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Driving forces behind land transformations in the Tamiraparani sub-basin, South India

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A B S T R A C T

The present study emphasizes the long-term (1992–2012) land alteration and its driving factors in the Tamiraparani sub-basin, south India. The multi-temporal landuse/land cover features were extracted from the Landsat images (TM and ETM+, 30 m resolution) using a supervised classification technique with maximum likelihood classifier. The extracted features were classified into various landuse/ land cover categories with level I classification scheme of NRSC, India. Six major landuse classes such as forest, settlement, barren land, water bodies, agricultural land and fallow land were recognized. The overall accuracy for the year 1992, 2002, and 2012 shows 85.55%, 82.81% and 83.59% respectively. The overall Kappa coefficients for the datasets are near to 0.8, which indicates acceptable accuracy for landuse/ land cover classification. The results reveals that the spatial extent of forest, settlement and barren land has evolved in the past 20 years but, the water bodies, agricultural land and fallow land has reduced significantly. The reduction in agricultural land in the study area for the past 20 years is due to the combination of natural environment and socio-economic factors such as low rainfall in the plains, increased surface temperature, reduced soil moisture condition, high rate of evapo-transpiration, reduced water storage level in the reservoirs and ponds, and reduced vegetation cover. These factors are linked with climate change, it alters the socio-economic condition of the area, and such situation will affect the overall ecosystem in the Tamiraparani sub-basin in the near future.

1. Introduction

Humans have been transforming their environment since the age of colonization and they distorted the landuse and land cover to fulfill their needs for survival (Phillips, 1991). The study on changing landuse and land cover has great significance for future landuse planning as well as managing water resources (Lambin et al., 2001). According to Turner at al. (1993), land-cover refers to the biophysical attributes of the earth's surface and immediate sub surface. It includes four variables namely, land, water, air, and man. On the other hand, land-use is a description of how people utilize the land for their needs by various management practices (Fisher et al., 2005; IPCC, 2000). Over the period, land is becoming a limited resource due to vast pressure in agricultural and demographic development. Hence, understanding the processes behind landuse/land cover change (LULCC) is vital for both scientific and policy actions (David et al., 2001). For systematic assessment, the landuse/ land cover (LULC) data is required to analyze the landscape dynamics and associated problems for maintaining the ecosystem in a sustainable way (Allan et al., 2015). This information will support in observing the dynamics of LULC under immense population pressure. Moreover, the quantum of change in utilizing the land resources is essential for proper planning and management. Traditionally, the method of monitoring landuse and land cover changes is based on field study (surveying) combined with large-scale aerial photography, which is often time intense, meticulous and costly (Groom, 2006). Recently, remote sensing technology has gained its application in regional as well as in global scales (Atzberger, 2013). Constant upgradation in methodology, software development and data processing made this tool an efficient system for providing reliable information on various natural resources. Furthermore, an integrated remote sensing (RS) and GIS approach can efficiently deal with the spatio-temporal information related to LULC change. It is well recognized in the scientific realm and is considered as an effective tool in quantifying LULCC (Yeh and Li, 1999).

Over the past decade, remote sensing has played a vital role in landuse/land cover change detection. LULC change detection studies are gaining importance with the availability of a wide range of sensors operating at various imaging scales. Significant research on computing the LULC change including the estimation of its accuracy has been carried out in the scientific world (Lillestrand, 1972). Byrne et al.

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(1980) have shown that Landsat multispectral data can be used to identify LULC changes very effectively. The validity of such techniques depends on ones thoughtfulness towards the earth morphology, limitations of the satellites, applied method and the aim of the work (Yang and Lo, 2002). Various remote sensing data products over time have often been incorporated into historical landuse information (Acevedo et al., 1996; Clarke et al., 2002; Meaille and Wald, 1990).

Classifying the satellite images to extract the landuse/land cover theme is one of the major steps in this type of study and it demands suitable processing techniques and quality of the satellite image being used (Lunetta, 1998). Digital image classification techniques is being widely used for the extraction of various LULC features as the pixels play a major role in determining the real world phenomena (Jensen and Gorte, 2001). Through the classification of remotely sensed image, thematic maps such as the LULC can be obtained and numerous researchers have standardized the monitoring technique with better interpretation (Tso and Mather, 2001; Chan et al., 2001). This is due to a wide variety of change detection techniques and algorithms have been developed over the past few decades. According to Owojori and Xie (2005), accuracy assessment is an essential and most crucial part of studying image classification and change detection in order to understand and estimate the changes accurately. It is important to be able to derive accuracy for individual classification if the resulting data are to be useful in change detection analysis. The popular method for estimating the accuracy in the change detection analysis is the confusion/error matrix method in which various assessments factors such as user accuracy, producer accuracy, overall accuracy, and kappa coefficient plays an important role in qualitative assessment (Congalton, 1991; Congalton and Green, 1999; Foody, 2002). Based on these technical guidelines, researchers throughout the world have been exploiting this technology for various applications in terms of landuse classification.

