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Remote sensing and GIS based forest cover change detection study in Kalrayan hills, Tamil Nadu

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Abstract: *The present study focuses on the role of remote sensing and geographic information system (GIS) in assessment of changes in forest cover, between 1931 and 2001, in the Kalrayan hills, Tamil Nadu. The trend of forest cover changes over the time span of 70 years, was precisely analysed using high resolution Satellite data. The study revealed that the forest cover was 275.6, 481.7 and 266.5 sq.km in 1931, 1971 and 2001 respectively. It was noticed that forest cover has increased between 1931 and 1971, because of the implementation of various afforestation schemes by the forest department and scared grooves. It also revealed that the forest cover loss between 1971 and 2001 could be due to Shifting cultivation and illegal encroachments by villagers; and the forest cover drastically decreased on plateau areas due to human population pressure. The study analyses the forest cover change in the tropical deciduous forest region of the Eastern Ghats of India. It is envisaged that the study would prove the usefulness of Remote Sensing and GIS in forest restoration planning.*

Key words: *Forest cover, Kalrayan hills, Remote sensing, Change detection, GIS*
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Introduction

As we are aware of the fact that the hills are known for its natural beauty. Forests are the green blankets that are naturally protecting the hill environment and preserving the natural resources. It is evident that the reported forest cover in our country including dense forest, open forest and mangroves is 67.83 m.ha which is 19.39% of India's geographical area (Anon,1999). It has observed that the Tamil Nadu State has comparatively less forest cover than required rate as prescribed by National Forest Policy (Anon,1976). Globally, every twenty minutes 1200 acres of forest are destroyed (Conservation International, 2000). Hence, it is essential to assess the forest cover and understand the reason for the decrease in forest cover. The recent researches show that the overwhelming population pressure, practicing of unscientific agricultural methods and the lack of awareness about the importance of forests among the populace in general and tribal folk in particular are the prime causes for deforestation / degradation of forests. The rates of depletion, reason for the deterioration and remedial measures to restore it are the essential factors to assess the forest cover in any terrain. The inventory of forest resources and forest cover assessment / change detection in the rugged topography or hill sector is not an easy task and it is a time-consuming process. This can be made easier only through the high spectral, spatial and temporal resolution qualities of remote sensing techniques. Indeed, the precise database pertaining to forest cover information is an imperative input of formulating various management plans and also remote sensing technology can be effectively utilized for change detection and monitoring activities (Jessica *et al*., 2001). According to Macleod and Congalton (1998), in general, remote sensing considers following four aspects of change detection (a) detect the changes, (b) identify the nature of change, (c) measure the aerial extent of change and (d) assess the spatial pattern of change.

Earlier, many researchers have carried out the change analysis through visual or digital interpretation. Forest cover change detection has been done, through visual interpretation of satellite data by Unni *et al*. (1985), Roy *et al*. (1991a,b), Sukumar *et al*. (1991), Porwal and pant (1989), Kushwaha (1990), Porwal and Roy (1992), Sudhakar *et al*. (1992), Unni (1992), Pant and Roy (1994), Das *et al*. (1997) and Pant and Jalal (1996), Batista *et al*. (1998), Birniel (1998), Luque (2000), Imbernon and Branthomme (2001), Young *et al*. (2001), Boyd *et al*. (2002), Larsson (2002), Roy and Joshi (2002), Rogan *et al*. (2002), Le Hegarat Mascle *et al*. (2006), Reis and Yomralioglu (2006) and Panigrany *et al*. (2010). However, the following researchers [Wickware and Howarth (1981), Williams and Nelson (1986), Yool *et al*. (1986), Frankilin and Wilson (1991), Forgham (1994), Macleod and Congalton (1998), Igbokwe

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(1999), Jessica *et al*. (2001), Dymond *et al*. (2002), Larsson (2002), Bouma and Kobryn (2004), Camacho-De Coca (2004), Ingram (2005) and Okeke and Karnieli (2006) have done the forest cover change detection through computer assisted Digital Image Processing (DIP) techniques. The basic principle of change detection through remote sensing is that the changes in spectral signatures commensurate with the change in land cover. The detailed procedure is to superimpose two period maps to find the change (Jessica *et.al*., 2001). Moreover, the process of change detection is premised on the ability to measure temporal impacts (Sabins, 1987). According to Singh (1989), change detection is the process of identifying differences in the state of an object or phenomenon by observing it in different times (multi-temporal variations). Meanwhile, it is evident that change detection can be precisely calculated using GIS technology and because of its high volume spatial and aspatial data handling capability. It would also help us to do overlay process with two or multi vector layers under single umbrella Lo and Shipman (1990) and Bhaduri *et al.* (2001). Some of the researchers have identified that the increase in vegetation cover has resulted in increased rainfall (Sarma, 2001; Dengiz *et al.,* 2009) and decrease in forest cover has direct relationship with socioeconomic status / marginal worker force (Murali, 2002). Hence an attempt has been made to analyze the forest cover changes to seek a sustainable balance in the hill ecosystem.

Materials and Methods

In the present study, for assessing the temporal changes in the forest cover, the Indian Remote Sensing Satellites (IRS) 1C LISS III geocoded FCC of 2001 on 1: 50,000 scale was made use of. As a time series data, the Survey of India (SOI) toposheets of 1931 and 1971 were also used. Moreover, the forest working plan reports and administrative maps were also taken into account.

The study area (Kalrayan hills environment) map was prepared from SOI topographical sheets on 1:50,000 scale. The forest cover, in the study area, during 1931 and 1971 were derived from the SOI toposheets of 1931 and 1971 on 1:50,000 (after converting it into same scale) respectively. As the data sources used are varied in nature, these pose problems while directly comparing the forest details with each other. The various forest classes given in the 1971 topographic sheet such as Dense mixed jungle, Fairly dense mixed jungle and Open mixed jungle do not find place in the 1931 topographic sheet; instead only the symbols representing the trees are given. Hence because of the varied classification adopted in these topographic sheets it was not possible to compare the various forest classes given in these two data sets readily. However, based

