Land use and land cover changes and their impacts in Pampa river basin in Kerala: A remote sensing based analysis

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Abstract: Increased rate of urbanization along with other human intervention factors have been cited as major challenges faced by river basins, which ultimately change the basin ecology and end up in serious natural havocs like floods and droughts. As far as a river basin is concerned, the spatio-temporal changes in land use have direct influence on its hydrological realm. Deforestation and conversion of waterlogged wetlands into built-up areas directly affect the characteristics of the basin and natural water flow regimes and the obvious consequence is flood. Analyzing the spatial and temporal variations in land use and land cover (LULC) of river basin provides meaningful insight to these issues. The state of Kerala in general, and the Travancore- the central region in particular, is well known for high level of growth in terms of socio –economic factors, literacy, health care etc. The extensive socio-economic changes have led to increased rate of infrastructure and building construction and profuse landscape changes in this region during the last decade. Consequently, the basin characteristics of Pampa river - flowing through the heart of this region – has succumbed to terrific variations. Recurring flood and drought has become a predominant feature of this river, which is the lifeline of the region. In this context, this study attempts to evaluate the LULC changes that have taken place in Pampa river basin during the last three decades by employing the remote sensing based digital images for the period from 1985 to 2012. From the results derived by analyzing satellite images, the possible human intervention factors have been identified and discussed. The transformations in the land use pattern of Pampa river basin revealed in this study are 'strong negative changes', aggravating the havocs now being experienced due to recurring flood and drought situations.

Keywords: LULC changes, Pampa river basin, Land use transformations

1. Introduction

Analyzing the spatial and temporal changes in land use and land cover (LULC) is one of the diagnostic methods to understand the problems persisting in a river basin. Rapid growth of urbanization along with other increasing human intervention factors have been identified as major reasons of land use changes and land conversions, which ultimately poses serious havocs like flood and drought. As far as a river basin is concerned, the spatio-temporal changes in land use in the basin have a direct influence on its hydrological realm. Currently fresh water resources in several parts of the globe are facing severe crisis due to unsustainable river utilization. Deforestation and conversion of waterlogged wetlands into built-up areas directly affect the characteristics of the basin and natural water flow regimes, and the obvious impacts are flood and drought.

The state of Kerala in general and the Travancore region (the mid-region of the State) in particular is well known for high level of growth, in terms of socio-economic, literacy and health care factors. River Pampa, which used to be a rich and sustainable source of water throughout the seasons, was known to be the lifeline of the Travancore region. However, the extensive socio-economic changes that Kerala has undergone in the past few decades resulted in an apparent increase in the rate of infrastructure and building construction in this region. Profuse landscape changes in this region have happened during the last few decades. The river basin experiences alternating cycles of recurring flood and drought. In the years 1993 and 1994 the region underwent acute water scarcity and the water level in the river Pampa hit rock bottom that the world famous Aranmula boat race was ruined. Similar dry spells occurred in 2003 and 2016 when the boat race had to be cancelled. A good number of villages and densely populated regions on the banks of this river also face the ravage of frequent severe floods. According to a research conducted by Swaminathan Research Foundation, the intensity, frequency and severity of floods in the region are increasing (M. S. Swaminathan Research Foundation, 2007). In July 2007, Alappuzha district in the Pampa basin witnessed the worst flood in sixteen years. Around 1,34,000 people were evacuated from the region. In the year 2008, within three months six incidents of floods occurred. In 2009 on the first day of the monsoon floods, 10553 persons including 2134 children were evacuated. In Pathanamthitta district (which occupies a major share of the Pampa basin) alone, the death toll was six and crop loss was worth Rs 5.64 crores. In this context, this study attempts to evaluate the changes in LULC in Pampa river basin during 1985 to 2012 and deliberate on the possible impacts of human intervention factors on the flood occurring in this river basin.

