

# Land-cover change in Goa– An Integrated RS – GIS Approach

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## Abstract

*Goa, with its' scenic beauty of sandy beaches, large population with relatively low human development index, forms a part of the Western Ghats biodiversity hotspot. The advent of tourism, enhanced mining activities, and population increase coupled with natural and anthropogenic changes due to modern societal demands has resulted in large scale change in the geo-ecological setup and landuse patterns causing direct impact on the human environment. The recent model for the hotspots of change identifies the potential areas of change in Goa and shows strong anthropogenic influences on the hotspots of change (Roy and Shrivastava, 2012). These changes need to be delineated for better understanding and for taking the necessary mitigate and remedial measures. Present work while providing baseline data, attempts towards understanding decadal land-cover changes using satellite data of last 40 years. Major changes were observed in vegetation and settlement/urbanisation pattern which needs to be monitored to avoid further degradation of the Goa's natural environment. The overall loss in vegetation is due to gain in settlement from 1973-2012. The loss in vegetation is partly attributed to mining activity although the exact extent is not calculated. However the loss of vegetation cover of 1973-1989 is changed to a gain during 1989-1999 and subsequent period due to afforestation/plantation measures by mining/forestry*

## 1. Introduction

Land-use and Land-cover Change (LULCC), known simply as land change, is commonly used as a general term for the modification of Earth's terrestrial surface. Land-cover of the earth's land surface has been changing since time immemorial at a range of spatial scales from local to global and at temporal frequencies of days to millennia and is likely to change in the future (Ramankutty and Foley, 1998 and Townshend et al., 1991). Normally, use of land is defined in an economic context, so we think of land as it is used for agricultural, residential, commercial, and other uses. Most fundamentally, land cover is a way of portraying the surface of the earth. Often this is done through a process of classification where regions of the earth are identified according to some of their more prominent, quantifiable attributes. However, strictly speaking, we can seldom really see the use of the land, except on the very closest inspection, so we consider also land cover—the visible features of the Earth's surface—included in the vegetative cover, natural and as modified by humans, its structures, transportation and communications, and so on

(Campbell, 2001). Land-use/land-cover components have a tendency to show spatial and structural changes in response to variations in physical, economic and cultural factors and the process of development. The assessment of availability of land resources and changing land cover pattern bring out the bottlenecks in sustainable development of land resources. It is an essential prerequisite to know the present or existing use of land in order to plan for its best possible use. The landuse within a particular region undergoes changes as a result of economic activities. Changes in land-cover are basically governed by competitions between different types of demand and reflect the impact of development activities. This demand is generated from urban areas, industrial and other tertiary activities, from non-industrial sector and infrastructure development. From a conceptual perspective, study of land-cover changes permits identification of long-term trends in time and space and the formation of policy in anticipation of the problems that accompany changes in Land-cover (Anderson, 1977, Estes and Senger, 1972, Jenson, 1978 and

Jensen and Toll, 1982). Due to influence of land-cover change on many of the environmental issues both direct and indirect, such as loss of biodiversity, changes in hydrological, carbon and nitrogen cycles, and climate change, it is important that these areas under intense change needs to be better understood for adapting suitable management strategies (Schilling et al., 2010 and Gao et al., 2010). Along the coast, land-cover change has been reported to be the prime cause of biodiversity loss, accounting for over 50% of the global biodiversity loss, and has thus gained global attention in the last decade (Sala et al., 2000). Management of natural resources has become a complex task as more and more socio-economic activities takes place viz., particularly with reference small states like Goa and its Coastal zone environments (Wagle and Kunte, 1993 and Kunte and Wagle, 1994). The forest-rich Goa, identified as part of the Western Ghats biodiversity hotspot, with a large population with relatively low human development index (Roy and Shrivastava, 2012), the with rampant mining activity is under tremendous pressure to meet its sustenance and economic requirements of the people (Myers et al., 2000 and Cincotta et al., 2000). This leads to reduction in forest area and dwindling biological diversity in the region. Land-cover change also influences the change in composition of the natural flora of the region by introducing multiple edges, where edge species predominate that are better adapted to utilize the scarce nutrients, replacing the endemic species especially in the climax or sub-climax forest. The recent availability of geospatial information technologies with satellite data helps us for better understanding of the land-cover change and its effect on human environment. Change Detection can be defined as the process of identifying

differences in the state of an object or phenomenon by observing it at different time. This process is usually applied to earth surface changes at two or more times (Coppin et al., 2004). Present work is a modest attempt to portray and understand the relative pace of land-cover change during the last 40 years (from January 1973 and Jan 2012), in major categories and provides inputs for micro-level spatial data creation for better management in future.