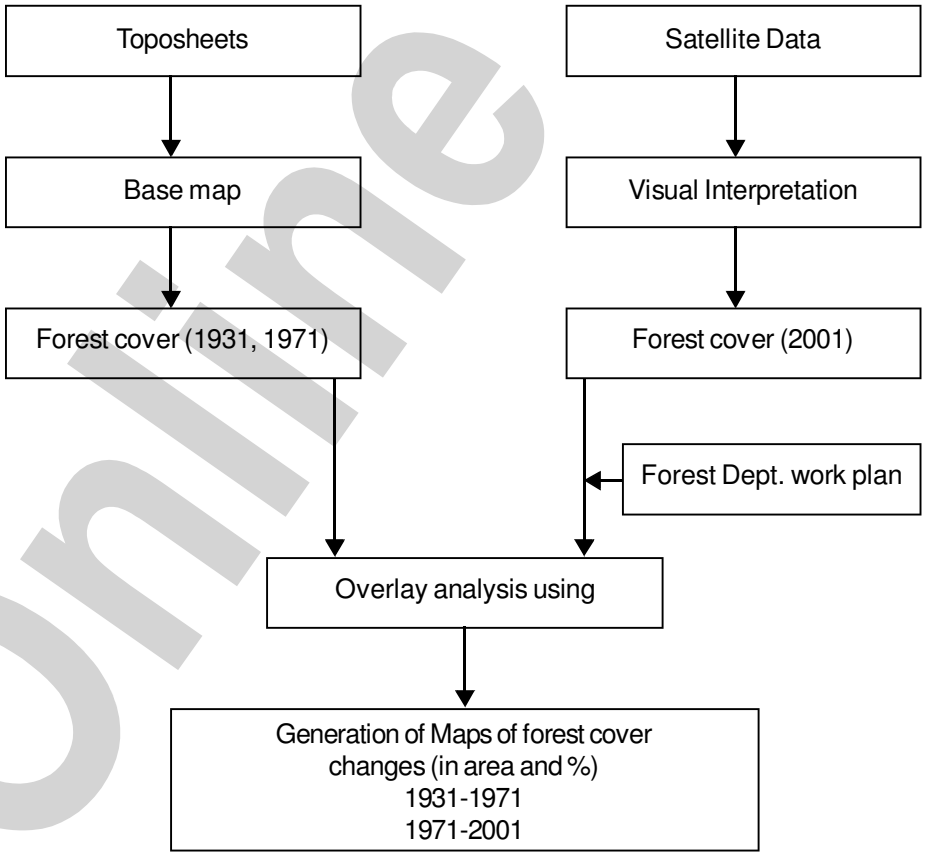

Fig. 1: Methodology flow chart

Fig. 1: Kalrayan hills and its environs location map

on the density of the symbols representing the trees which are depicted on the topographic sheets, the relative densities of the vegetation in the area can be known. Nevertheless in these topographic sheets, categories such as forests, scrub, rocky outcrops, agriculture and human habitations which are readily given, were compared with one another and were used for carrying out change detection studies for the period 1931 and 1971.

The same classes were then visually interpreted from the 2001 IRS 1C LISS III geocoded satellite data by using the common image interpretation elements. The forest areas were delineated from their red tone and contiguous pattern. The scrubs were identified from their brownish yellow tone, coarse texture and scattered pattern. The agriculture and human habitations were identified from the light reddish-brown tone and regular pattern. The rocky outcrops /slopes were identified from their brighter tone, absence of vegetal cover

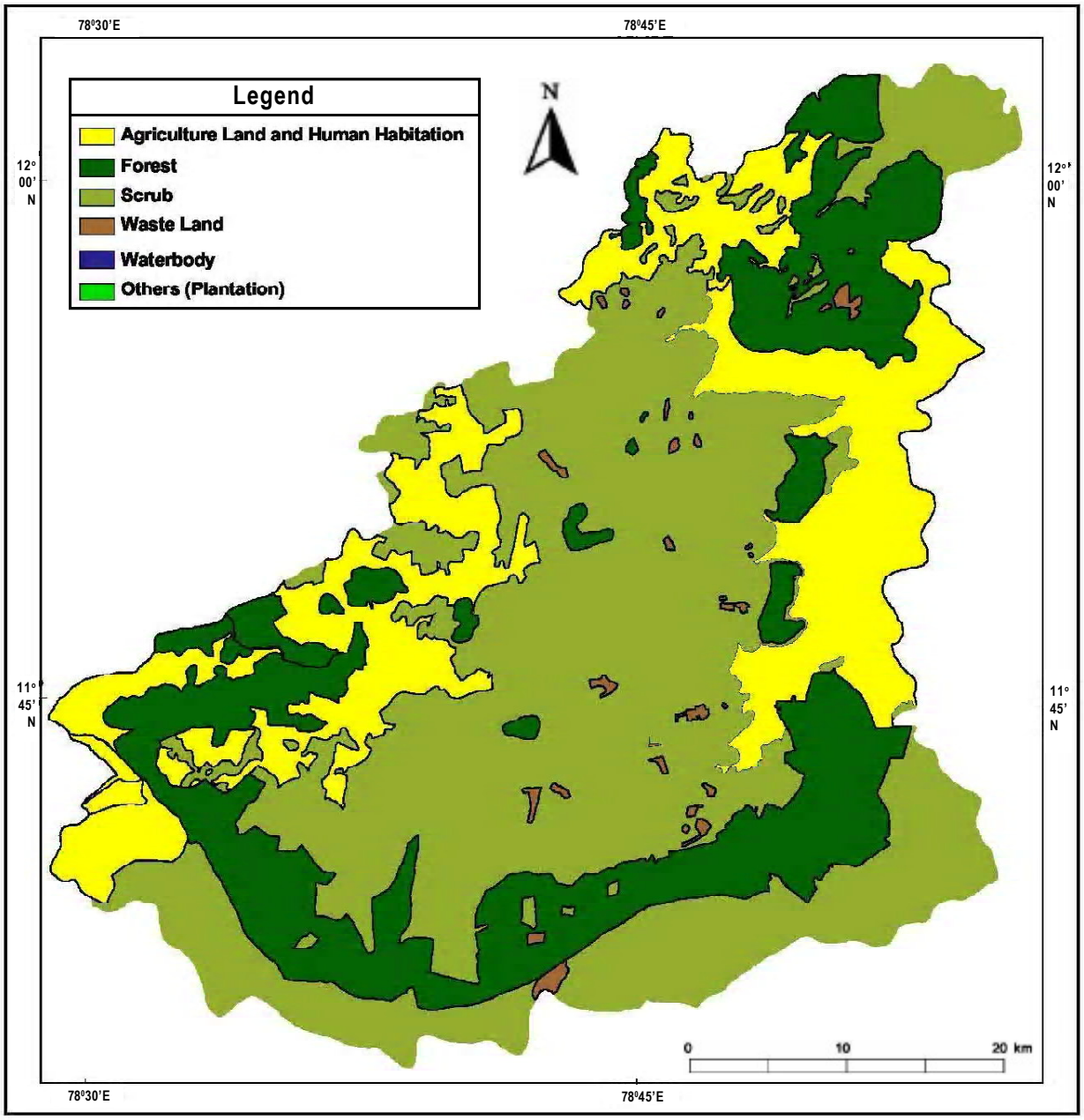

Fig. 2: Kalrayan hills and its environs forest cover - 1931

and their association to the steeper slopes. Necessary field checks were carried out and correction were made at required places and the various classes *viz.*, forests, scrubs, agriculture and human habitation, and rocky outcrops were identified. Thus, a thematic layer depicting the various forests and other land use classes were generated. The primary forest type and Landuse maps were prepared based on field observation and image interpretation. Then, the softwares such as Arc info 3.5.1 and Arc GIS were used to prepare the classified (final) forest cover and land use maps. Finally, the status of changes (either increase or decrease) during 1931-1971, 1931-2001 and 1971-2001 and land covers was assessed by overlaying the forest maps of various period (1931, 1971 and 2001). The final maps which represent the Forest cover, forest cover changes during 1931, 1971 and 2001 (both area and percentage) were also generated.