Numerous recent studies have successfully employed remote sensing based LULC analysis to identify the watershed and river basin characteristics in India. A land use based study on the Khanpara watershed area of

Assam-Meghalaya region was done by Santanu and Tivari (Sarma and Saikia, 2012). Roy *et al.* (2008), in a significant work, developed a satellite-based methodology for evaluating the forest ecosystem. Samarakoon (2004) employed satellite based land use images for flood mitigation studies of Dhaka city. In a study by Bhaskaran and Baijulal (2008), land use changes in a limited portion of the Pampa river basin were examined through satellite images.

2. Land use pattern of the study area

Pampa river encompasses a basin area of approximately 2235 km^2 spread over four districts of the state of Kerala, viz., Idukki, Pathanamthitta, Kottayam and Alappuzha. The study is done only on the part of the basin which exclusively belongs to the Pampa river. The area lying to the western side of Veeyapuram (i.e., lower Kuttanad and parts of upper Kuttanad, covering an area of nearly 455 km^2) is not included in this study since it is drained jointly by Pampa, Achancoil, Manimala and Meenachil rivers and has unique geological and ecological characteristics. Hence, a total area of around 1780 km^2 comes under the purview of this study. A map of study region is provided as Fig. 1. As per the census 2011, the total population in the above four districts is about 6.40 million (Census of India, 2011). The area extends over thick tropical forests, wasteland, built up (urbanized and semi-urbanized) settlements, few water bodies and a rich agricultural bowl called Kuttanad.

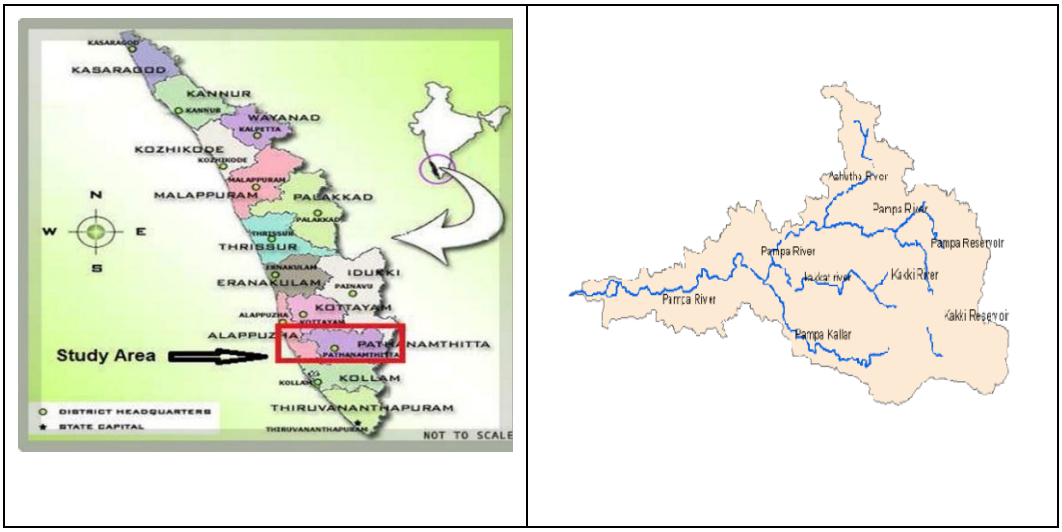


Figure 1: Pampa river basin - the study area

The land use pattern of this river basin is unique and diverse. Physiographically, the 2235 km^2 of river basin terrain has three natural regions namely, lowland (about 229 km^2), midland (about 933 km^2), and highland (about 1073 km^2) (Fig.2). The high land consists of high altitude areas of thick forests whereas midland consists of region of cash crops like rubber and tea. The low land is basically providing agrarian crops like rice, paddy and coconut. The undulating topography, vibrant climate and vivacious hydrology of this river basin are unique and provide multitudes of lively micro ecosystems. Though the official statistics does not highlight any significant changes in the forest cover and cropping pattern, many recent researches brought out that the utilization pattern of pampa river basin has been substantially altered by human interventions.

