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# ASSESSMENT OF FOREST COVER CHANGE IN PART OF THE NORTHERN WESTERN GHATS: A CASE STUDY OF THE KAS AND PANCHGANI PLATEAUS

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## Abstract

*The Kas and Panchgani plateaus in the Western Ghats are well-known for their peculiar features like laterite rich area, floral diversity, endemism and tourism. The area has serious concern because of threat to the natural environment by forest fragmentation of land use land cover change such as a built-up area expansion on agriculture land and numerous infrastructural development activities. In the process, forest fragmentation was examined using geospatial technology and Fragsat 4.2 programme for distinct classes using landscape metrics such as the Class Area (CA), Percentage of Land (PLAND), Edge Density (ED), and Largest Patch Index (LPI) at the class level. The analysis of spatial patterns on land use and land cover maps was created using Landsat 5, 7, and 8 digital data for the years 1989, 1999, 2006, and 2015. The findings of the foregoing investigation revealed that both the plateau have the problem of forest fragmentation and comparatively Panchgani plateau has more fragmentation. Landscape metrics revealed that the landscape has changed significantly and provides more precise information on the fragmented areas. The study has relevance in the context of measuring extend of degradation and necessary conservation actions.*

***Keywords:*** Forest Fragmentation, Fragstats, Landscape Metrics, Western Ghats.

## Introduction

The deforestation problem is pertinent despite many conservation drives. Since 1990, the worldwide primary forest has decreased by more than 80 million hectares, and also habitat loss (Flowers et al., 2020) and forest degradation (Rahman et al., 2016) have been cited as serious risks to biological diversity. Deforestation and fragmentation are major concerns in tropical forest management and conservation activities, with worldwide implications. In India, the forests have dramatically changed over the last few decades in the Himalayas, Eastern Ghats and the Western Ghats (Reddy et al., 2010). Among them, Western Ghats have more fragmentation due to anthropogenic activity such as tourism activity, agricultural expansion, and maximum pressure on the forests for livelihood. Deforestation occurs mainly due to the fragmentation process which causes loss of forest covers in small patches and which results in huge loss over a longer period of time. Fragmentation of previously contiguous forests getting transformed into small patches

(Jaybhaye et al., 2016) and edge impacts within a forest-deforested boundary zone have also detrimental physical and biological effects on the forest (Gascon et al., 2000). Understanding the effects of forest cover change is critical for biodiversity conservation since large portions of tropical forests are spread along with agricultural landscapes (Hill et al., 2011). The term "forest fragmentation" refers to the separation of a big forest area into small parts (Liu et al., 2019). Fragmentation is a dynamic process in which a landscape's habitat pattern changes dramatically over time. Fragmentation is characterised as the conversion of major forest sections into smaller, non-contiguous pieces while simultaneously reducing forest area, increasing forest edge, and isolating big forest regions (Laurance, 2000).

Human development activities such as plantation, mining, road construction, agricultural activities, utility corridors, or human intrusion in forest areas usually separate these parts. Most landscape patterns presently consist of big human settlements, growing agricultural areas, and dispersed and isolated ecosystems as a result of human activities. Most conservation reserves are surrounded by rapidly changing forests and appear to be built to function as isolated natural systems over time (Bennett, 2003). Deforestation has several negative consequences, including loss of ecosystem, the defeat of a significant carbon sequestration source, effects on climate change and in tropical forests there are negative consequences for people's lives. Deforestation leads to the extinction of many species and has three consequences on biological diversity and habitat destruction (Badhe and Jaybhaye, 2021).