The landuse system is extremely dynamic and substantial transformation occurs due to changing socio-economic and natural environment that may lead to unfavorable effects on the fragile environment. The change in landuse and land cover of an area can adversely affect the water and energy balance, which directly influence the climatic condition in all scales. Besides, its implications on environmental sustainability, LULC change can also affect the food security of the region. For example, conversion of agriculture land to settlement may become a threat to future food security (Brown, 1995). Therefore, understanding the trends in landuse change in relation to the driving factors will provide essential information on landuse planning and sustainable management of resources (Turner et al., 1995). In India, the pace of urban population is increasing day by day with 22.5 million in 1991 to 35 million in 2005 (Chauhan and Nayak, 2005). Such rate of urban growth leads to the transformation of fertile lands to settlements and other recreational land for human use. Moreover, the same phenomenon is applicable at a basin scale where life is supported through various biogeochemical cycles. The population pressure and climatic variability affects the LULC pattern in the Tamiraparani sub-basin. The twin cities of Tirunelveli and Palayamkottai have been expanding considerably without even sparing the agricultural lands. The climatic variability and failure of monsoon also affects the productivity of the study area, which can induce significant soil erosion and water quality problems in different landuse conditions. The aim of the present study is to examine the LULCC in the Tamiraparani sub-basin and to identify the driving forces behind the LULC change derived from multi-temporal Landsat TM and ETM+ imageries for a period of 20 years.

2. Study area

The Tamiraparani sub-basin is located in the Tirunelveli district of southern Tamil Nadu, India (Fig. 1). The study area lies between 77° 9′ – 77° 48′ E longitudes and 8° 27′ – 8° 55′ N latitudes, covering a total catchment area of 2055 km^2. It has a varied topography with high hills in the west and plain lands towards the east. The difference in the elevation varies from 1826 m in the west to 29 m (above msl) in the east. Normally, the study area is controlled by northeast and southwest monsoon. The southwest monsoon is active during the months of June to September and the average rainfall during this period is around 35 mm. During October to December, the northeast monsoon becomes active with an average rainfall of 150 mm. The annual rainfall in the study area is around 845 mm. However, the annual average rainfall in the Western Ghats alone contributes to nearly 2000 mm depending on the altitude of the region. Generally, hot and dry season prevails in the plains over a better part of the year. The temperature increases steadily from the mid February and get to its peak in the month of May with a maximum temperature of 37.1 °C. The temperature gradually drops during the onset of southwest monsoon in June. Further, in the middle of October the temperatures decrease appreciably until January, which is the coolest part of the year with the mean daily maximum temperature of about 30–31 °C. The mean daily minimum in these months is about 22–23 °C. The relative humidity in the study area ranges from 55% to 65% and it exceeds over 65% during the northeast monsoon season. The wind velocity is frequently high in the study area and it varies from 2.8 to 35.5 km/h. The wind direction is mainly northwesterly or westerly during May and September and from October to February winds are mainly northeasterly or northerly. Tamiraparani River and its tributaries drain the study area, which affords perennial irrigation to a large area on which two crops are normally raised. The study area has been classified as seventh order drainage basin with dendritic to sub-dentritic drainage pattern, which is characterized by irregular network of stream channels in different directions joining the main Tamiraparani River. A diverse landuse system is noticed in the Tamiraparani sub-basin with forestland in the west (comprising the Western Ghats), agricultural lands in the flood plains of the major tributaries of River Tamiraparani, and barren lands with shrubs in isolated patches throughout the plains. The dominant landuse types in the study area are forestland, barren land, agricultural land, and fallow land, apart from settlements and water bodies.

3. Materials and methods

3.1. Data acquisition and pre-processing

Landsat Thematic Mapper and Enhanced Thematic Mapper multispectral data acquired on 11th January 1992, 26th January 2002, and 19th January 2012 has been used for extracting various categories of landuse classes. The Landsat data products were downloaded from GLCF website (http://glcf.umd.edu/data/). The satellite data were registered to the Universal Transverse Mercator (UTM) map projection (Zone 43N) and scaled to planetary reflectance. The resolution of the acquired images was 30 m and the data was processed into a four-channel data stack of the visible and near infrared bands. Basic image distortions in each band were refined through radiometric and geometric corrections. The image quality was improved by applying various enhancement techniques like spatial filtering, density slicing, contrast stretch, and edge enhancement. Prior to image classification, a level 1 classification scheme established by NRSC, India was used for further analysis. ERDAS IMAGINE 2009 image processing software was used to compute each LULC classes in the study area using the Maximum Likelihood Classifier (MLC) algorithm of supervised image classification technique.