Physiographic units, altitudes and areas

Unit	Altitude (m)	Area (km^2)	Area (%)
Lowland	0 – 7.5	228.86	10.24
Midland	7.5 – 75	933.34	41.76
Highland	> 75 m	1072.80	48.00

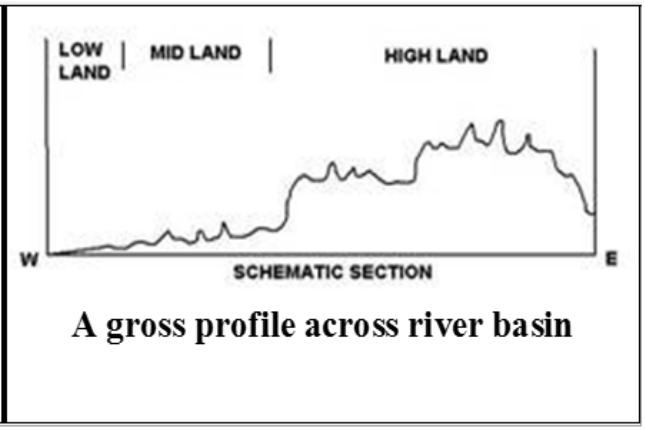


Figure 2: Physiographic pattern of river basin (Source: Kerala State of Environment report)

3. Methodology

Remote Sensing (RS) and Geographic Information System (GIS) have been widely applied to understand the LULC changes and are considered to be a powerful tool to document the spatio-temporal changes of an area for the purpose of conservation and management of natural habitats. The multispectral images obtained from recent satellites provide satisfactory spectral resolution, which in turn offers a reliable means to diagnose LULC changes. The satellite images were obtained from ISRO and belong to the following satellites. Year 1985 – Landsat: Year 1995-IRS-1C: Year 2005 Resourcesat-1: Year 2012 Resourcesat- 2. Landsat Thematic Mapper data for 1985 has a ground resolution of 30 m. LISS - III sensor data (having ground resolution of 23.5 m) have been utilized for the years 1995, 2005 and 2012 in this study. In order to avoid the image processing errors due to seasonal variations, images pertaining to the month of April, which is a peak summer period, were considered. The basin area was delineated using the relevant Survey of India (SOI) topographic maps. Pre-processing of the images has been carried out using software *Erdas Imagine*. Supervised classification was done in the spatial analyst extension of Arc *GIS* under multivariate tool set. Maximum likelihood classification method was adopted for this.

In this study, the classification of the study basin area of 1780 km^2 has been carried out for six main categories viz: forest land, agriculture land, built up area, wasteland, grass land and water bodies.

4. Results of image analysis

Land use changes in the river basin of Pampa during the years 1985, 1995, 2005 and 2012 have been mapped. The selection of data for the above years was predominantly decided by the availability of clear, cloud free satellite images of this region. A summary of results of analysis is shown in table 1. The land use map pertaining to the years 1985 and 2012 corresponding to each category are provided in figure 3 for comparison.