Study area: The study area, the Kalrayan hills, part of Eastern ghats, lies between the north latitudes 11° 36' and 12° 01' N and the east longitudes 78° 29' and 78° 54' E (Fig. 1). It forms part of three districts *viz.* Salem (southern and south western portion), Villupuram (Central and Eastern portion) and a small pocket in the northern most part of the study area forms part of Thiruvannamalai district and covers an area about 1158.4 km^2. Locally, the Kalrayan hills is

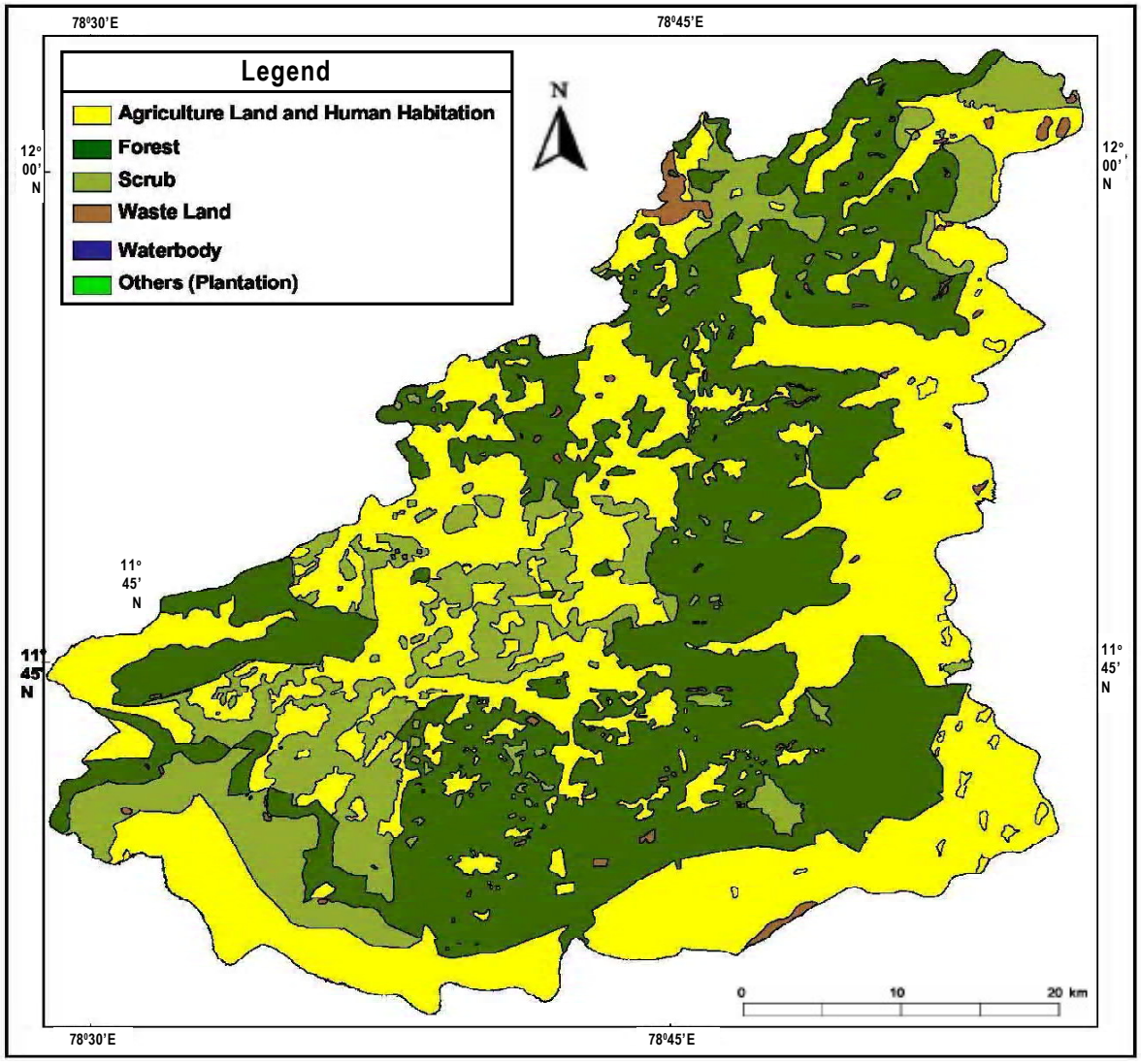

Fig. 3: Kalrayan hills and its environs forest cover - 1971

divided into '5' nadus (clusters of villages), such as Periyakalrayan (western part), Chinnakalrayan (northern part), Jadaya gaundan (southern and eastern part), Kurumba gaundan (central part) and Ariya gaundan (North). The study area emcompasses 79 revenue villages (Sakathivel *et al*., 2006). It acts as catchment for Gomukhi, Kariakovil and Manimuktha rivers. It supports life to more than 1 lakh people those who have been living in and around the Kalrayan hills. The hill also posses innumerable tourism potentialities like Periyar and Kaviam waterfalls, jungle streams, Kariakovil and Gomukhi dam, rivers and rivulets and lovely jungle walks. It is also called as Poor man's hill station of Tamil Nadu (http.// Villupuram.nic.in). Geologically, the study area is composed of Charnockite and basic dykes, Peninsular Gneissic complex of Eastern Ghat Super Group. The Pyroxinites, syenites, anorthosites, calc-granulite, carbonatites *etc.*, are also found to occur and belonging to Precambrian era (Matthew, 1981). Magnetite granite and black granite also occur in few patches (Kadavul and Parthasarathy, 2001). The northernmost tip of the Study area, Perugulathur region, is attributed to Eastern ghat Orogeny (Anbazhagan *et al.*, 1991) and the study area is encircled by Sathanoor dam, in the northern part (where the earth tremors were located close to N40°E - S40°W trending fault (Vemban *et al.*, 1997). The Kalrayan hills stand east of the Tenandamalai, being separated from it by the Kottapatti valley (Francis *et al*., 1995) in the west and it is being separated from Kolli hills by W-E trending Attur Valley in the South. The average annual rainfall in the study area ranges from 782.98 to 1787.20 mm. The temperature varies from a minimum of 25°C to a maximum of 40°C. The altitude varies from 126 to 1298 m. The study area is composed of seven soil types and varies from red-loam to black clay (Kadavul and