3.2. Post classification and accuracy assessment

Post classification includes sieving and clumping in which the former removes isolated classified pixels and the later clump adjacent similar classified pixels together using morphological operators. After sieving and clumping, the classification accuracy is improved to 95.8%. The best way to express the classification accuracy is by developing an error/confusion matrix. The confusion matrix works by comparing the

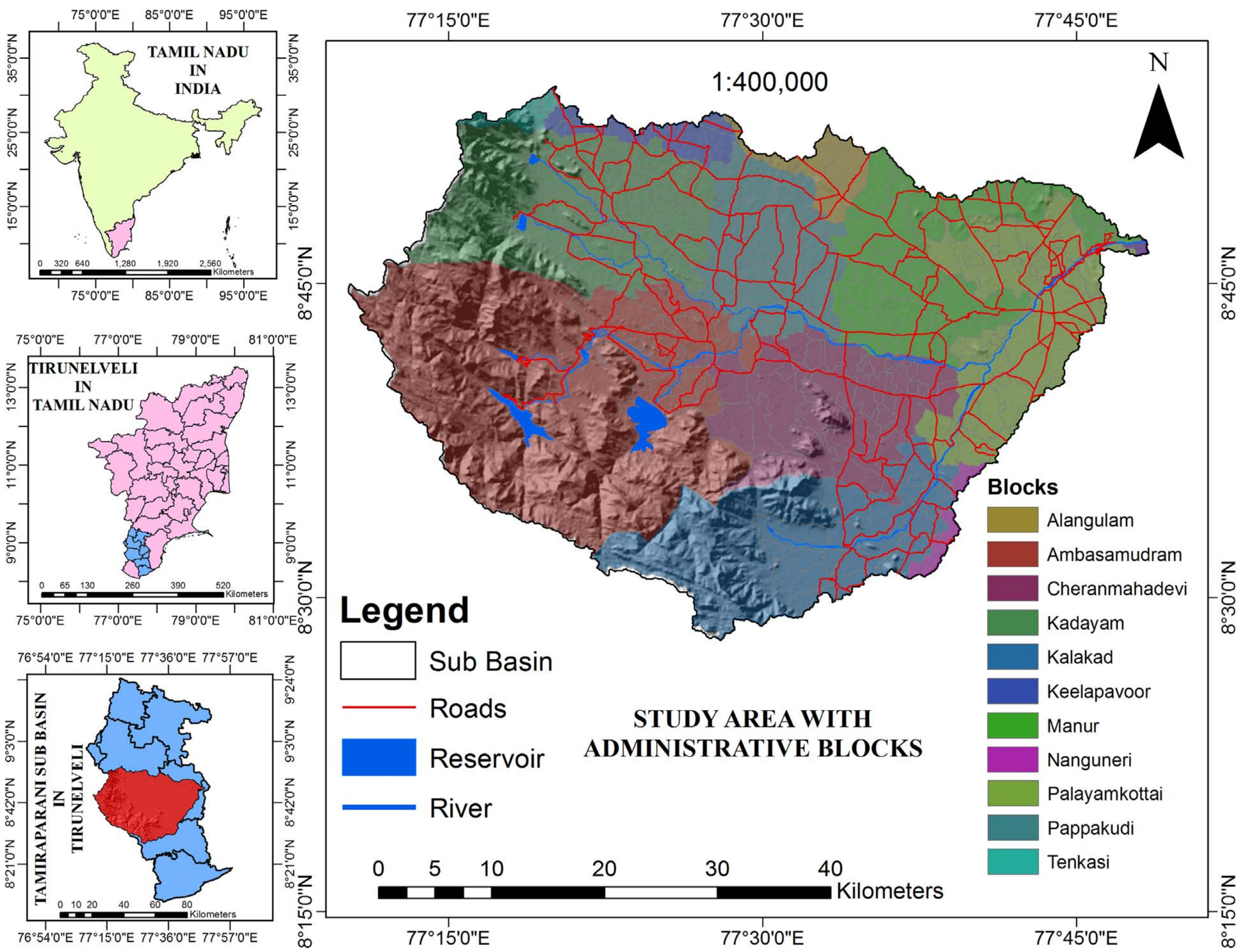

Fig. 1. Location map of the study area.

ground truth data with the results obtained from automated classification. An error matrix expresses several characteristics about classification performance. The overall accuracy of classification can be calculated from the error matrix, which is established by dividing the sum of reference pixels by the sum of correctly classified pixels. Likewise, the accuracy's of individual categories can be calculated by dividing the number of correctly classified pixels in each category by either the total number of pixels in the corresponding rows or column.

4. Results and discussion

4.1. Landuse and Land cover pattern

The landuse and land cover distribution of six landscape types for the year 1992, 2002, and 2012 are shown in Fig. 2. The geospatial extent in square kilometer and area coverage in percent for the study area is shown in Table 1 and its graphical representation is also shown in Figs. 3 and 4. The classified landuse types in the study area are agricultural land, barren land, fallow land, forest, settlement and water bodies. The details of these landuse types are discussed below.

In the study area, the forest landuse is the most dominant landscape with an average terrestrial coverage of 36% (Table 1). They are semi-evergreen in nature and being a reserved forest with strict forest management practice, the forestland has been noticed with a marginal increase in its coverage area. In 1992, the coverage of forestland is 729.36 km^2 and it increased to 754.83 km^2 with a raise of 25.47 km^2 in 2002. Later in 2012, a marginal increase of 9.49 km^2 of forestland has been noticed in the study area, which account for a total aerial extent of 764.32 km^2. A close examination of forestland and agricultural land (probably plantations) especially in the foot hills of the study area reveals a dynamic relationship with each other, i.e., the forestland is increased in the last 20 years by sparing the agricultural land in the foothills of the Western Ghats (Fig. 2). Particularly, the afforestation programme organized by the state government has also improved the forestland cover in the study area.