## 2. Study Area

The entire state of Goa with an area of about 3700 sq. km and over 105 km coastline is chosen for the present study. Goa, India's smallest state by area and the fourth smallest by population, is situated between 14°53'54"N and 15°48'00"N and 73°40'33"E and 74°20'13"E (Figure 1) and forms a part of Western Ghat biodiversity hotspot. The climate of Goa is warm and humid for most part of the year with day-time temperatures of over 35°C (95°F) in the month of May. Most of Goa's annual rainfall is received through the monsoons starting from early June till late September with an average rainfall is approximately 325cms. Some of the most biologically diverse vegetation patches are characteristics of the Western Ghats of Goa region. Despite, Goa being one of the most stressed regions due to the growing population, increased mining and extraction of forest resources leading to the habitat change and degradation of the natural forest areas (Mascarenhas, 1998), there have been no attempts in the past to understand the extent and changes in Land-cover. Therefore the present work on Land-cover change of Goa, while filling the gaps in the available literature, also provides impetus towards more detailed studies on Land-cover changes.

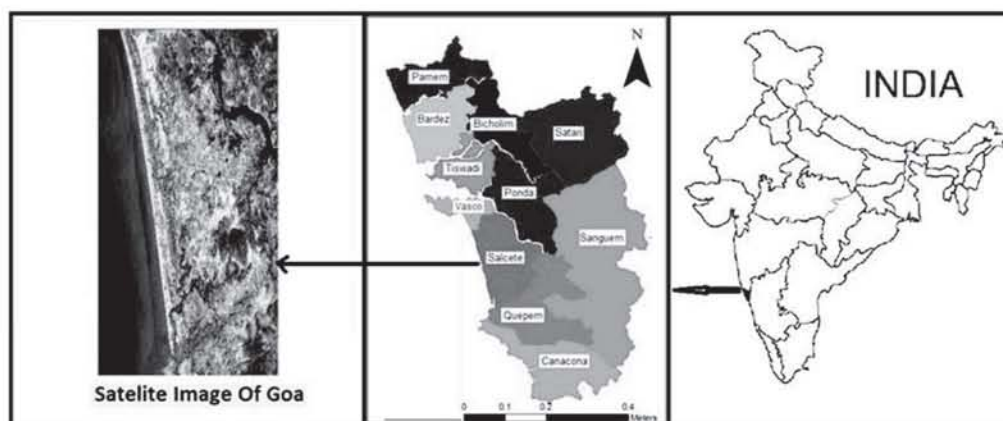


Figure 1: Location map of study area

### 3. Land-cover change Detection Study

In recent decades, anthropogenic Land-cover change has been proceeding much faster than natural change and this unprecedented rate of change, a major environmental concern worldwide, causing greater impact on small states like Goa. The development in geospatial technologies and availability of high resolution satellite data facilitate better understanding and monitoring of such land-cover changes particularly for broad overview for future planning by administrators. Land-cover changes in satellite imagery between two dates translate into changes in radiance which is influenced by various factors (viz. sensor calibration, solar angle, atmospheric conditions, seasons, or earth surface). The first premise of using imagery for change detection of the earth surface is that change in the earth surface must result in a change in radiance values. Secondly, the change in radiance due to earth surface changes must be large compared to the change in radiance due to other factors. A major challenge in land-cover change detection of the earth surface using imagery is to minimize the effect of these and other factors. This is usually performed by carefully selecting relevant multi-date imagery and by applying pre-processing treatments (Lu et al., 2004).

