Journal of Aquatic Biology & Fisheries | 2020 | **8** | S | pp. 1-6
Special Issue on Rivers
ISSN 2321–340X

Damage Assessment and Changing Nature of Land Use with Special Reference to the Flood Plain Areas of Aluva and Paravur Taluks, Kerala

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Abstract

Recent consecutive floods in Kerala had a devastating impact on the lives of the people living along the banks of the major rivers. Periyar, the longest river and the second largest river basin in Kerala, was the most affected basin where large hectares of land were inundated adversely. The present paper examines the temporal correlation of flood damages that occurred in Kerala and analyzed the peripheral land-use change of Periyar River for a stretch of 25km flowing through Aluva and Paravur Taluks of Ernakulam District, Kerala. For this, damages pertaining to flood hazards in Kerala from 1970 to 2018 have been correlated and land-use change along the periphery of the Periyar River has been identified by classifying Landsat images of 2008 and 2018 using supervised classification technique. The changes depict huge encroachment on the banks of the river and are highly susceptible to inundation. There is a huge expansion of the built-up area within a span of 10 years around the river, which are highly prone to flood. The study on flood damages and land-use change are extremely useful to local government, disaster management authorities, NGOs and local residents for evaluating the gravity of the situation and to adopt proper planning for protecting the environment thereby minimizing the exposure to future flood hazards and risk.

Keywords: Natural hazards, Remote sensing, River regulation zones

1. Introduction

Physiographic conditions and climatic uncertainty along with human interventions on land has increased the susceptibility of Kerala to multiple hazards and subsequently altered it into a place in turmoil. The so-called 'God's own country' has already experienced the wrath of nature in the form of deluge for two years in a row. Experts have opined that floods may repeat in the coming years as well. This recurrent phenomenon affects normal living and people are forced to move in search of safety. Topographically, the cities and towns in the state are situated along the foothills of the Western Ghats and the valleys of rivers emerging from the Ghats. The westward trending slope helps rainwater to reach the streams from uplands at a very fast pace and hence the intensity of floods is higher along the stream as it emerges into the low lying plain.

Floods, most of the time, are the aftermath of a heavy or continuous downpour which is caused when the volume of water received from rains far exceeds the carrying capacity of a river, stream or even soil. When the riverbanks overflow, the adjacent alluvial flats called floodplain inundates making it an area most prone to flooding. Though floods are essential for maintaining the ecostatic balance downstream, land-use changes and habitations along flood plain have increased the risk of floods aggravating into disasters. Approximately 50 million hectares (mha) of land in India are said to be flood-prone and as per the State Disaster Management Plan 2016 of Kerala, 5642.68 km^2 or 14.52% of the total area of the State is prone to floods. Hence, the present study examines the temporal pattern of damages resulting from floods in Kerala and the changing nature of land use along the floodplains of Periyar river falling within the jurisdiction of Aluva and Paravur taluks of Ernakulam district, Kerala.

1.1. Historical Account of Major Deluges of Kerala

1.1.1. Deluge of 1341 A.D

Historical records pertaining to Periyar floods of 1341 are limited. However, various manuscripts have been discovered by historians and documented in various books. Dr.K.P.Padmanabha Menon, in his book 'History Of Kerala-Volume 1' refers to the flood of 1341, as an extraordinary event that opened up an estuary. The 1341 flood resulted from torrential rains that flooded the ancient port town of Kodungallur or Muziris, leading to its decline and destruction. The massive flood brought down silt and deposited on the port making it inaccessible for ships for trade. A storm near Cochin in 1341 also led to the emergence of a new island, but inspection suggests this to be a common accretional feature of storms along the Malabar Coast (Bendick and Bilham, 1999). Thus, 1341 flood led to the emergence of the island of Vypin and Cochin port probably by the accumulation of silt transported by flooding of the Periyar river.

1.1.2. Deluge of 1924

Popularly known as 'The great flood of 99' which occurred in July 1924. Here, 99 refers to the Malayalam calendar year 1099. The continuous downpour for three weeks submerged many present-day districts of Kerala in flood. The main cause for the deluge is said to be the breach of the Mullaperiyar dam after 29 years of its construction. The flooding not only inundated the Munnar town but also washed away Karinthiri Hills.