The main cultivated crops in the study area are paddy, sugarcane, groundnut, pulses and plantains. The spatial extent of agricultural land shows a significant decreasing trend in the study area (Fig. 2). Between 1992 and 2002, there is a reduction of 5% in agricultural land and from 2002 to 2012 it is further reduced to 4%. In 1992, the spatial coverage of agricultural land is 596.65 km^2, which contributes to 28.7% of the study area. However, such spatial extent of agricultural land is reduced in 2002 with a total coverage of 493.3 km^2 that accounts for 23.7% of the study area. Whereas, the agricultural land is further reduced to 410.47 km^2 in 2012 that accounts for 19.7% of the study area (Table 1). The decrease in agricultural land for the past 20 years is mainly due to frequent monsoon failure and land degradation, which results in conversion of agricultural land into fallow land. It is also observed that the agricultural lands associated with the alluvial plains of Tamiraparani river is being converted to settlements near Tirunelveli - Palayamkottai stretch. Such anthropogenic pressure is a major factor for agricultural land reduction.

Barren lands are the second most dominant land cover in the study area. They are associated with exposed soil and thorny bushes. The spatial coverage of barren land in 1992 is 428.28 km^2, which corresponds to 20.6% of the study area. In the year 2002, the barren land cover is further raised to 585.38 km^2 covering 28.1% of the study area and a marginal raise is observed with a spatial extent of 629.87 km^2

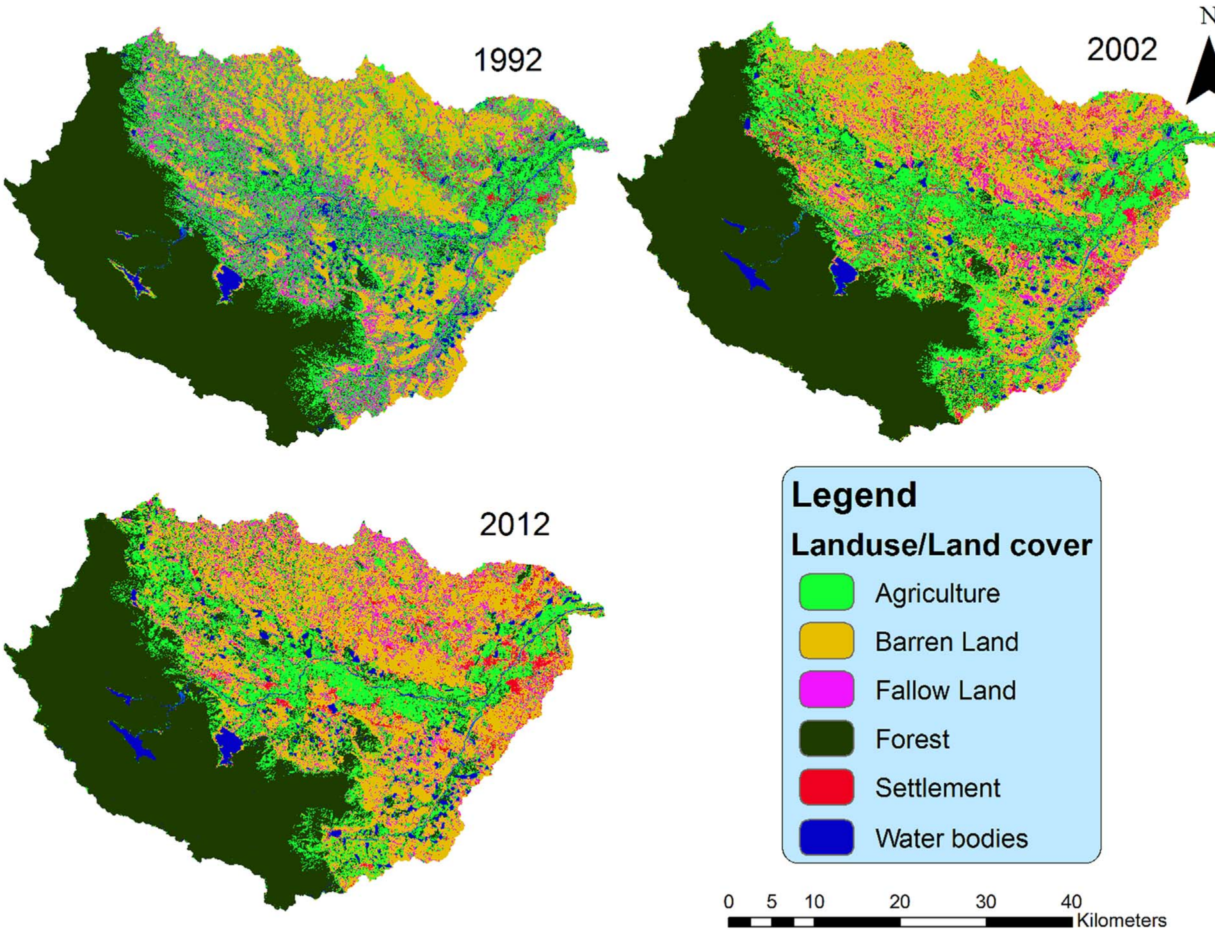

Fig. 2. Landuse and land cover map for the year 1992, 2002, and 2012.