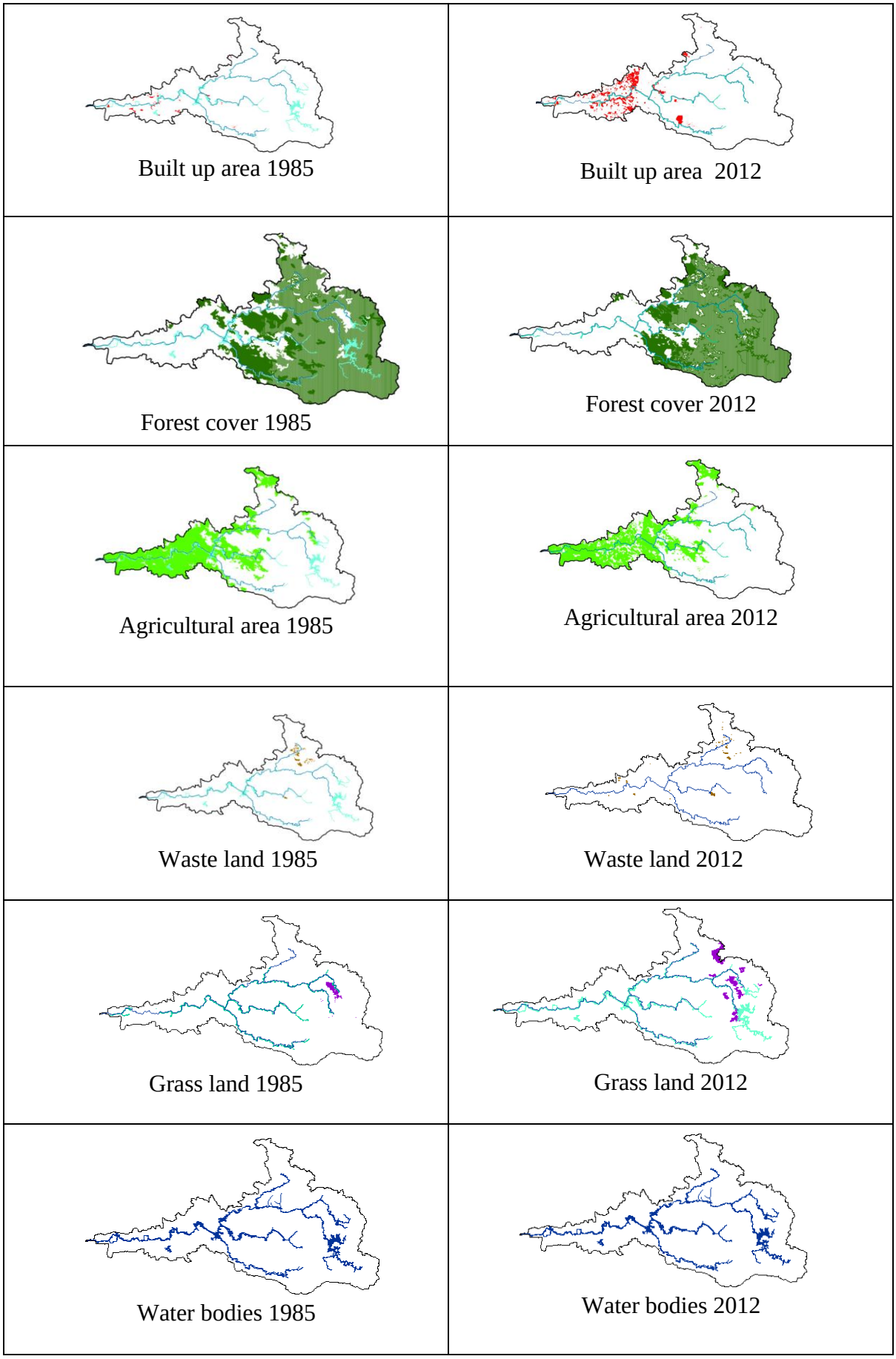
Table 1: Summary of results of LULC mapping

LULC category	Area occupied (km^2) in the year			
	1985	**1995**	**2005**	**2012**
Built up area	16.90	31.30	38.50	70
Forest	1167	1156	1146	1114
Agriculture	520.80	512.60	515.10	507
Wasteland	12.60	13.40	14.10	23.40
Grass land	25.10	29.10	28.70	28
Water bodies & other class	37.60	37.40	37.60	37.60
Total	1780	1780	1780	1780

The above results clearly testify significant changes in the pattern of land use in this river basin over the period of study.

4.1 Built up area

During the period of study, significant increase has been observed in the built up area in this river basin. A total built up area of about 16.9 km^2 in the year 1985 has increased to 70 km^2 by the year 2012. The increase in built up area (314%), corroborates with the change in urbanization depicted in the map-to-map comparison of this study. The increase has predominantly happened in the downstream regions, that too at regions which are in very close proximity of the river. These regions are already densely populated and undergoing a high rate of urbanization (7.64% decennial growth, 2011 Census). Various studies have indicated that this rapid urbanization is on account of the fast changing socio-economic transition structure of this region [NIU, KSUDP]. The phenomenal increase in the built up area of the river basin is one of the factors contributing to the flood havoc of this region.