1.1.3. Kerala Floods, 2018 and 2019

Kerala flood of 2018 is considered the worst flood of the century. Kerala flood was caused by the above-average

Received on: 02-03-2020; Revised on:1-11-2020; Accepted on: 25-11-2020

seasonal precipitation, multi-day extreme precipitation, above-normal reservoir storage, and extreme precipitation in the catchments upstream of the reservoirs (Mishra *et al, 2018*). The abnormal high rainfall from 1 June to 19 August severely flooded 13 out of 14 districts in the State which was 42% above normal. The Central Water Commission's report on Kerala Flood 2018 indicated that the rainfall of August 15-17, 2018 in Kerala was almost of the same order as that of rainfall which occurred during July 16-18, 1924. Around 433 human lives were lost in this deluge. In 2019, on the first anniversary of the catastrophic flood of the century, the state witnessed a flood of similar intensity once again, suggesting a possible shift in the rainfall regime.

Some experts have commented that the topographical variation induced by adverse changes in land use as the major contributing factor that intensified the floods. According to them, the failure in acting as per the Gadgil recommendations on managing the ecologically sensitive Western Ghats aggravated the situation. The state recorded a loss worth Rupees 149.26 billion as a result of the floods of 2018. A sector-wise division of damage and loss recorded in the state is furnished in Table 1.

1.2. Previous Studies

Studies on floods are gaining momentum all over the world. Awopetu e*t al*. (2013) examined the effect of the flood on the socio-economic aspects, in their paper titled 'The impact of the flood on the socio-economic status of residents of Wadata and Gado-villa communities in the Makurdi metropolitan area of Benue State, Nigeria'. It focused on demographic variables of the study area and highlighted the negative impact of the flood on the socio-economic well-being of the residents. Haq *et al*. (2012) in their paper 'Techniques of Remote Sensing and GIS for flood monitoring and damage assessment: A case study of Sindh province, Pakistan' employed mapping of flood extent and assessed the damages made by flood using geospatial techniques. The study helped to carry out rapid damage assessment.

Remarkable work has been carried out on floods in India, as well. Singh and Sharma (2009) have prepared an urban flood hazard map in their paper 'GIS and a remote sensing-based approach for urban flood-plain mapping for the Tapi catchment, India' using geospatial technologies. The study interlinked spatial and temporal data using GIS tools, identified frequency of flood occurrence and prepared a flood risk map at various water levels. Ahmed and Kranthi (2018) in their paper 'Flood Vulnerability Assessment using Geospatial Techniques: Chennai, India' carried out a watershed analysis to identify the extent of flooding and assessing damage towards built-fabric, roads and railway line. Satellite imageries were analyzed using geospatial techniques. They have also prepared a map of flood prone areas and depleted water sources and classified the areas based on vulnerability.

However, in Kerala, there are only a few floods based studies conducted. This is due to the fact that Flood scenario in Kerala was not frequent until 2018. Mishra *et al*. (2018) studied the impact of rainfall received during the Kerala flood in 2018. The study focused mainly on major reservoirs of Kerala. They analyzed the rainfall data received from 1901 and did a comparative study. The study suggests seasonal and extended range forecast of rainfall and improved forecast of extreme rain events can help in reservoir operations. Roy *et al*., (2018) developed a vulnerability map on flood hazard in their paper 'Development of Flood Hazard Vulnerability Map for Alappuzha District' and demarcated the areas into different flood risk zones. The study suggested the methodology to be simple and cost effective for identifying vulnerable zones. Many reports have been published by the Kerala State Disaster Management Authority portraying the vulnerability of the state to various disasters. The research paper focuses on the damages that have occurred due to floods in the state, as well as the influence of land-use change in increasing vulnerability to floods in two taluks of Ernakulam district, making use of remote sensing tools. Human-induced land degradation is affecting the biophysical environment of the floodplains thereby damaging the Periyar riverine ecosystem. This not only speeds up the intensity of flood hazards but also increases casualties on people residing in wet point settlements.