Table 1
Landuse and land cover distribution for the year 1992, 2002 and 2012.

Landuse class	1992		2002		2012	
	Area in Sq.km	Area in%	Area in Sq.km	Area in%	Area in Sq.km	Area in%
Forest	729.36	35.0	754.83	36.2	764.32	36.7
Water bodies	68.75	3.3	65.6	3.2	66.06	3.2
Agriculture	596.65	28.7	493.3	23.7	410.47	19.7
Fallow Land	217.09	10.4	128.22	6.2	146.88	7.1
Settlement	42.37	2.0	55.17	2.6	64.90	3.1
Barren Land	428.28	20.6	585.38	28.1	629.87	30.2

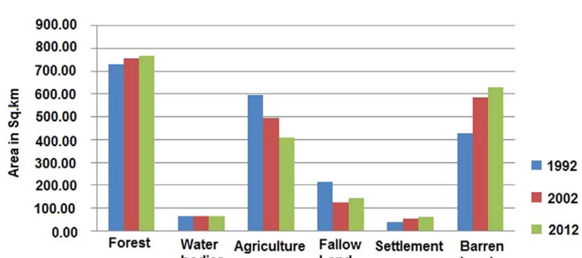

Fig. 3. Distribution of landuse and land cover in area.

covering 30.2% in 2012 (Table 1). The difference between 1992 and 2002 barren land cover is 7.5%, which is quite high. This is happened due to poor rainfall, lack of work force to retain agricultural activities and poor socio-economic conditions, which has forced the young farming generation in search of alternative livelihood. However, this trend has been decelerated between 2002 and 2012 with a marginal increase of 2.1%. This can be attributed to the existence of stabilized land conditions in different landscapes, but still there is a fluctuation of nearly 2% in the study area except agricultural land, which showed a difference of 4% (Fig. 2).

Fallow lands are associated with agricultural lands and used for cultivation but they are temporarily un-cropped for one or more season, but not less than one year (Ruthenberg, 1980). The fallow land cover in 1992 is 217.09 km^2, which comprises of 10.4% of the study area. This is due to the effect of varied agricultural practices such as crop rotation, dry land farming and rain fed agriculture (Fig. 2). It is also noted that these lands are engaged in cultivation only on favorable seasons. However, in 2002, the spatial extent of fallow land is reduced to 128.22 km^2 comprising of 6.2% of the study area. Further, in 2012, a slight increase (0.9%) in fallow land is noticed as compared to 2002, which accounts for 7.1% of the study area (Table 1). This is due to the unavailability of water to cultivate these lands and left idle for years, which slowly transforms to barren land. This can be observed in the northern part of the study area by comparing the 1992 image with 2012 image. In 1992, the agricultural land and its associated fallow lands in the northern part of the study area are linked with stream channels. Later in 2002, these lands are transformed to fallow and barren land, the barren land has increased by occupying the fallow lands in 2012. This trend is noticed in the whole study area where the water availability is scarce.

The water bodies in the study area show a negligible variation from 1992 to 2012 (Fig. 2). In 1992, the aerial extent of water bodies is 68.75 km^2 covering 3.3% of the study area. In 2002, it is slightly reduced to 65.6 km^2, which accounts for 3.2% of the study area. Later in 2012, a marginal increase is noticed with an aerial extent of 66.06 km^2,

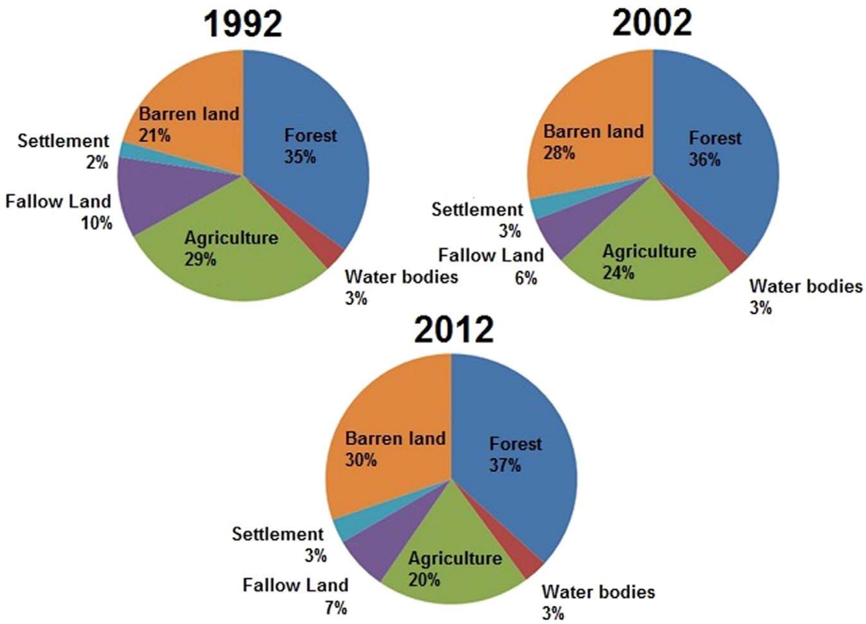

Fig. 4. Distribution of landuse and land cover in area percentage.