Figures 3: Comparison of land utilization in 1985 (left) and 2012 (right)

4.2 Forest cover

About 40% of the basin area is covered under forest. While a major share of this is on account of the notified tropical monsoon forest, in the image classification, thick forest plantation also forms under the category 'forest'. While the forest cover in the year 1985 was approximately 1167 km^2, the same has dwindled to 1114 km^2 by the year 2012, involving a reduction of about 4.5%. This amounts to an annual shrinkage of forest cover of the region by about 0.2%. Though a few official statistics indicate that the forest area of Kerala as 'reasonably stable', it is a well-known fact that the forest cover in the pampa river basin is depleting on account of various reasons. The main reasons for the forest cover shrinkage are the deforestation - both legal and illegal-, encroachments, irrational expansion plans of the pilgrimage areas like Sabarimala, and above all the absence of an effective preservation policy. In fact, if the coverage on account of thick green plantation corps could be segregated, the actual rate of forest cover depletion would be much more.

4.3 Agriculture area

The results show that the total agricultural area has come down by 3% over the period of study. The main agricultural production of rice, coconut etc is limited to the downstream and middle regions of the basin. A few studies have identified that this slowdown of agriculture dynamism in central Travancore region are mainly on account of various socio-economic factors and 'political climate' non-conducive for labour oriented agriculture activities (Economic Review, 2007; KSCSTE). However, though marginally, the change in pattern of basin utilization from agrarian to non-agrarian applications adds to the flood related issues of the region, apart from making the state of Kerala more import dependant on food.

4.4 Wasteland

Wastelands are lands that cannot be put to productive use. They include barren and rocky lands, degraded forests, scrub lands, abandoned quarries, lands subjected to excessive erosion, which are deprived of complete topsoil etc. Wasteland may also be formed due to salinity and infertility of the soil used by poor land practices. An area of 12.6 km^2 has been mapped in 1985 as waste land where as this has substantially increased to 23.4 km^2 by the year 2012 indicating about 85% increase. It can be seen that the wasteland during 1990s was sparsely distributed in the upstream alone, whereas by the year 2012 it has substantially spread to the rich down stream river basin also. This is evidently on account of the human intervention factors like indiscriminate sand mining, excavating fertile soil for clay mining etc and poor land practices that resulted in excessive soil erosion. The shrinkage of river and alterations of the river ecology also aggravates the flood features of this river.

4.5 Grassland

The grasslands in the Pampa river basin, popularly known as 'Plumed' are located in the upstream region of the basin, surrounding the holy shrine 'Sabarimala'. With a marginal increase during the year 1985-95, this has slightly dwindled by the year 2012. This is mainly on account of the human intervention by the pilgrims, by using this grassland as trekking pathway to the Sabarimala temple. The projections for the year 2020 and 2025 also shows that if the same trend continues, the grassland area may remain more or less unaltered.

4.6 Water bodies

This class includes lakes, tanks and similar water collections near the basin. This class remained more or less unchanged throughout the period of analysis. As a total transformation of the LULC of the river basin will have impacts on the water bodies also, it is necessary to carefully preserve this region to ensure the sustained health of the basin.

4.7 Significance of results

The most significant observations in this study are the exponential increase in the built up area (314%), quick transition of fertile land to waste land (85%) reduction in agriculture land (3%) and marginal decrease in the forest cover (4.5%). It was observed that during period 1985 to 1995 the agricultural pockets of Elanthoor, Ranni Pazhavangadi and Chengannur villages have been converted to built up land. This conversion further increased during the decade 1995 to 2005 when Kadapra, more parts of Chengannur and Ranni Angadi which were agriculture – predominant villages became urbanized and forest land in Thannithode village was also transformed to a built up hub. The period 2005 – 2012 witnessed the distribution of built up land further downstream to convert agricultural lands in the villages Niranam, Kadapra, Pandanad, Kuttoor, Koipram, Aranmula, Kidangoor, Mezhuvely etc. During this period, parts of the Pampa river was also encroached in the villages of Ranni, Athikkayam and Vadasserikkara. The rapid increase in the built up area bears a significant impact in the basin ecology, especially in aggravating the flood havoc in Pampa river basin. This many fold increase in infrastructure and built up area in the close proximity of the river channel blocks the natural flood plain and there by the flood water levels in the remaining areas increase substantially. Massive and irrational infrastructure realizations is quite apparent all around the villages and towns in this river basin. This is mainly due to the absence of an infrastructure policy, scientifically taking care of the river basin and its ecology.