This paper aims to critically evaluate the flood induced damages recorded in Kerala in terms of loss of people and property over 49 years and the impact of land-use changes on the floodplains of Periyar river flowing through Aluva and Paravur Taluks of Ernakulam district, Kerala, and its role in accelerating the damage to environment and economy. The aim has been achieved by fulfilling the following objectives, which are: (i) To examine the temporal pattern of damages resulting from flood reported in Kerala from 1970 to 2018, and (ii) To evaluate the land-use changes along the flood plains of Periyar flowing through Paravur and Aluva Taluks of Ernakulam district, over a period of ten years and thereby assessing the increasing vulnerability to flood induced damage.

Table 1. Value of Flood Damages under various sectors in Kerala (2018)

Sector	Damage Indian Rupees(10^7)	Loss Indian Rupees(10^7)	Total Effect Indian Rupees(10^7)
Housing, Land, and Settlement	5027	1383	6410
Agriculture, Fisheries, and Livestock	2975	4180	7155
Public Infrastructure	890	471	1361
Total	8892	6034	14926

Source: Kerala Flood 2018, Post Disaster Needs Assessment Report, KSDMA

2. Materials and Methods

The study assessed the data pertaining to damages caused by floods in Kerala from 1970 to 2018. The assessment helped to identify the decade in which the state was worst affected by floods in terms of damage to people and property. The present paper also focuses on the land-use changes that have occurred along a 2 km buffer of the Periyar River flowing through Aluva and Paravur taluks that form a contiguous zone spread across the flood plains of the River Periyar. Aluva and Paravur were the most flood-affected taluks of Ernakulam district during the 2018 flood. Both taluks are well drained by the Periyar river and its tributaries.

Identifying the land use/land cover helps to understand the characteristics of the land surface. Spatio-temporal analysis of land use provides a clear picture of changes that have occurred in an area. The study randomly selected a spatial extent of the 25km stretch of the Periyar river flowing through Aluva and Paravur Taluks to evaluate the changing nature of land use along the floodplains. For this, a 2km buffer area along the 25 km stretch was demarcated and a base layer was prepared.

The study was done using Landsat imageries of 2008 and 2018 downloaded from the USGS Earth Explorer website. For 2008, imagery taken by Landsat 5 Thematic Mapper was used and for 2018, Landsat 8 OLI/TIRS was used. The details of the imageries selected for the study are given in Table 2. For land-use classification, Erdas Imagine software was used. In Erdas, bands of each imagery were stacked and clipped to the base layer. For Landsat 5 TM, the stacked bands were 1,2,3,4,5 and 7 and for Landsat 8 OLI/TIRS, stacked bands were 2,3,4,5,6 and 7.A supervised classification was performed to generate land use maps.

Four major land use/ land cover classes were identified namely; built-up area, vegetation, wetlands, and waterbody and the area under each class were calculated. The classified images are given in figure 6 and the area calculated for each class are given in Table 4.

Damage assessment resulting from floods at the state level was done by a comparative study of the loss incurred over a period of 49 years. The damage in terms of loss of human life and property was assessed for the chosen time frame.

3. Results and Discussion

Flooding incurs serious damage to the surrounding. People are forced to leave their homes. The economy gets badly affected. The aftermath of a flood can be severe and surviving becomes a hard option for the most vulnerable population. The present paper has assessed the flood damages in Kerala and evaluated the changing nature of land use along the floodplains of Aluva and Paravur taluks of Kerala.

Damage Assessment of Floods in Kerala

The damages caused by floods in Kerala from 1970 to 2018 are given in Table 3.When one evaluates the decadal pattern of data pertaining to flood damages that occurred in Kerala from 1970 to 2018, the greatest number of people were affected during the decade 1980-89 and the least number of people were affected during 2000-09 (Fig. 2). Around 7.25 million population was affected in the year 1989, which is the highest recorded figure for the decade. Maximum human lives were lost (1231 deaths) in the decade 1990-99 (Fig. 3). A total of 265 people lost their lives in the year 1992 alone.

