	66.67	100	83.33	100	80	100
Barren Land	87.5	100	87.5	87.5	81.82	81.82
Agriculture	84.61	78.57	88.89	72.72	93.33	73.68
Year	2013		2018		2020	
Overall Classification Accuracy	84.93		86.21		87.5	
Overall Kappa Statistics	0.82		0.84		0.85	

Built-up area has shown the lowest user accuracy of 62.5% in 2018 while lowest producer accuracy has been exhibited by plantation in 2013 (63.16%). Hence this classification is within a very good range, based on the classification scale proposed by (Moriassi *et al.*, 2007). (Direse Tewabe and Temesgen Fentahun, 2020) carried out a study on LULC changes in Lake Tana Basin, Northwest Ethiopia using remote sensing and GIS for the years 1986, 2002 and 2018. This study has got an overall accuracy of 84.21%, 83.32%, and 89.66% for 1986, 2002 and 2018 respectively and the kappa values were 0.79, 0.83 and 0.89.

Land Use/Land Cover Changes in the steep slope area of the watersheds

The Land Use/Land Cover changes in the very steep slope to steep slope area of the Kakkarathode-Palathingal watershed were analysed. During field visits, we have observed the landslides in that area, which was occurred during 2018 and 2019 floods. The LULC changes is very much important to know about the changes detection, especially in the steep slopes for the proper management. The results showed that the build-up land increased by 1.92 ha in the year 2020, when compare to 2013. Similarly, Waste land and barren land increased by 4.41 ha

and 1.35 ha in the year 2020. Plantation and Agriculture reduced by 4.35 ha and 2.3 ha in the year 2020. The classified area shown in the Fig. 8. The major changes in the LULC classes in the steep slope, is one of the reasons for landslide occurrence in the study area. LULC changes induced by human activities such as unendurable rural road development (Karsli *et al.*, 2009, McAdoo *et al.*, 2018), deforestation, monoculture cultivation, irrigation, mining, cut slopes for buildings and other engineering works lead to slope instability

(Sheela *et al.*, 2017). LULC involves cut and fill also alter the morphology, hydrologic process and soil characteristics (Garfi *et al.*, 2007, Vuillez *et al.*, 2018). LULC may escalate when population increases in a slope region, leading to increased demand of built up areas, agriculture land and road (Prompter *et al.*, 2014), leads to more mass movements in the mountainous areas (Lorente *et al.*, 2002). The application of coir geo-textile with suitable agronomic practices can be followed in the waste land and barren land for the slope stability.

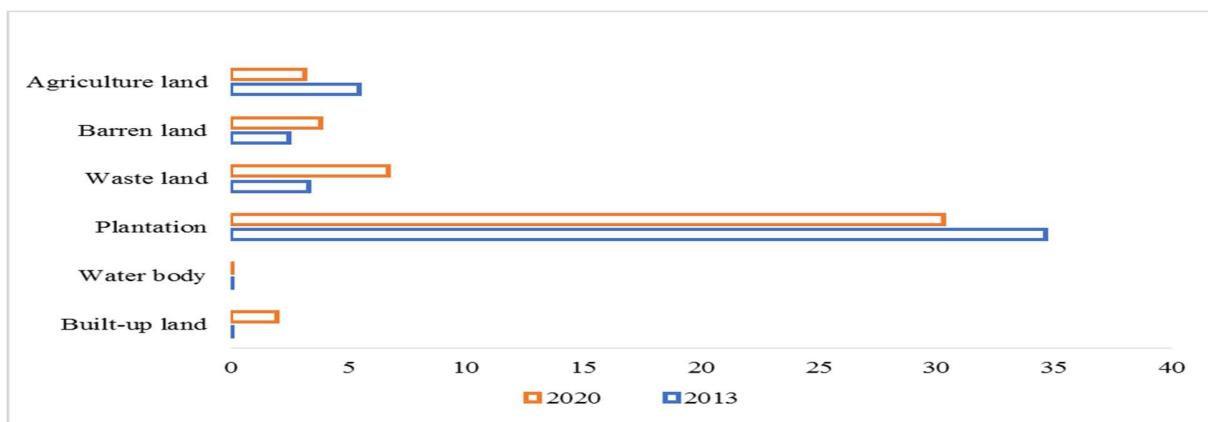


Figure 8: Area represented in steep slope of the watersheds

Nature Based Solutions in the Watersheds

During the year 2013 to 2020, the agricultural land of 10 per cent of total area was converted into barren land due to flood or human interventions. The possible way of changing the barren land into cultivable land with the proper adoption of naturally based solutions like coir geo-textile and other solutions. Coir-geo textile can control the soil erosion by acting as ground cover mulch. The mulch define to any bio-mulch materials would be decomposed fully or partially over a period of time and serving as nutrient to the crops. It reduces the flow velocity of runoff water and keep the soil intact. The coir geo-textile act as mulch, create favorable environment to germinate seeds by regulation of soil temperature, humidity, manure and controlling weeds. Application of coir geotextile for soil erosion and slope stabilization, soil was tested with varying slope and moisture content. The results indicate that the geotextile performed better for slope protection and soil