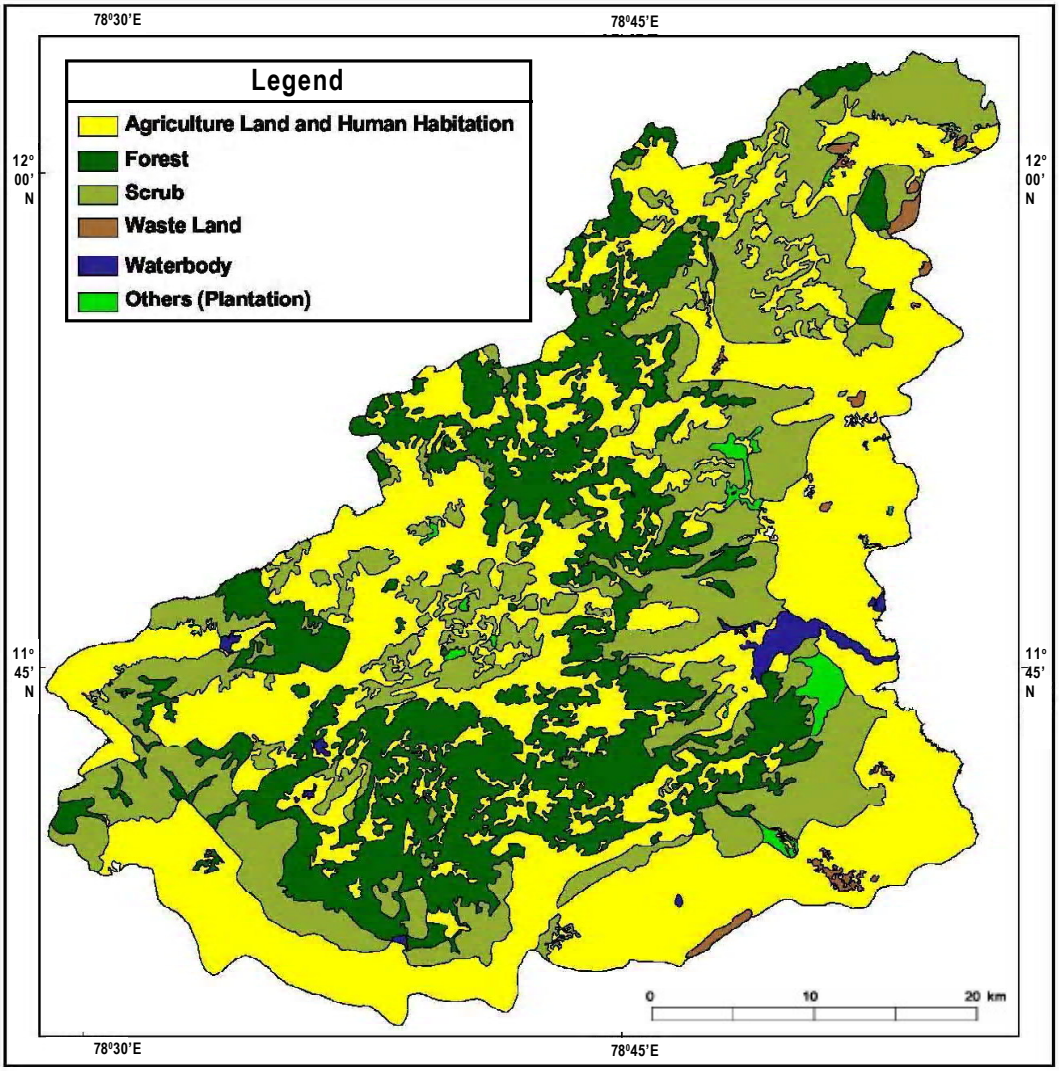

Fig. 4: Kalrayan hills and its environs forest cover - 2001

Parthasarathy, 2001). In the study area numerous lineaments and their points of intersection have been identified and most of them show NE-SW trending direction (Sakthivel *et al*., 2003). A prominent shear zone trending in a N-S direction cut across the entire hills.

Results and Discussion

The following section deals with the forests and various land covers in the study area over the period of 70 yrs.

Forests and various land cover categories in 1931, 1971 and 2001: The spatial distribution of forests cover in 1931 is vividly shown in Fig. 2. Forests occupied by 275.6 km^2, which is about 23.79 % of the total study area. The area under scrubs and agriculture and human habitation in the study area were 598. 4 and 266. 7 km^2 respectively. *i.e.*, these categories occupied about 51.66 and 23.02% of the study area respectively. Wastelands and water bodies constituted 8.79 and 8.87 km^2 respectively, which is about 0.76 and 0.77% respectively of the study area. From the Fig. 2. it evident that the forests cover was found be restricted to Aruna, Mannur, Tumbal, Pattimedu, Jadayagoundan slopes, Takarai, Parigam, Kanai, Puttai and Rangapanur reserved forests.

The spatial distribution of forests cover in 1971 is shown in Fig. 3. In the year 1971, the forests occupied 481.7 km^2, which is about 41.58% of the study area. The area under scrubs and agriculture and human habitation in the study area were 168.5 and 488.7 km^2 respectively *i.e.* these categories occupied about 14.54 and 42.19% of the study area, respectively. Wastelands and wasterbodies constitute 10.6 and 8.9 km^2 respectively, which is about 0.92 and 0.77% respectively, of the study area.

The spatial distribution of forests cover in 2001 is shown in Fig. 4. The different land use and their areal extents have been maped and estimated.