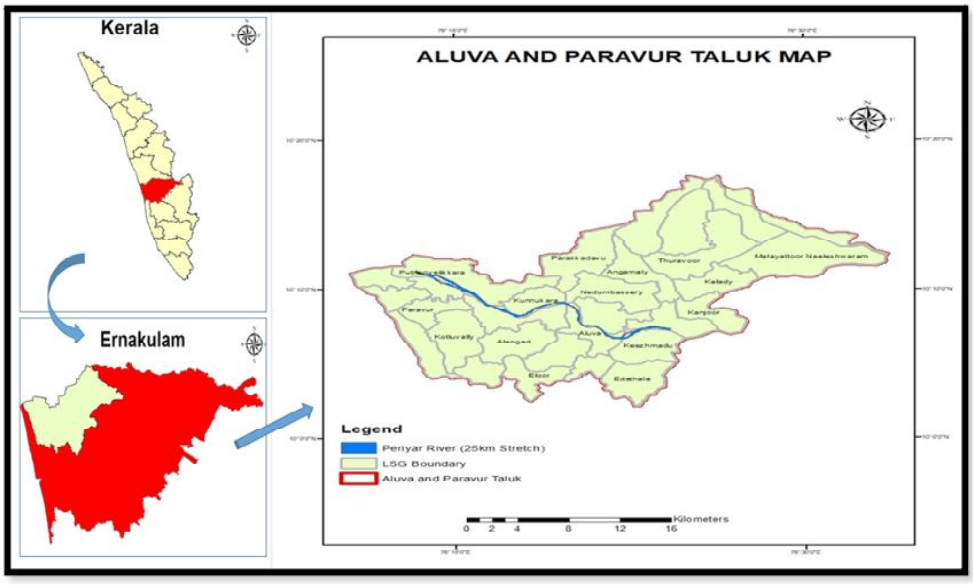

Fig. 1. Map of Aluva and Paravur Taluks in Kerala, India

Table 2. Details of Satellite Imageries used for Land Use Classification

Year	Satellite	Sensor ID	Spatial Resolution	No. Of Bands	Path and Row	Date of Acquisition
2008	Landsat 5	TM	30m	7	144/53	27-12-2008
2018	Landsat 8	OLI &TIRS	30m	11	144/53	06-02-2018

*TM - Thematic Mapper *OLI - Operational Land Imager *TIRS - Thermal Infrared Sensor

Table 3. Flood Damage in Kerala from 1970 to 2018

Decades / Year	Affected Population (in million)		No. of Human Lives Lost		No. of Houses Damaged		Total Cost of Damages for Crops, Houses and Public Utilities in Indian Rupees (10^7)	
	Total	Peak Year	Total	Peak Year	Total	Peak Year	Total	Peak Year
1970-79	13.12	1978 (3.82)	516	1977 (142)	292998	1978 (147248)	130.417	1974 (21.756)
1980-89	46.405	1989 (7.25)	682	1982 (128)	1000579	1985 (478514)	2068.876	1989 (774.59)
1990-99	15.195	1991 (8.869)	1231	1992 (265)	371632	1992 (129177)	3792.008	1992 (1325.36)
2000-09	1.981	2009 (1.223)	398	2009 (142)	60941	2009 (22744)	732.17	2009 (607.331)
2010-17	3.43	2013 (2.839)	792	2013 (198)	68906	2013 (26694)	1378.565	2013 (675.53)
2018	5.4		433		258684		14926	

Source: CWC& Kerala Flood 2018 (PDNA)

The number of houses damaged was the highest during 1980-1989 (Fig. 4.) when 478514 houses were damaged due to floods in the year 1985 alone. The value of the total cost of damages was highest for the decade 1990-99 (Fig. 5.) when Rs 13.25 billion was the highest estimated cost of damage for the year 1992 alone. By analyzing the data, it is evident that 1985, 1989, 1992 were the worst flood-affected years in terms of the damage recorded. However, on assessing the damages that occurred during the 2018 flood which was a single year single event, the loss incurred in 2018 is much higher in comparison to all others since it was in this flood that most number of human lives were lost. 433 people lost their lives in this flood.

Land Use Change Between 2008 and 2018

From the maps obtained after Supervised classification, for 2008 (Fig. 6.) and 2018 (Fig. 7.), it is evident that the built-up area dominates the landscape in 2018, which was previously covered by vegetation in 2008. This significant decline in both vegetation and wetland has made the area vulnerable to floods. In 2008, it is clear that vegetation holds 66.09% of the total area in the buffer zone of 2km, around the Periyar river.