which is negligible (3.2%) when compared with 2002 data (Table 1). The availability of water in the water bodies is controlled by rainfall, evaporation, and water usage through irrigation and domestic supply. Consequent failure of northeast monsoon is one of the main reasons for unavailability of water in the study area, which induces transformation of agricultural land into fallow land, and long-term fallowness leads to barren lands. It is also noticed that the major water bodies (ponds and tanks) are found parallel to the main channels of Tamiraparani and its tributaries. This reveals that the water draining from minor streams are collected in the ponds and tanks before it joins the main channel of Tamiraparani river. Such water bodies are essential for irrigation as well as a source for groundwater recharge.

The aerial extent of settlements in 1992 was 42.37 km^2 covering 2% of the study area. Due to urban expansion, the settlement has increased to 55.17 km^2 corresponding to 2.6% of the area and the settlement areas have increased to 64.9 km^2 that account for 3.1% of the area in 2012 (Table 1). This highlights that around 0.5% of settlement area is increasing every 10 years. The fertile agricultural land, fallow land and few parcels of barren lands have contributed to the expansion of settlement areas. The down streams of Tamiraparani river (eastern part of the study area) is observed with an increasing urban development in the twin cities of Tirunelveli – Palayamkottai stretch followed by Melapalayam, and Pettai (Fig. 2). These areas show significant urban growth and thereby reducing the fertile agricultural land and urban sewage is dumped into the Tamiraparani river. Such intense pressure is degrading the environmental condition of the river system and adjacent lands.

4.2. Accuracy assessment

Accuracy assessment highlights the possible sources of errors in a classified image, which enhance the map quality. The standard method to represent the accuracy of classification result is confusion matrix or simply called as error matrix (Foody, 2002). This method expresses the number of samples assigned to a particular class relative to number of samples assigned to remaining classes. They can be measured using three different scales in percent namely producer's accuracy, user's accuracy and overall accuracy. Producer's accuracy is defined as total number of correct classified units of class xy divided by total number of class xy units identified in reference data. Whereas, user's accuracy is defined as the correct class xy divided by total number of units classified as class xy and overall accuracy is the sum of all correctly classified units divided by total number of units (Congalton and Green, 2009). For the present study, 300 validation pixels covering six LULC types have been identified from field survey and the ground truth points were marked with a global positioning system (GPS). The producer's accuracy, user's accuracy, overall accuracy and Kappa coefficients are computed and shown in Table 2. The overall accuracy for the classification performed in 1992, 2002, and 2012 datasets is 85.55%, 82.81% and 83.59% respectively. The overall Kappa coefficient of 1992, 2002 and 2012 landuse maps are near to 0.8, which indicates acceptable accuracy for landuse classification.

Table 2
Accuracy assessment of classified LULC for 1992, 2002 and 2012.

Class Name	Producers accuracy %			Users accuracy %			Kappa coefficients		
	1992	2002	2012	1992	2002	2012	1992	2002	2012
Forest	98.61	85.29	80.39	85.54	80.56	80.39	0.799	0.776	0.755
Water	66.67	84.85	87.5	85.71	87.5	70.00	0.846	0.832	0.657
Agriculture	97.73	95.64	90.77	86.00	90.91	93.65	0.831	0.897	0.915
Fallow	94.87	92.57	95.12	86.05	74.14	33.33	0.835	0.689	0.325
Settlement	50.00	76.19	89.54	80.00	84.21	87.80	0.794	0.811	0.858
Barren	95.00	90.21	94.56	85.25	81.48	90.38	0.815	0.797	0.882
Overall accuracy		85.55%	82.81%	83.59%					
Overall Kappa coefficient		0.8186	0.7930	0.7995					

Table 3
Landuse and land cover change from 1992–2002, 2002–2012 to 1992–2012.

Landuse Class	Change detection (Area in Sq.km)		
	1992–2002	2002–2012	1992–2012
Forest	25.47	9.49	34.96
Water bodies	−3.15	0.46	−2.69
Agriculture	−103.35	−82.83	−186.18
Fallow Land	−88.87	18.66	−70.21
Settlement	12.8	9.73	22.53
Barren Land	157.1	44.49	201.59