#### 3.1 Materials and Methodology

The present work on the Land-cover change study of Goa makes use of the digital satellite data of four time periods (Landsat MSS Data -4 Bands- Jan 1973; Landsat MSS Data -7 bands- Jan 1989; Indian Remote sensing Satellite (IRS) 1C LISS III Data-4 Bands-Jan 1999 and IRS- LAMX Data -4 Bands-Jan 2012), SOI Topographic maps and other secondary sources of information/maps are used. Ground truth at selected sites on random basis was collected to validate the results of digital change analyses. The satellite images of four time periods have been initially pre-processed by applying Image enhancement, geo-referencing, band extraction functions available under ERDAS Imagine 9.2 and ENVI 4.7 image processing software systems. The FCCs for four time periods have been used to observe the general categories of land-cover and to assess their distribution. The image classification for change analysis and the various spatial analyses were performed using ENVI 4.7 and ArcGIS 9.3. The Change detection and change analyses of the entire digital satellite data sets of four decades were carried out using the IDRISI Taiga - LCM Module. The Land Change Modeler (LCM) for Environmental Modeling and Ecological

Sustainability is a solution designed to address the pressing problem of accelerated land conversion and the very specific analytical needs of biodiversity conservation which has been found suitable to use in the present study in order to understand the Land-cover changes in Goa during the last four decades. In LCM, land cover change prediction utilizes two land cover maps from two different dates (time 1 and time 2) to predict what the land cover will be in the future (time 3). The complete work flow that has been adopted in the present study is given in Figure 2.

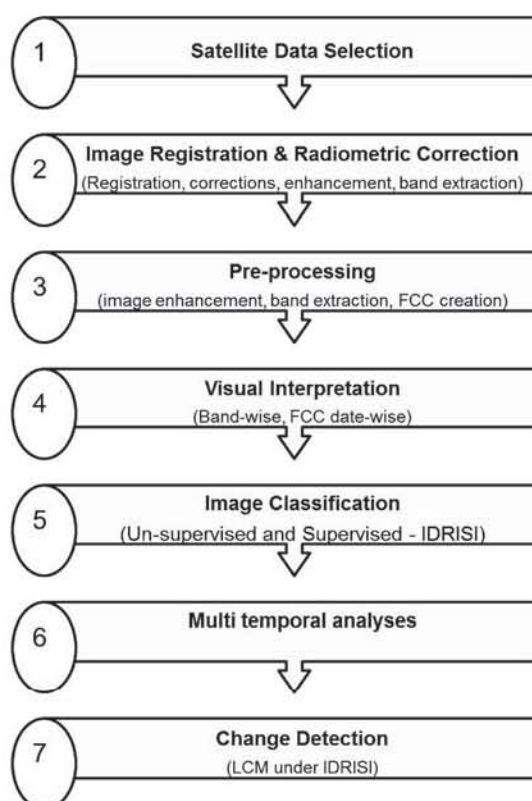


Figure 2: Workflow for Change Analysis

#### 4. Results and Analyses

The False Colour Composite (FCC) for all the four data sets were created prior to application of classification procedure in order to observe the variation in land-cover categories and to get an idea about the number of land-cover classes for subsequent classification. Only four major categories of land-cover (viz., water bodies, Settlements, Vegetation and Openland) were used for the change detection study.

Figure 2 depicts the general distribution of the land-cover categories for the four time periods from FCC and classified imageries. Vegetation has been observed as a major land-cover in all the data sets. Table 1 displays the distribution of land-cover for entire time period from 1973-2012. The integration of image processing and spatial analytical functions along with change detection module in IDRISI provided greater advantage for the analysis of multi-temporal data for change detection. The land-cover change analysis is performed by using LCM module of IDRISI following the image differencing and multi-temporal spectral mixture analysis.

The change analyses each pair of dataset 1973-89, 1989-1999, 1999-2012 calculated the corresponding Gains and Losses for each land-cover category along with the net change for each time period and the result of the same is shown in Figure 3. The vegetation and settlements classes have been more dominant/dynamic land-cover categories in each data set as shown in Figure 3. Subsequently, the second run of change analysis was performed for the two data sets the oldest (1973) and the latest (2012). The calculated gains and losses and net change in each land-cover category for the entire time period from 1973-2012 is shown in Figure 4.