However, its areal extent has drastically reduced by 36.9% of the total land use in 2018. This declining trend is mainly due to land conversion to settlements. A comparative appraisal of the land use maps of 2008 and 2018, it is evident that huge encroachment has occurred along the banks and periphery of the river over a period of 10 years. Most of the floodplain areas have now been converted into built-up land. It increased from 21.89% of the total land use (in 2008) to 61.43% (in 2018). (Table 4.)

As the name implies, flood plains are the most affected areas during floods and an increase in human settlements in the area accentuates the risk of flood related disasters.

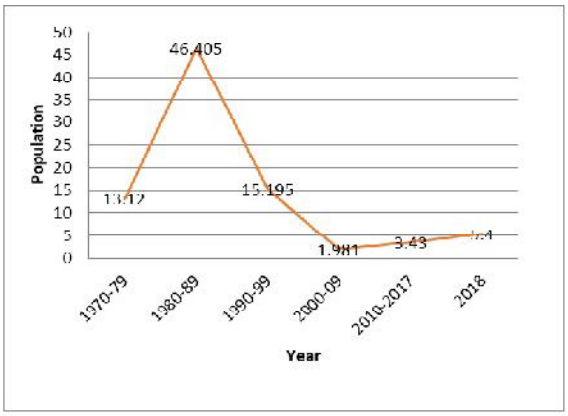

Fig. 2. Decade-wise flood affected population (in million) in Kerala

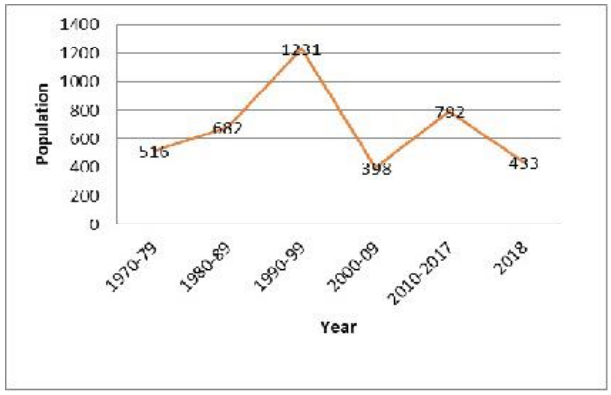

Fig. 3. Decade-wise loss of human lives due to floods in Kerala

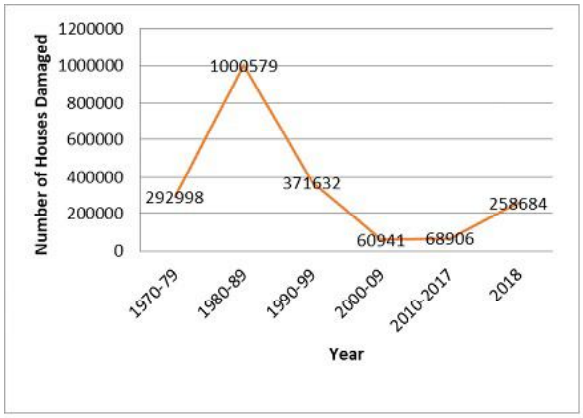

Fig. 4. Decade-wise number of houses damaged in floods in Kerala

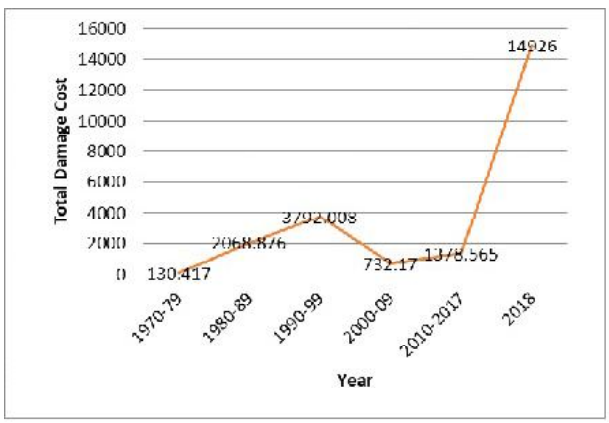

Fig. 5. Total damage cost to crops, houses and public utilities due to flood in Kerala