erosion, hence it is biodegradable and eco-friendly (Subramani T. 2012). The effectiveness of coir geotextile in various treatments in terms of biomass production, erosion protection, and soil moisture content. The findings showed that using grass and geotextile as a treatment is an efficient eco-hydrological strategy for preventing erosion and maintaining a stable slope (Vishnudas S *et al.*, 2006).

Procedure for installing coir-geotextile

Site assessment: Considerations for the first step include slope analysis, rainfall patterns, soil type and consistency, level of damage, etc. select the appropriate coir geotextile and gather a sample of the vegetation cover.

Site preparation: The slope area is demarcated and levelled. The ground should be free of stones, earth masses.

Slope application: Slope assessment, blanket selection, vegetation selection, soil type, procedure for stabilizing the slope.

Channel application: assessment of channel, linear and vegetative selection, stabilization.

Vetiver Grass Application

The application of vetiver grass is a natural solution to reduce environmental risk in numerous ways. *Vetiveria zizanioides* L Nash, an Indian perennial grass currently known as *Chrysopogon zizanioides* L Roberty, was first established by the World Bank for soil and water conservation. It is a very useful, simple, affordable, low-maintenance method of reducing the impact of natural disasters. When combined with ecosystem management, vetiver grass can be employed as an extremely effective and efficient eco-DRR solution to address the problem of catastrophe in both the long and short term (Joice K Joseph *et al.*, 2017). Vetiver buffer, planted at 5 m intervals on a 45° slope, considerably decreased runoff, soil losses, and enhanced crop yields. It also has promise for reducing GHG emissions, assisting with climate change adaptation and mitigation, and improving water usage efficiency (Effiom Oku *et al.*, 2015).

Conclusion

The impact study of flood in various Land Use / Land Cover classes of Kakkarathode- Pulikkal and Palathingal watershed for the years 2013, 2018 and 2020 were studied using Remote sensing and GIS. The analysis of LULC maps identified that almost half of the area was occupied by Plantation (49.75% in 2013, 55.5% in 2018 and 49.46% in 2020) followed by Agricultural land. Agricultural Land, Paddy and Mixed plantation were continuously decreasing from 2013-2020, while Barren Land, Waste land and Built up area were constantly expanding. Plantation and Water body have exhibited undulations in their area during the period of study. Agricultural Land and Built up area were mainly distributed in the northern part and Plantation was mainly concentrated on the southern part of the Watershed. A small town along with more settlements was seemed to be gradually developing over time, resulting in the expansion of

built up areas in the classification. Paddy is converted into other more profitable cultivations like banana, rubber, Areca nut, Vegetables etc. over a period of 30 years. This area is considered as mixed plantation (converted paddy) in this study. People lose interest in paddy cultivation and turn it into other plantations and cultivations mainly because paddy cultivation has more risk factors and has high maintenance costs. This study possesses a high degree of accuracy with overall accuracy greater than 85% and kappa values greater than 0.81 in all three classifications. The study resulted in a LU/LC analysis for the study region, which would aid land use planners & watershed stakeholders in formulating and implementing effective management of water resources and agricultural practices with nature based solutions. The natural based solutions like open weave geotextile erosion control meshes for the steep slope of barren land and waste land can be used for slope stability and erosion control. In a wide range of environmental situations with different rainfall intensity and soil types, woven jute products performed alternative solutions for controlling natural and man-made erosion. Sediment from bare ground can be protected using jute geotextile. On decomposition, JGT does not draw upon valuable nitrogenous reserves - rather its residue is beneficial & acts as mulch for vegetation growth. Natural fibre geosynthetics must be employed where natural vegetation is the long-term answer to control erosion. Judicious selection of geosynthetic product should be done keeping in consideration of environmental issues and positive attributes (even sometimes better) of natural products. Naturally based solutions like Vetiver grass and other erosion control grass can be grown in the disaster-prone areas of the watersheds mainly in barren and waste land.

Conflict of interest

The authors declare that they have no conflict of interest.

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