Table 1: Land-cover area (in sq.mts)

Table 1: Distribution of Land-cover area of Goa (in sq.km)				
Year	Water Bodies	Vegetation	Settlement	Openland
1973	79.17 (2.19%)	1702.65 (47.04%)	461.65 (12.75%)	1375.95 (38.02%)
1989	127.16 (3.51%)	545.28 (15.05%)	1533.46 (42.33%)	1416.32 (39.10%)
1999	133.12 (3.68%)	869.60 (24.03%)	1598.01 (44.16%)	1018.29 (28.14%)
2012	219.28 (6.06%)	635.94 (17.57%)	1893.60 (52.31%)	871.40 (24.07%)

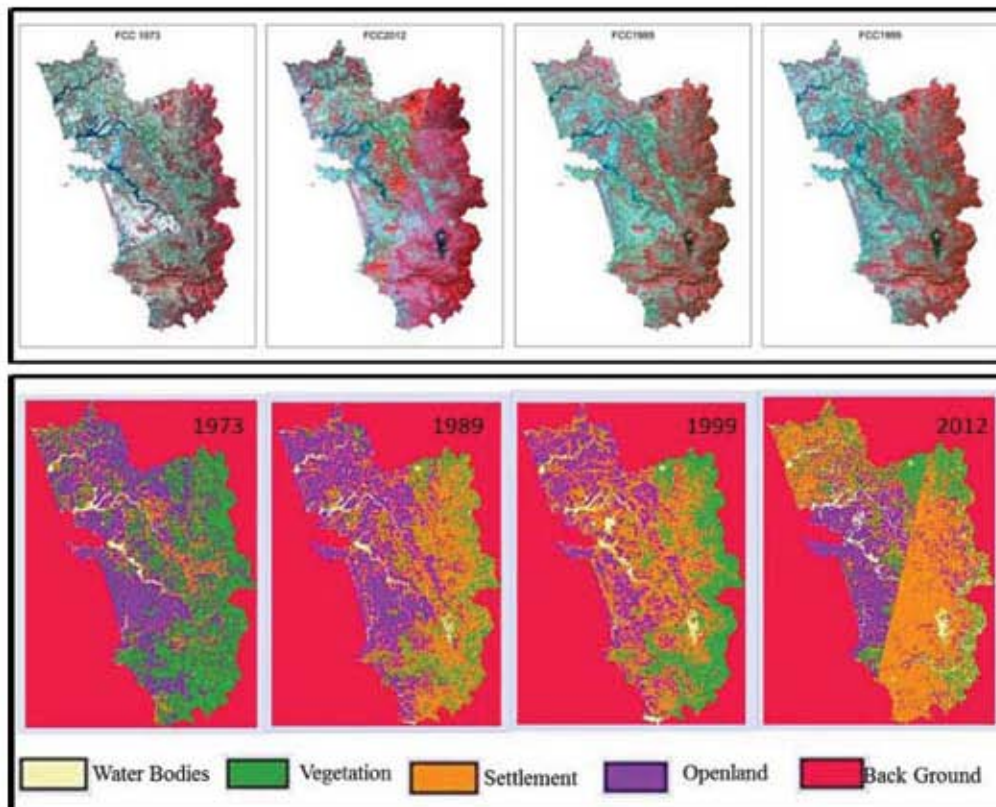


Figure 3: FCCs and classified images of Land-cover classes Goa for 4 time periods