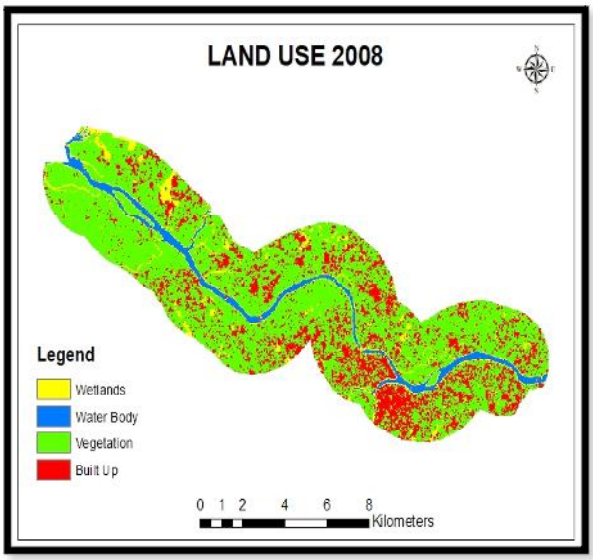

Fig. 6. Land Use Map of 2008 showing flood plains along Paravur and Aluva stretch of Periyar river

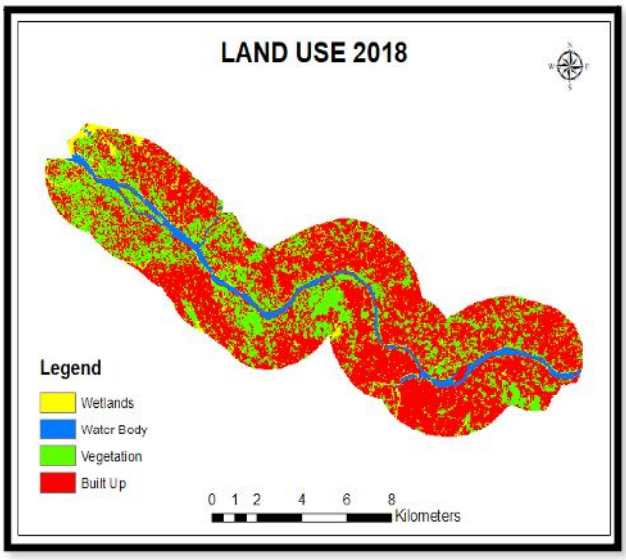

Fig. 7. Land Use Map of 2018 showing flood plains along Paravur and Aluva stretch of Periyar river

Table 4. Area of different land use classes

Land Use Classes	Colors assigned to each class	2008		2018		% Change
		Area (In hectares)	Area (In %)	Area (In hectares)	Area (In %)	
Built-up	Red	2620.08	21.89	7350.03	61.43	+39.54
Wetland	Yellow	773.01	6.46	557.55	4.66	-1.8
Vegetation	Green	7907.31	66.09	3492.81	29.19	-36.9
Water body	Blue	663.48	5.54	563.49	4.7	-0.84

Flood plains are a natural ecosystem fed by the alluvium carried down by the rivers and the natural flooding processes has kept these areas fertile over the ages. The flood plains which are most suited for agriculture are now being converted into human settlements mainly owing to the increasing pressure on land, in general.

A shrinkage of wetlands in the region has been observed and is a cause of serious concern. Wetlands help in controlling the impact of the flood by slowing down the flow of water. It serves as sinks for flood water wherein water finds its way to recharge the neighbouring aquifers. It acts as sponges by absorbing excess water. Wetland areas have decreased from 773.01 ha in 2008 to 557.55 ha in 2018. The varying pattern of land use for a span of 10 years is clearly depicted in the pie diagrams (Fig. 8). It needs to be noted that the conversion of wetland and highly vegetated zones for other purposes, in turn, has destroyed the habitats of a number of aquatic flora and fauna along