Further, major increase in wasteland area indicates the alarming level of human intervention. It was observed that in the decade 1985 – 1995 wasteland spread in the forests of Kumily while the same phenomenon occurred in the forests of Peruvanthanam in the decade 1995 – 2005. The period 2005 – 2012 witnessed spread of wasteland throughout the basin. In this period the agricultural lands in the villages of Elappara, Vechoochira, Naranamoozhi, Ranni Perunad, Ranni, Mylapra, Naranganam, Ayiroor and Aranmula and the forest lands in Peermade, Peruvanthanam, Mundakkayam, Seethathode, Chittar and Aruvapulam were converted to wasteland. The mathematical model

showing the 'best fit' for this variation is a 'MMF function', which also is a steady growth function. Though moderate in mathematical terms, this transition of fertile river basin to waste land is a matter of serious concern. The silt formation (consequent to sand mining), unauthorized settlements in basins (called 'Purambokku'), drying of rivulets, formation of scrub lands etc. contribute to increase in rapid transition of fertile land to wasteland regions, which will aggravate the flood.

The reduction in agriculture area is a clear indication of the slowdown in the agrarian dynamism of this region. The rich agricultural bowl is quickly transiting towards non-cropping barren fields or housing settlements. This is in corroboration with a few studies which showed that the crop efficiency and cropping pattern itself of this region is fast changing. Such a transition, that too of an agriculture-predominant region is certainly an indication of a strong negative change. Though marginally, the reduction in forest cover also is another factor aggravating the intensity of flood havocs. Natural tropical forest act as an effective sponge for reducing the quick rain water run off and prevents flash floods. Further, forest cover in the river basin prevents soil erosion altering the river contours. Many studies have shown that forest cover is an effective stabilizing factor to control unlimited run offs. The annual reduction in forest cover in the river basin, will aggravate flood incidents.

5. Conclusion

The radical variations in the land use pattern of Pampa river basin revealed strong negative changes, directly affecting the basin ecology and aggravating the flood and drought situation of this river basin. The exorbitant increase in built up area, fast transition of fertile land to wastelands, increased deforestation, changing agrarian crop intensity etc calls for an urgent need for a diligent policy formulation to protect the river and basin. Also, there should be a conscious urban planning policy to cap the rate of urbanization in the river flood plain. Perhaps the only prescription is an urgent comprehensive policy planning with diligent implementation.

References

Bhaskaran Baijulal and P. Prateesh (2008). Land use change in upper catchment of Pampa river basin – A GIS based approach. Journal Eco-chronicle, vol.3, No.2. June 2008, pp: 127-130.

Census of India (2011). Provisional population totals – website http://census india.gov.in.

Economic Review (2007). Publication by State Planning Board, Government of Kerala.

KSCSTE. Kerala State Council for Science, Technology & Environment, Government of Kerala- Various reports- Website: www.kscste.kerala.gov.in/

KSUDP. Kerala Sustainable Urban Development Project, Government of Kerala. Report- Website http://ksudp.org.

M. S. Swaminathan Research Foundation (2007). Measures to mitigate Agrarian distress in Alappuzha and Kuttanad wetland ecosystem: A study report. Website. www.kuttanadupackage.in.

NUI. National Institute of Urban affairs, New Delhi. Various study reports - Website: www.niua.org.

Roy, P.S., V. Bhanumurthy, C.S. Murthy and T. Chand Kiran (2008). Space for disaster management: Lessons and perspectives. Journal of South Asia disaster studies. 1(1): 157-177

Samarakoon, L. (2004). Land use planning for flood mitigation of Dhaka city using remote sensing and GIS. ISTS-2004 n-22: 1-5.

Sarma, Santanu and Trivani Saikia (2012) Prioritization of subwatersheds in Khanapara-Bornihat area of Assam-Meghalaya (India) based on land use and slope analysis using remote sensing and GIS. Journal of Indian Society of Remote sensing. Sep.2012.40 (3): 435-446.