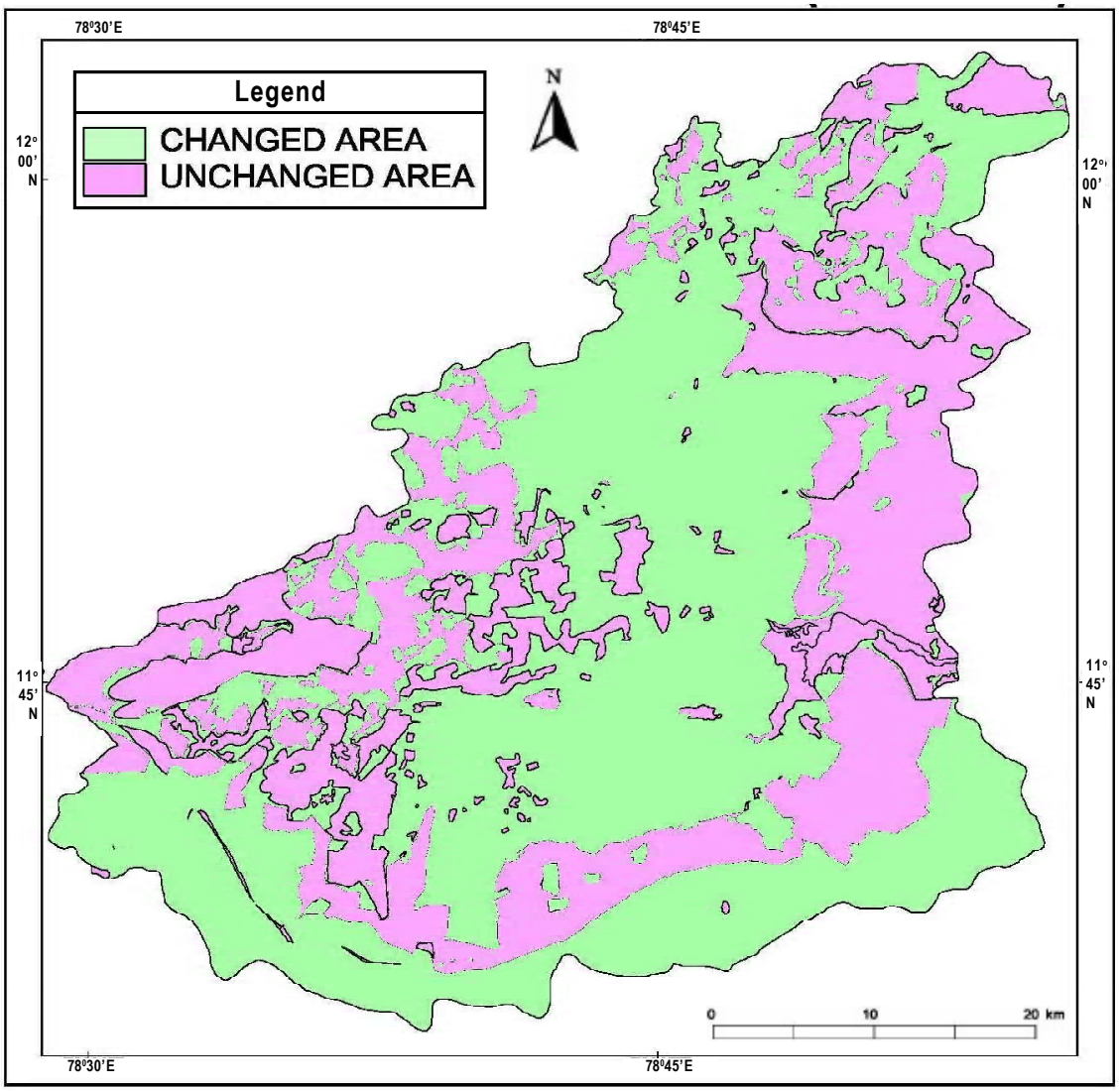

Fig. 5: Kalrayan hills and its environs forest cover changes (1931-1971)

In the year 2001, the forests occupied 266.88 km^2 (Fig. 4) which is about 23.58% of the total study area. The area under scrubs and agriculture and human habitation in the study area were 308.33 and 546.04 km^2 respectively. These categories occupy about 26.75 and 47.37% of the areal extent of the study area respectively. Among the wastelands, water bodies and others (plantations) constituted about 7.08, 8.87 and 10.62 km^2 which occupy about 0.61, 0.77 and 0.92% respectively.

Major changes between 1931 and 1971 and 1971-2001: The spatial distribution of forests cover changes and the variations that had taken place during the period 1931-1971, 1971-2001 and 1931-2001 are shown in the following Figs. *viz.*, Fig. 5,6 and 7. In the study area, forests which were occupying 275.6 sq.km in 1931 is found to occupy 481.7 sq.km in 1971. The forests which occupied cover in 23.79% for the study area in 1931 increased to 41.58% in 1971. During the period between 1931-1971 forests have increased by 196.86 sq.km. In the study area, scrub which occupied 589.03 sq.km. during 1931 got drastically reduced to about 166.79 sq.km in 1971 *i.e.*, there have been decrease in scrub by about 422.24 sq.km. In terms of percentage, the scrubs, which occupied 51.66% of the study area in 1931, got reduced to 14.54% in 1971. Thus it is clear that during the period 1931-1971, scrubs have decreased drastically. This indicates that there was no human interference in the hill ecosystem during this period.

In the year 1971, the forests occupied 481.7 km^2, which is about 41.58% of the study area and the scrub was 168.5 km^2 (*i.e.* 14.54% of the area) and the forests have been decreased as 266.88 km^2, which as about 23.58% in 2001. About 215.5 km^2 area of forests have been lost during the period 1971-2001. However in 2001, scrubs occupied 308.33 km^2, covering about 26.75% of the study area about 141.54 km^2 area is occupied by scrub during the period 1971-2001. The analysis shows that during