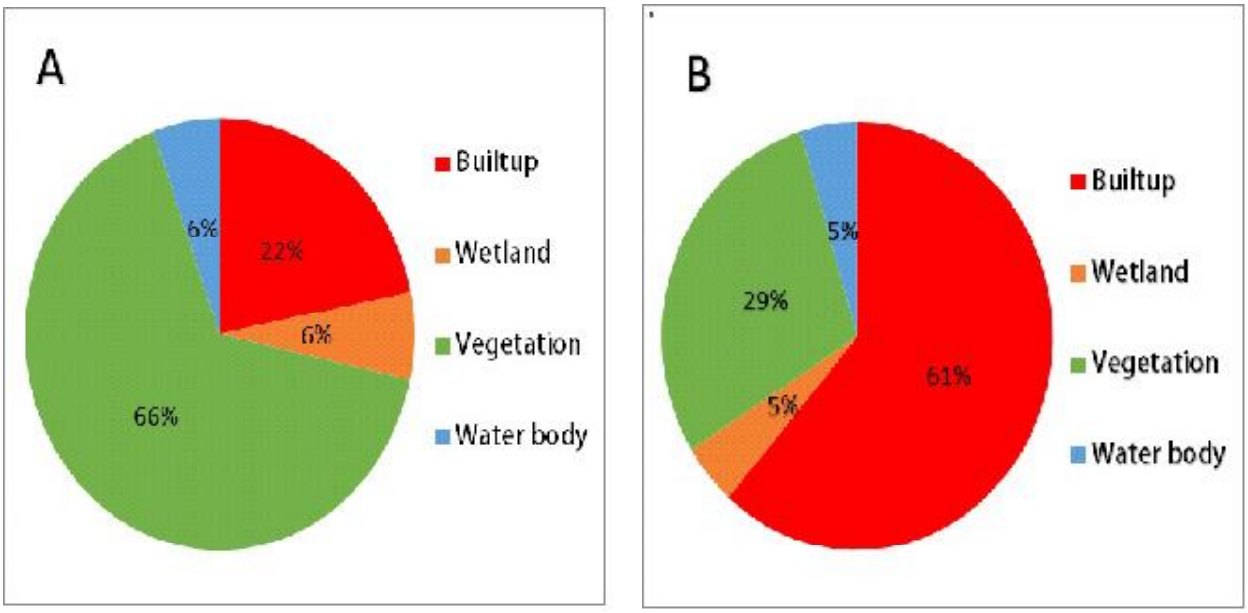

Fig. 6. Percentage of Area Under Various Land Uses: Flood plains of Periyar river along the Paravur and Aluva stretch. A) Land Use percentage of 2008 B) Land Use percentage of 2018

the lower reaches of the river which in turn has led to the loss of rich biodiversity as well. With the elimination of a considerable hectarage of wetlands, which served as natural sinks, areas previously unaffected by floods have become flood-prone. The human population and property which is exposed to flood have increased rampantly between 2008 and 2018, which is indicated by the phenomenal increase of built-up land in the region.

4. Conclusion

Kerala flood of 2018 had a devastating impact on the lives of the people living along the banks of major rivers. Most of the floodplains have been converted into residential areas as the floods have been kept under control by the construction of dams across the rivers. Ignorance on flood vulnerability and associated disasters which loom over these locations has led to an increase in settlements, especially along the Periyar riverfront. There is a lack of awareness among the local communities on the precautionary measures to be taken to reduce their vulnerability to floods. Therefore, there is an urgent need for developing strategies for effective disaster preparedness and thereby mitigating the impacts of flood-related disasters and protect the riverine ecosystem. It is quite hard to revive the ecosystems to its past glory. However, if checks are not placed to prevent conversion and also to revive the ecosystems, many of the endemic species will soon be endangered. Hence there is an urgent need for proper implementation of River Regulation Zones to preserve the riparian vegetation and the ecosystems which are unique to the river.

Since much of the floodplains are under human habitation, real-time flood forecasting has to be evolved through flood modelling. This is very much essential for effective mitigation, disaster preparedness and also reducing flood risk. It is also necessary to engage the communities occupying the floodplains in disaster mitigation and also in conserving the fragile riverine and riparian ecosystems. Making the community aware of their vulnerability and vesting conservation of the ecosystem to a community who has been made aware of the risks involved in destroying ecosystems, will in a significant way allow putting an end to unscrupulous exploitation of the natural environment.

Acknowledgements

Authors acknowledge the University Grants Commission (UGC) for the financial support provided in the form of UGC-JRF.

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