Remote sensing has been established as a sophisticated technique for forest monitoring systems that can improve data about fragmentation patterns and distribution of forests (Mayaux et al., 2005). Remote sensing data provide an opportunity to study change detection in forest cover and link additional environmental and human factors to the spatio-temporal pattern of such changes (Dewan et al., 2012). Riitters et al., (2004), use temporal land use land cover (LULC) to examine patterns of forest fragmentation on a global scale and also investigate species loss due to forest fragmentation on a local scale. Fynn, I. E., and Campbell, J. (2019) investigated the effects of various spatial resolutions on common fragmentation metrics using several images formats in their forest fragmentation research. Recent studies have used geospatial methods to investigate the impact of human activities on forest fragmentation (Riitters et al., 2016; Aditya et al., 2018; Shapiro et al., 2016; Sarkar, A. A. 2019) based on accessible geospatial data on forest cover (Rose et al., 2015). Batar et al., (2017) used geospatial tools to investigate forest fragmentation, the findings of the study demonstrate that human activities are the primary reasons for forest decline and fragmentation. The quantification of various levels of fragmentation is made easier due to multi-temporal satellite images and geospatial technology. FRAGSTATS is a programme that calculates landscape patterns (McGarigal et al., 2002) can be used to compute landscape pattern measurements and can assist forest loss and fragmentation are quantified and revealed in various ways (Riitters et al., 2004).

The study area is economically sensitive and has significant human interference with perspective tourism development and basic infrastructure development. This dynamic is necessary to maintain frequently and assess for development on sustainability. The impact of human interference is significant. Its impact has been assessed in terms of change in land use land cover and general identification of change in area under forest. The nature of deforestation needs to assess in detail in terms of different causes of subsequent different forms of loss of vegetation cover. Therefore the forest fragmentation is a process useful to explain the nature of deforestation which will be useful to design strategies for conservation measures.

## Study Area

The Kas and Panchgani plateaus are selected for the study of forest cover change using landscape metrics such as class area (CA), percentage of land (PLAND), edge density (ED), and largest patch index (LPI). These are well-known tourist destinations of the Satara district of the Western Ghats region (Figure 1). Both have similar feature like the same elevation, ranging from 1100 to 1300 metres above sea level and also plateau in relief feature.

Panchgani plateau, an area of 170 sq. km is 1293 meters above sea level. There are many dams in the around the area: Wai, Bavdhan, and Nagewadi dams in the east; Gureghar in the west; Khingar in the south and Rajpuri and Dhom Dam is to the north.

The Kas Plateau, famously known as the Valley of Flowers, is located 25 kilometres from Satara, Maharashtra. In 2012, it was declared a UNESCO World Heritage Site. During the monsoon season, from August to early October, the entire grassland transforms into a valley of flowers. The Kas Plateau is recognized for its unique ecosystem, which includes a variety of herbs, shrubs, plants, butterflies, and insects, as well as its scenic beauty. The Kas Plateau is made up of four separate plateaus. The main tableland of Kas lies between Latitude 17°43'36.50" to 17°45'21.95" North and Longitude 73°47'29.13" to 73°50'56.51" East, covering an area of 150.2 sq. km. at an altitude of 1200 m. The Kas plateau is comes under the ecologically sensitive zone where variety of unique flora and fauna species are found.

## Data and Methodology

LULC maps were derived from the data source of Landsat imagery for the years 1989, 1999, 2006 and 2015 (Table 1). These images formed the base for the classification of LULC as well as estimation of forest cover in the study areas. According to Chuvieco (1996), before the images could be used to study changes in forest cover and fragmentation, they had to be corrected geometrically, atmospherically, and topographically. The LULC maps are generated using hybrid classification technique based on Maximum Likelihood classifier in the supervised classification and ISO cluster unsupervised classification. At the time of taking training datasets for image processing, the representation of all classes of radiance according to spectral signature value was taken into account (Chuvieco, 1996). The categories of LULC identified for the study were dense vegetation, open vegetation, scrubland, barren land, agriculture, water bodies, and wet land.