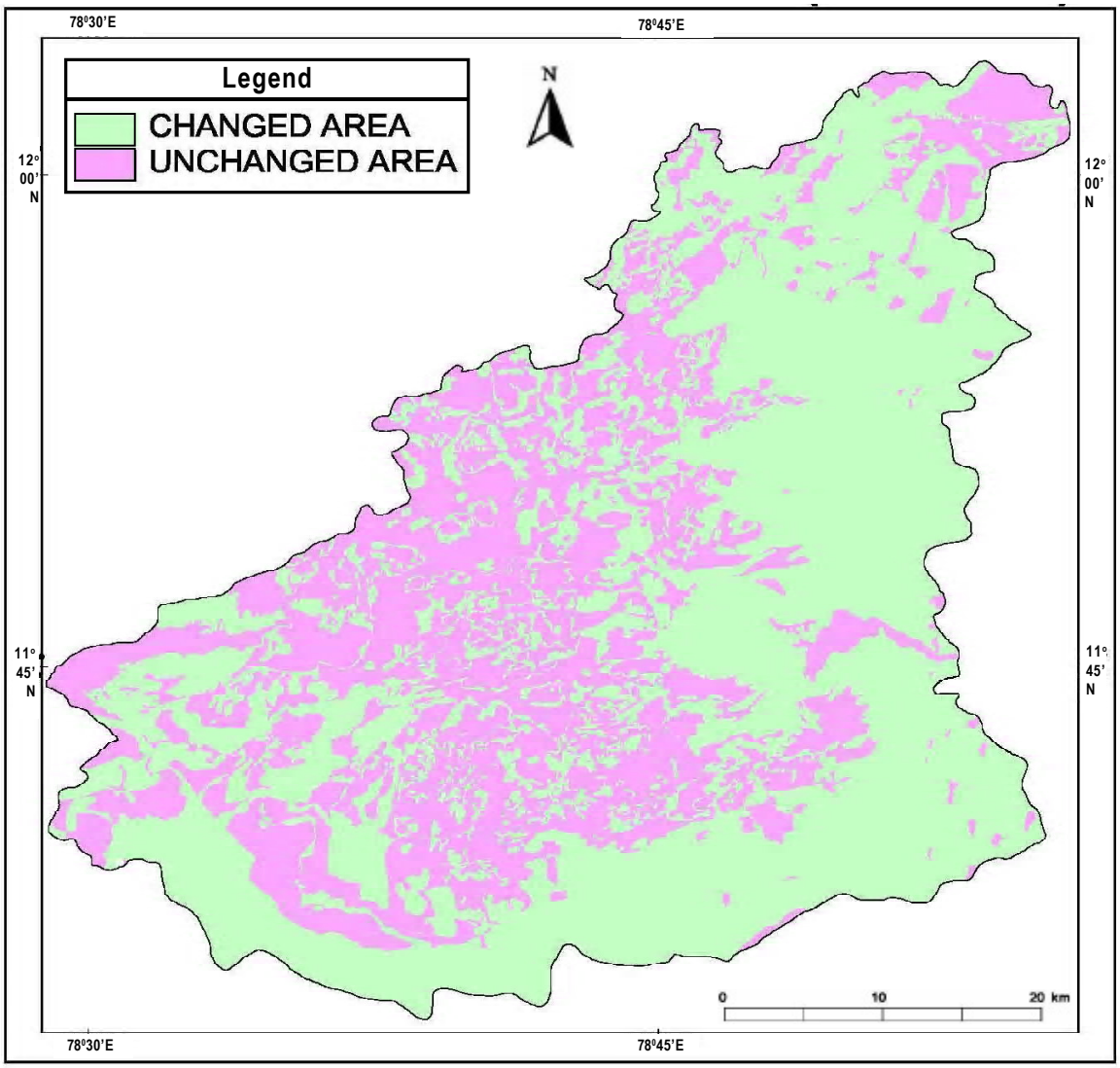

Fig. 6: Kalrayan hills and its environs forest cover changes (1971-2001)

the period 1971-2001, scrubs have drastically increased. The study also reveals that there has been drastic change in forest cover because of intensive agriculture during 2001. The main reason for forest cover decrease may be due to illegal felling and forest fire and shifting cultivation (Arnon *et al*., 1991).

All these observations clearly prove that decreased the period 1931-1971 forests have increased intensively and during the period 1971-2001 forests have decreased drastically. It is also inferred that forests cover in the study area has also been notably changed from 1931 to 2001. It also indicates that the area under agriculture human habitation has substantially increased due to population pressure and forests degradation.

The seventy years (1931-2001) of forest cover and its variations has been precisely analysed. The study reveals that the rate of forest degradation is more during the period from 1971 to 2001. The results reflect the lack of awareness in forest conservation. Hence, the importance of Social forestry, motivation of "Sacred grooves farming system" for preserving the original endemic species (as observed at upper reaches near Kariyalur and Vellimalai evergreen forests) and to create awareness among children and local people by organizing various villages / school-wise awareness programmes are emphasized. The present study also has opened so many avenues for a detailed study such as micro level / watershed wise vegetation analysis and forest cover changes assessment.

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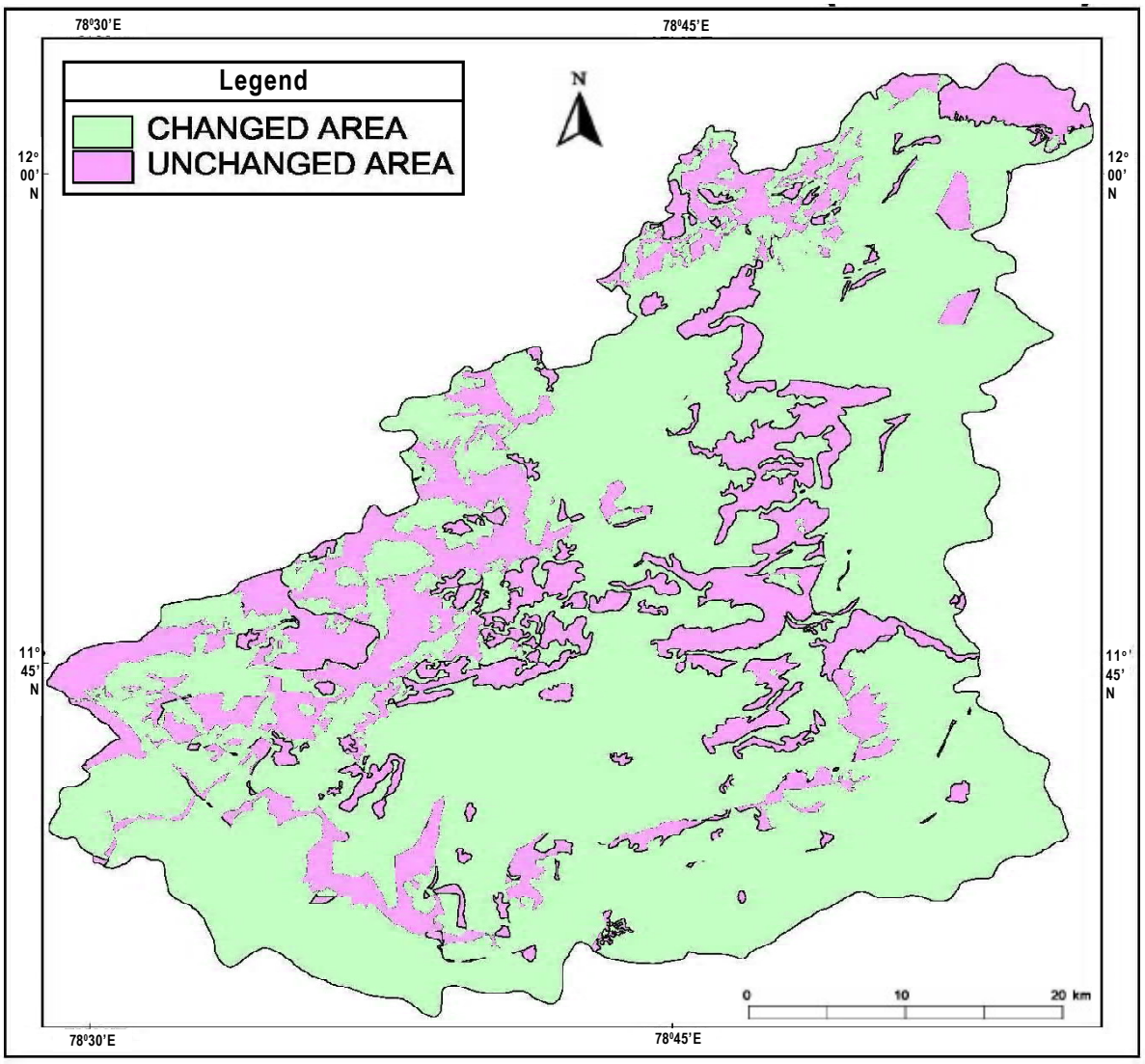