4.3. Land transformation

Between 1992 and 2012, significant amount of land transformation has occurred in which 259.08 km^2 of land has involved in land transformation process. The changes detected in different landuses such as forest, water bodies, agriculture, fallow land, settlements, and barren land are shown in the Table 3. The forestland in the study area has gained 25.47 km^2 between 1992 and 2002 and 9.49 km^2 between 2002 and 2012 with a total gain of 34.96 km^2 within 20 years (1992–2012). Meanwhile, the agricultural land has lost (-) 103.35 km^2 in 1992–2002 and (-) 82.83 km^2 in 2002–2012 with a total loss of (-) 186.18 km^2 (1992–2012). The vanished agricultural lands from 1992 to 2012 was transformed to forest (28.8 km^2), barren land (138.99 km^2) and settlement (18.39 km^2) (Table 4). The agricultural lands in the form of plantations near to the foothill areas have been converted to forestland through afforestation and strict forest protection measurements by the Tamil Nadu state government. The barren land in the study area has gained 157.1 km^2 between 1992 and 2002 and 44.49 km^2 in 2002 and 2012 with a total gain of 201.59 km^2 (1992–2012) (Table 3). Such increase is due to the transformation of agricultural land (138.99 km^2), fallow land (59.91 km^2) and water bodies (2.69 km^2) to barren land (Table 4). This increase in noticed throughout the plains especially in the north and northeastern part of the study area. Climate induced change such as failure of monsoon and raising surface temperature followed by socio economic condition has provoked the raise of barren lands in the study area. The fallow land and water bodies showed a mixed response. In which, the fallow land has lost (-) 88.87 km^2 during 1992–2002 and gained 18.66 km^2 in 2002–2012 with a total loss of (-) 70.21 km^2 (1992–2012) (Table 3). The lost fallow land has been transformed to forest (6.16 km^2), barren land (59.91), and settlement (4.14 km^2) (Table 4). Fallow land to forest transformation has been noticed in the foothills of Western Ghats and is associated with the agricultural lands (plantations). The transformation of fallow land to barren is noticed mostly in the northern part of the area where water availability is scarce. Fallow lands associated with agriculture in the eastern part of the study area have been changed to settlements. This is due to the urban expansion in the twin cities of Tirunelveli and Palayamkottai. In the case of water bodies, the area lost is (-) 3.15 km^2 during 1992–2002 and area gained in 2002–2012 is 0.46 km^2 with a total area loss of (-) 2.69 km^2 (1992–2012) (Table 3). The lost water bodies have been transformed into barren lands (Table 4). They are shallow in nature and most of them are seasonal. The settlement has gained 12.8 km^2 and 9.73 km^2 during 1992–2002 and 2002–2012 respectively with a total gain of 22.53 km^2 for the last 20 years (1992–2012) (Table 3). The graphical representation of landuse change and land transformation is shown in Figs. 5–7.

Table 4
Land transformation from 1992 to 2012.

Land transformation	Area Sq.km	Area %
Agriculture to Forest	28.80	11.1
Agriculture to Barren	138.99	53.6
Agriculture to Settlement	18.39	7.1
Fallow to Forest	6.16	2.4
Fallow to Barren	59.91	23.1
Fallow to Settlement	4.14	1.6
Water bodies to Barren	2.69	1.0
Total	259.08	100.0

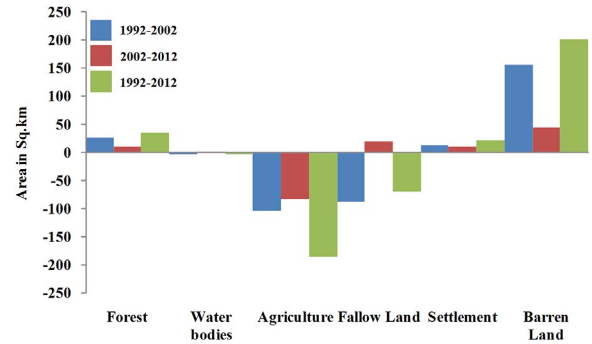

Fig. 5. Graphical representation of landuse change during 1992–2002, 2002–2012, and 1992–2012.

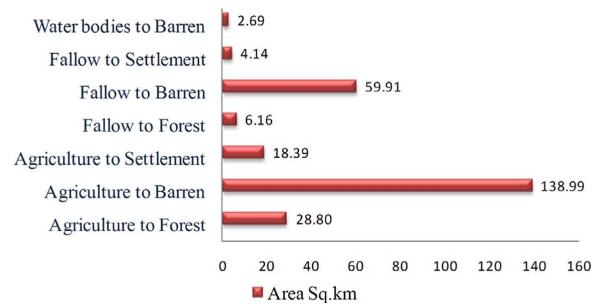

Fig. 6. Graphical representation of land transformation in km^2 for the period of 20 years (1992–2012).

5. Driving force identification

According to International Geosphere-Biosphere Programme (IGBP) and International Human Dimensions Programme on Global Environmental Change (IHDP), the three main driving forces of landuse and land cover are natural environments, landuse management, and socio-economic factors (Nunes and Auge, 1996; Turner et al., 1995; Vellinge, 1998). In which, the natural environments include climatic variables and regional morphology such as temperature, precipitation and land topography. But, landuse management refers to developmental policies, such as land allotment, zoning, urban area development, transportation and water networks for irrigation and drinking water supply. The socio-economic factors include demographic

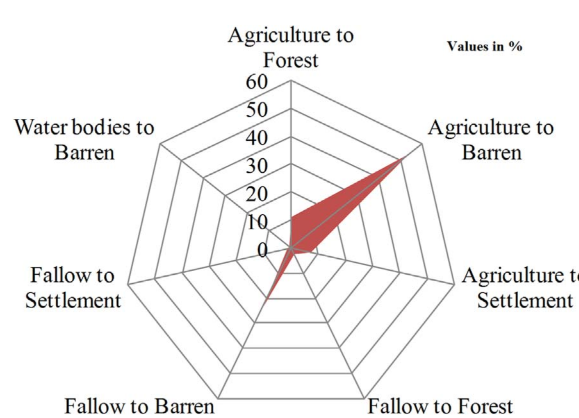

Fig. 7. Graphical representation of land transformation in % for the period of 20 years (1992–2012).

information, literacy level, societal factors, economy and technology development.