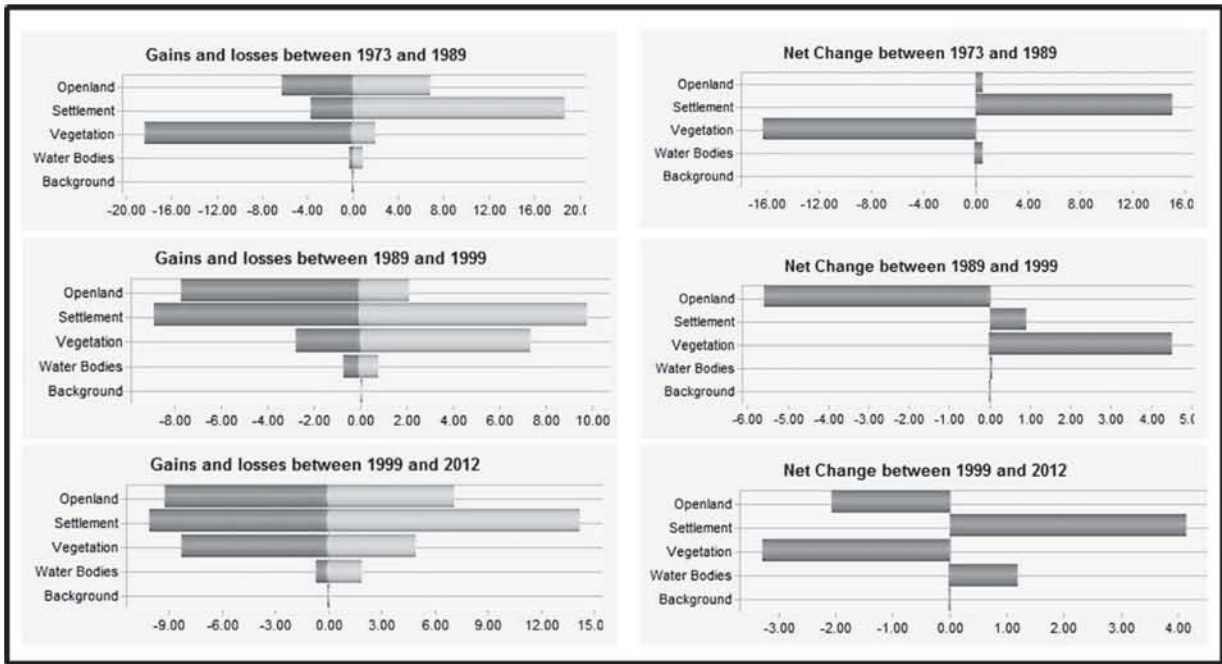


Figure 4: Land-cover change (Gains and Losses and net change) for the three time periods

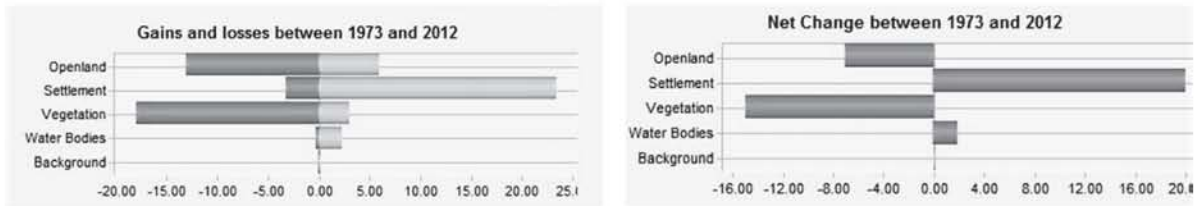


Figure 5: Land-cover change (Gains& Losses and net change) for the last four decades (From 1973-2012)

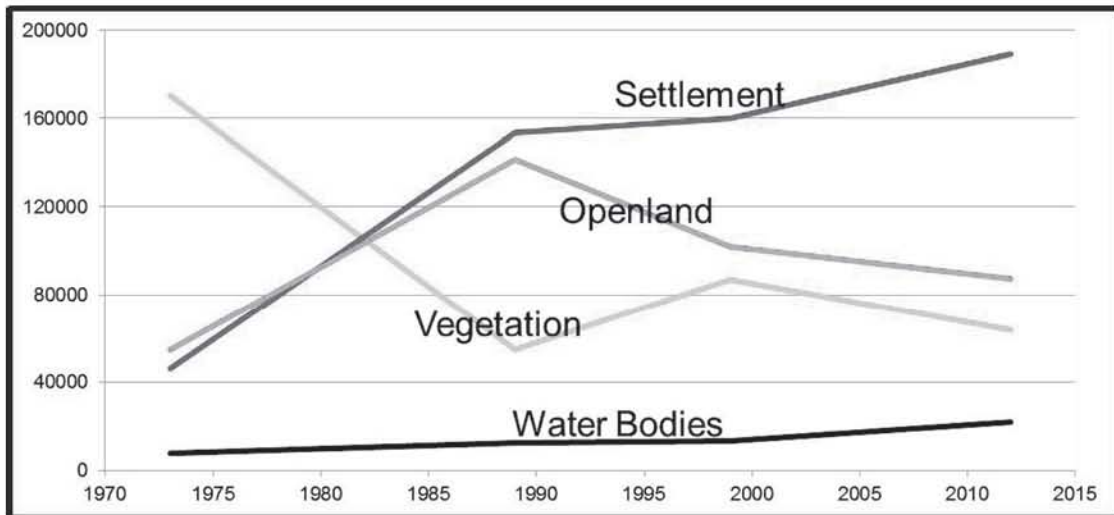


Figure 6: Plot showing the trend of the Land-cover change in Goa during 1973-2012