Fig. 7: Kalyayan hills and its environs forest cover changes (1931-2001)

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References

Anbazhagan, S.: Study of geology and structure of Perungulathur area in Thiruvannamalai Sambuvarayar District, Tamil Nadu, using Remote Sensing Techniques. Photonirvachak. *J. Ind. Soc. Rem. Sen.*, **19**, 135-140 (1991).

Anonymous: National forest policy. National commission on agriculture, ministry of agriculture and cooperation, New Delhi (1976).

Anonymous: Reconnaissance report, Tamil Nadu Forest Department (1991).

Anonymous: Conservation International, http://www.conservation.org/biodiversity (2000).

Anonymous: Forest and Tree: Contribution as carbon sink, Ministry of Environment and Forests, New Delhi (2009).

Batista, G.T., Y.E. Shimabukuro and W.T. Lawrence: The long term-monitoring of vegetation cover in the Amazonian region of northern Brazil using NoAA-AVHRR data. *Int. Nat. J. Rem. Sensing*, **19**, 245-265 (1998).

Bhaduri, B., M. Shankar, A. Sorokine and A. Ganguly: Spatio-temporal visualization for environmental decision support. *In:* Geospatial visual analytics: Geographical information processing and visual analytics for environmental security (*Eds.:* R. De Amicis). NATO Science for Peace and Security Series C: Environmental Security. *Springer Netherlands*, **5**, 331-341 (2009).

Birniel, A.B.M.E.S.B.R.W: An analysis of land cover changes in the Northern Forest of New England using multi-temporal Landsat MSS data. *Int. J. Rem. Sensing*, **19**, 245-265 (1998).

Bouma, George A. and Kobryn and T. Habina: Change in vegetation cover in East Timor, 1989-1999. *Nat. Res. Forum,* **28**, 1-12 (2004).

Boyd, D.S., G.M. Foody and W.J. Ripple: Evaluation of approaches of forest cover estimation in Pacific Northwest, USA, using remote sensing. *Appl. Geog.*, **22**, 375-392 (2002).

Camacho-De Coca, F., F.J. Garcia-Haro, M.A. Gilabert and J. Melia: Vegetation cover seasonal changes assessment from Thematic Mapper imagery in a Semi-arid landscape. *Int. J. Rem. Sen.*, **25**, 3451-3476 (2004).

Das., S, S.C. Behera and Kar: Hydrogeomorphological mapping in ground water exploration using remotely sensed data – A case study in Keunjhar District, Orissa. *J. Ind. Soc. Rem. Sens.*, **25**, 247-260 (1997).

Dengiz, Orhan, Tugrul Yakupoglu and Oguz Baskan: Soil erosion assessment using geographical information system (GIS) and remote sensing (RS) study from Ankara-Guvenc Basin, Turkey. *J. Environ. Biol.,* **30**, 339-344 (2009).

Dymond C.C., D.J. MIddenoff and V.C. Radeloff: Pheonological differences in Tasseled cap indices improve deciduous forest classification. *Remote Sensing of Environment*, **80**, 460-472 (2002).

Forgham, A.: A new technique for map revision and change detection using merged Landsat TM and SPOT data sets in an urban environment. *Asian-Pacific Rem. Sensing J.*, **7**, 119-128 (1994).

Francis, W., Frederick Nicholson, C.S. Middlemiss, C.A. Barber, E. Thurston and G.H. Stuart: Gazetteer of South India. A Mittal Publication, New Delhi (1995).

Franklin, S.E. and B.A. Wilson: Vegetation mapping revision and change detection using SPOT MLA and Landsat Imagery in Kluane National Park. *Canadian. J. Remote Sensing*, **17**, 217-232 (1991).

Igbokwe, J.I.: Geometrical processsing of Multi-Sensor, Multi-Temporal Satellite images for change detection studies. *Int. J. Rem. Sensing*, **20**, 1141-1148 (1999).

Imbernon, J. and A. Branthomme: Characterization of landscape patterns of Deforestation in Tropicalrainforests. *Int. J. Rem. Sensing*, **22**, 1753-1765 (2001).

Ingram, J.C., T.P. Dawson Technical Note: Interannual analysis of deforestation Hotspots in Madagascar from high temporal resolution satellite observations. *Int. J. Rem. Sensing*, **26**, 1447-1461 (2005).

Jessica, P.K., M.C. Porwal, P.S. Roy and G. Sandhya: Forest change detection in Kalarani Round, Vadodara, Gujarat – A Remote Sensing and GIS approach. *J. Ind. Soc. Rem. Sensing*, **29**, 129-135 (2001).

Joamsen, S.J. and P.M. Ramsay: Changes in high-altitude polylepis forest cover and quality in the Cordillera de Vilcanota, Peru, 1956-2005, *Biological Conser.*, **138**, 38-46 (2007).

Kadavul, K. and N. Parthasarathy: Population analysis of Alphonsea sclerocarpa Thw. (Annonaceae) in the Kalrayan hills of Eastern Ghats, India. *Int. J. Ecol. Environ. Sci.*, **27**, 51-54 (2001).

Kushwaha, S.P.S.: Forest type mapping and change detection from satellite imagery. *ISPRS J. Photogrammetry Rem. Sensing*, **45**, 175-181 (1990).

Larsson, H.: Analysis of variation in land cover between 1972 and 1990, Kassala Province, Eastern Sudan, using Landsat MSS data. *Int. J. Rem. Sensing*, **23**, 325-333 (2002).

Larsson, H.: Acacia canopy cover changes in Rawashda forest reserve, Kassala Province, Eastern Sudan, using linear regression NDVI models. *Int. J. Rem. Sensing*, **23**, 325-333 (2002).

Le Hegarat Mascle, S., R. Seltz, L. Hubert Moy, S. Corgne and N. Stach: Performance of change detection using remotely sensed data and evidential fusion: Comparison of three cases of application. *Int. J. Rem. Sensing*, **27**, 3515-3522 (2006).