The driving forces behind natural environments are controlled over a global scale (for example climate change) and the regional disturbances in topography are controlled either by long-term natural process or by anthropogenic activities. They have the capability to convert a particular landuse such as water bodies and forest over a period of time. Whereas, the driving force behind landuse management is controlled by the suitability of different land conditions. For instance, the reduction in agricultural land in the study area for the last 20 years is due to the combination of natural environment and socio-economic factors such as low rainfall in the plains, increase in surface temperature, reduced soil moisture condition, high rate of evapo-transpiration, reduced water storage level in the reservoirs and ponds, and reduction in vegetation cover. These factors are linked with climate change and it alters the socio-economic condition of the area, for example food security, economic status, and population growth. This will enhance the possibility of further land degradation through human activities like mining, forest logging, and transforming the natural resources into value added products for human use.

The main driving factors of agriculture landuse change for the past 20 years include the farming practices adopted in the study area such as cultivation of water demanding crops like paddy, sugarcane, plantains etc. The water demand for cultivating such crops is high and the water availability in the basin is scarce including the storage capacity of major reservoirs. However, construction of check dams in the Tamiraparani river has somehow supported the standing crops along the alluvial plains but in unfavorable conditions the water supply for irrigation ceases. This scenario triggers the transformation of agricultural land into fallow land, where dry land cultivation practice is adopted such as cultivation of pulses and other cash crops. The groundwater is the only source for such cultivation and the water yield gradually decreases due to poor recharge potential. If such condition persists for a period of time then the fallow land gradually becomes barren. The soil type also plays an important role in landuse shift because specific soils support only a few crops and the water holding capacity of the soil determines its cultivation pattern. The flood plains of the study area are generally composed of alluvial soil and most of the crop productivity is noticed in this type of soil followed by red loamy soil and black cotton soil. But, the black cotton soil often generates cracks in the dry seasons due to high plasticity and clay content and makes it unfit for cultivation. This reveals that the scarcity of water is the major driving force for soil based landuse shift in the study area.

The urban development in the study area is driven by infrastructure, transportation access, demographic trends, and economic development. The migration of rural population to the cities for better employment opportunity is the main cause for urban expansion. This results in increased urban land utilization and exploitation of various natural resources without even sparing the fertile lands. However, such conditions can be restored, not entirely but in a small scale by adopting sustainable landuse management policies through technology development. For the socio-economic factor, the driving force includes the GDP in agricultural, industrial, and service sectors and most importantly the education levels in the society. Because, most of the damage happening in the landscapes is due to either lack of knowledge and skills or unscientific method of exploitation, precisely the long term effect on the environment. For minimizing the effect of such land degradation, a well-planned landuse policy is required to address the long-term impact and the capability to withstand the effect of future climate change.

6. Conclusion

The haphazard urban growth, declined water resources and rapid destruction of agriculture lands and its conversion to fallow and then to barren land needs special attention to study the landuse and land cover pattern and changes in the Tamiraparani sub-basin. The present study highlights the long-term (1992–2012 – 20 years) change in landuse/land cover of Tamiraparani sub-basin. The analysis of multi-temporal landuse maps indicates that the spatial extent of forest, settlement and barren land have increased drastically. Whereas, water bodies, agricultural land and fallow land have greatly declined during the past 20 years. The geographical area of barren land has increased to 10% during these 20 years, and the extent of agricultural land is decreased to 9%. Such variation indicates deprived environmental condition with loss of biodiversity. The increase in forestland cover up to 1.7% indicates the rejuvenation of Kalakad - Mundanthurai Tiger Reserve (KMTR) through strict forest conservation measures and increase in settlement area up to 1% indicates the urban growth in the study area, which is more confined to the twin cities of Tirunelveli - Palayamkottai. This expansion represents the conflict between the population and agricultural land, and may cause serious agricultural crisis. The decrease in water bodies (0.1%) and fallow land (3.3%) and subsequent conversion to barren land signifies the unavailability of water (monsoon failure) and rising temperature in the study area can be related to the effect of regional climate change. The increasing trend in barren land results severe soil erosion in an extreme rainfall condition. Moreover, the runoff from barren land contains high level of dissolved ions and increases the concentration of total suspended sediments in the surface water. The urban expansion near to the Tamiraparani river has induced serious river water contamination, which lead to degradation of water quality. Similarly, the alluvial plains of Tamiraparani river and its tributaries are actively engaged with agricultural activities induces abnormal nutrient loadings in the river water. Therefore, there is a need to establish buffer zones along the riparian areas of main streams and tributaries to reduce anthropogenic effects on river water quality. Finally, an optimal landuse management strategy must be adopted in the study area.

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