## 5. Discussion

Land-cover change can be characterized as land-cover conversion from one land-cover category to another and modification as a change in condition within a land-cover category. Understanding of the dynamics of land-cover distribution, conversion and modification is crucial for better understanding of the earth's surface processes viz. land-cover productivity, biodiversity and hydrological cycles. Several national and international programs (IGBP, LCLUC, GEO, and GOF-C-GOLD) have provided guidelines for land-cover change studies. In the present study area, the state of Goa, tourism activity has been the major economic activity particularly in coastal tracts. Substantial part of cultivable land in these coastal tracts is transformed to constructed area to meet the demand from tourism industry and relatively small area is found under barren category. Major Land-cover changes have taken place in coastal villages and vulnerable ecosystems in the villages – sand dunes, mangroves and khazans are experiencing extensive damage (TERI, 2000b). It is also observed from the present study that there has been an overall change in land-cover categories either for conversion or for modification. Mining is another important economic activity of the study area. According to TERI (2002), it has been observed that the large scale mining during the last two decades resulted in depletion of vegetation cover. The present study also supports the earlier observation by TERI. It is clearly evident from ground truth that the occurrence of number of mine pits (small isolated water bodies) and dumps (barren areas). Change in Land-cover from agriculture or forest to open/barren areas in many parts is also attributed to the mining activity adjacent to forest cover whereas the laterite quarrying for construction is responsible for the loss in vegetation which has been observed particularly in the areas close to settlements and coastal tracts. As per the available information, Goa records an increase in forest area from both sources (Forest Survey of India-FSI and State Forest Report-SFR), but increase is higher as per FSI statistics (848 km) compared to SFR statistics (by 359 km). The increase in FSI statistics is witnessed only in the latest 2001 SFR. In all earlier assessments the forest area in Goa has remained unchanged. SFR 2001 records 1785 sq. km area under dense forest, while 1999 SFR record 995 sq. km dense forests. The remote sensing based study of selected mining region of Goa undertaken by TERI shows that vegetation cover has reduced by more than half due to intensive mining of the area over a period of 10 years.

But it is also observed that large scale afforestation carried out under various schemes covering 12,732 ha of area during 1990-91 to 1998-99. The present study is essentially undertaken to portray an over-all land-cover change throughout the entire study area without going into details of minor/major land-cover changes in different areas. The study analyses the four major land-cover categories and suggest an overall depletion of vegetation land-cover due to settlement and other urban activities. A change in vegetation land-cover to settlement category is clearly observed from the present study (Table 1 and Figures 5 and 6). The overall loss in vegetation category (forest/other areas) is been related to the gain of settlement land-cover which has been supported with the land-survey and town and country planning statistics of increased housing projects. Part of the loss in vegetation land-cover is directly related to the increased mining activity (as evidenced from earlier studies by TERI and recent observation by a supreme court appointed team) however, it is also observed that most of such mining affected forest areas have shown good amount of increase in vegetation cover due to afforestation programs undertaken by mining and other organizations. The present study clearly depict a gain in vegetation cover during 1989-1999 period as compared to the loss of vegetation cover during the preceding period from 1973-1989.

## 6. Conclusions

- A clear change in landuse pattern of vegetation and settlement classes is observable from the present study.
- The overall loss in vegetation area (forest/other) is essentially due to gain in settlements from 1973-2012.
- The loss in vegetation is also partly due to mining activity although the exact extent is not calculated in the present study.
- However, the loss in vegetation from 1973-1989 is changed to a gain in vegetation from 1989-1999 and subsequently mainly due to afforestation/plantation measures by mining/forestry and others.

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