Lo, C.P. and R.L. Shipman: A GIS approach to Land use change dynamics detection. *Photogrammetric Engg. Rem. Sen.*, **56**, 1483-1491 (1990).

Luque, S.S.: Evaluating temporal changes using Multispectral Scanner and Thematic Mapper data on the landscape of a natural reserve: The New Jersey Pine Barrens, a case study. *Int. J. Rem. Sensing*, **21**, 2589-2610 (2000).

Macleod, R.D. and R.G.A. Congalton: Quantitative comparison of change- detection Algorithms for Monitoring Eelgrass from Remote Sensed Data. *Photogrammetric Engg. Rem. Sens.*, **64**, 207-216 (1998).

Matthew, K.M.: Materials for a flora of the Tamil Nadu Carnatic, Rapinet Herbarium Trichy Publishers, Trichirapalli (1981).

Murali, K.S., I.K. Murthy and H. Ravindranath: Joint forest management in India and its ecological impacts. *Environ. Manage. Hlth.,* **13**, 512-528 (2002).

Okeke, F. and A. Karnieli: A. Methods for fuzzy classification and accuracy assessment of historical aerial photographs for vegetation change analyses. *Int. J. Rem. Sensing*, **27**, 1825-1838 (2006).

Panigrahy, R.K., M.P. Kale, U.Dutta, A. Mishra, B. Banerjee and S. Singh: Forest cover change detection of Western Ghats of Maharashtra using satellite remote sensing based visual interpretation technique. *Curr. Sci.*, **98**, (2010).

Pant, B.R. and D.S. Jalal: Environmental hazards in the Central Himalayas - A case study. *In*: Research in Geography. Disasters and environmental Monitoring and Forecasting (*Ed.*: R.B. Singh). APH Publishing Corporation, New Delhi **2**, 291-297 (1996).

Pant, D.N. and P.S. Roy: Analysing forest cover and land use dynamics in central Himalayan using remote sensing and GIS. *In*: Proc. ISRS silver jubilee symposium on remote sensing for environmental monitoring and mangement with special emphasis on hill areas, Dehradun, India. pp. 44-52 (1994).

Porwal, M.C. and D.N. Pant: Forest cover type and land use mapping using landsat Thematic Mapper - A case study for Chakrata in Western Himalayas, Uttar Pradesh. *J. Ind. Soc. Rem. Sensing*, **17**, 33-40 (1989).

Porwal, M.C. and P.S. Roy: Vegetation type discrimination on landsat TM date in heterogeneous forested landscape of western ghats – Accuracy evaluation from large scale aerial photographs. *Ind. Soc. Rem. Sensing*, **20**, 21-33 (1992).

Reis, S. and T. Yomralioglu: Detection of current and potential hazelnut (Corylus) plantation areas in Trabzon, North East Turkey using GIS and RS. *J. Environ. Biol.*, **27**, 653-659 (2006).

Rogan, J., J. Franklin and D.A. Roberts: A comparison of methods for monitoring multi temporal vegetation change using Thematic Mapper imagery. *Rem. Sensing Environ.*, **80**, 143-156 (2002).

Roy, P.S., B.K. Ranganath, P.G. Diwakar, T.P.S. Vohra, S.K. Bhan, I.J. Singh and V.C. Pamdian: Tropical forest type mapping and monitoring. *Int. J. Rem. Sensing*, **129**, 2205-2225 (1991a).

Roy, P.S., K.K. Das and K.S.M. Naidu: Forest cover and land use mapping in Karbi analog and north Cachar Hills districts of Assam using landsat MSS data. *J. Ind. Soc. Rem. Sensing*, **19**, 113-123 (1991b).

Roy, P.S. and P.K. Joshi: Forest cover assessment in North-East India – the Potential of temporal wide swath satellite sensor data (IRS-1C WiFS), *Int. J. Rem. Sensing*, **23**, 4881-4896 (2002).

Sabins, F.F.: Remote sensing principles and interpretations. W.H. Freeman and Co., San Francisco, USA. pp. 696-697 (1987).

Sakthivel, R., M. Manivel, A. Alagappa Moses, A. Chandramohan and D. Vijay: Hydrogeomorphological mapping in Kalrayan Hills, Tamil Nadu. *Ind. J. Geomorphol.*, **8**, 1-6 (2003).

Sakthivel, R., M. Manivel, N.J. Raj, V. Pugalanthi and D. Kumaran Raju: Role of remote sensing in geomorphic mapping: A case study from Kalrayan hills, parts of Eastern Ghats, Tamil Nadu. *Ind. J. Geomorphol.*, **11**, 103-112 (2006).

Sarma, V.V.L.N., G. Murali Krishna, B. Hema malini and K. Nageswara Rao: Land use / Land cover change detection through remote sensing and its climatic implications in the Godavari Delta region. *J. Ind. Soc. Rem. Sensing,* **29**, 86-91 (2001).

Singh, A.: Digital change detection technique using remote sensing data. *Int. J. Rem. Sensing*, **26**, 1-6 (1989).

Sudhakar, S., N. Krishnan, P.K. Das, A.K. Raha and A.K. Ghosh: Forest resource management strategies using remote sensing techniques - A case study. *I.T.C.J.*, **3**, 285-290 (1992).

Sukumar, R., H.S. Daltaraiya, H.S. Suresh, J. Radhakrishnan, R. Vasudeva, S. Nirmala and N.V. Joshi: Longterm monitoring of vegetation in a tropical deciduous forest in Mudumalai, South India. *Curr. Sci.,* **62**, 608-616 (1991).

Unni, N.V.M., P.S. Roy and V. Parthasarathy: Evolution of landsat and airborne multispectral data and aerial photographs for mapping forest features and phenomenon in a part of Godavari basin. *Int. J. Rem. Sen*, **6**, 419-431 (1985).

Unni N.V.M.: Forest and ecological applications of IRS-IA data. Natural resources management – A new perspective. Publication and Public Relations Unit, ISRO H.Q., Bangalore. pp. 108-119 (1992).

Vemban, N.A., K.S. Subramaniam, K. Gopalakrishnan and Venkata Rao: Major Publications / lineaments of Tamil Nadu. Geol. Survey of India's Misc. Publication. pp. 53-56 (1997).

Young, S.S. and C.Y. Wang: Landcover change analysis of China using global-scale pathfinder AVHRR Landcover (PAL) data, 1982-92. *Int. J. Rem. Sensing*, **22**, 1457-1477 (2001).

Yool, S.R., J.L. Star, J.E. Estes, D.B. Botkin, D.W. Eckhardt and D.W. Frank: Performance analysis of image processing algorithms for classification of natural vegetation in the mountains of southern California. *Int. J. Rem. Sens*., **7**, 683-702 (1986).