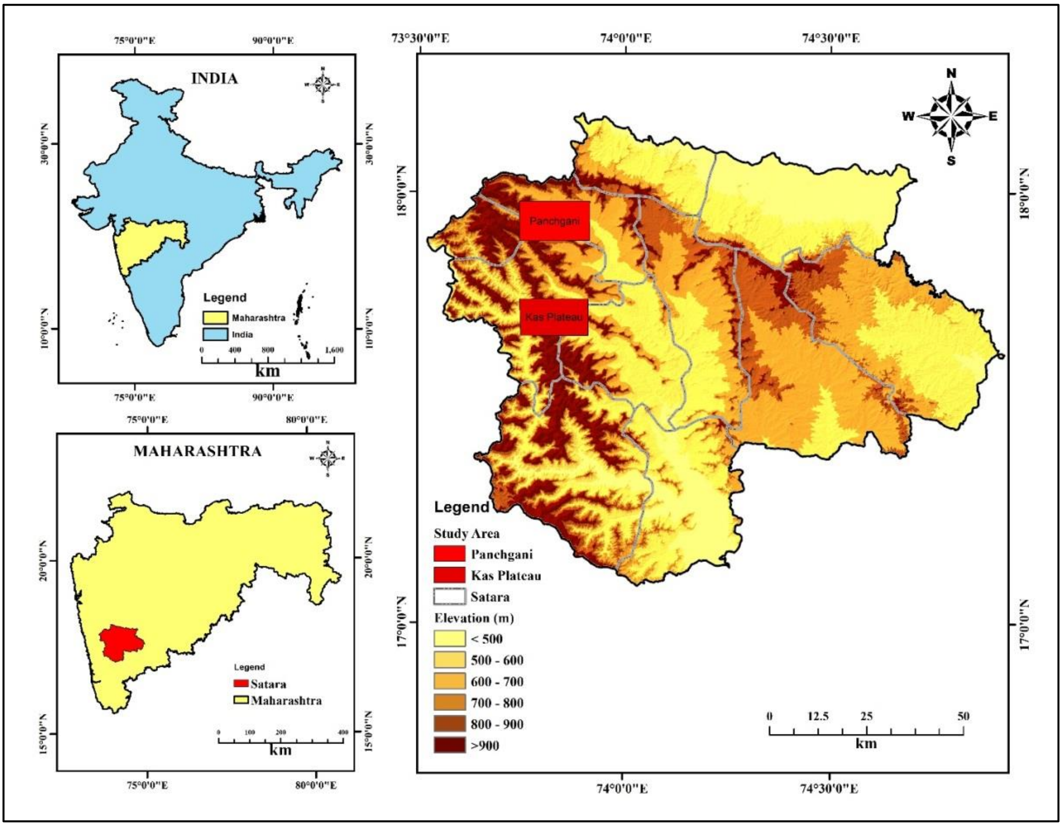


**Figure 1. Location Map of the Study Area: Kas and Panchgani Plateaus**

**Table 1. The Satellite Data Source**

| Acquisition Date | Satellite | Sensor | Sources | Spatial Resolution |
|---|---|---|---|---|
| 28th February 1989 | Landsat 5 | TM | USGS | 30 |
| 14th November 1999 | Landsat 7 | ETM+ | USGS | |
| 18th February 2006 | Landsat 7 | ETM+ | USGS | |
| 19th February 2015 | Landsat 8 | OLI | USGS | |

Image processing techniques are essential for this study which involves the preparation of base map and identifying the LULC of the study area. The fragmentation pattern was determined applying Fragstats statistical software for image analysis (Narmada et al., 2021). A set of four metrics comprising of class area (CA), percentage of land (PLAND), edge density (ED) and largest patch index (LPI) (present landscape consisting of the largest patch) were chosen for the present study. The Fragstats software was utilized to compute these indices on the class metrics derived from LULC classified images.

*Fragstats*

FRAGSTATS is a programme for analysing spatial patterns and quantifying landscape elements, has been commonly used to predict landscapes features (McGarigal and Marks, 1994). FRAGSTATS generates indices that describe each mosaic patch, every patch class (class), and the entire landscape mosaic. The study areas are ecologically sensitive but become vulnerable due to irresponsible tourism activity and chaotic development. Hence, with the understanding of dynamism in forest degradation, there is a need to discover the extent of forest degradation with the spatio-temporal change in LULC and forest cover, and to assess the changes in various parameters of landscape metrics and compare the fragmentation of two different eco-sensitive areas of Western Ghats. To assess the transition in LULC categories and forest cover for the application of landscape spatial indices, ArcGIS 9.3 software was used. Fragstats software 4.2 was used to create these indices or spatial metrics (McGarigal et al., 2002). Fragstats software has the advantage of assisting in the comparison of the spatial pattern of landscape. The spatial configuration of native forest fragments was quantified and compared using the class area (CA), percentage of land (PLAND), edge density (ED), and largest patch index (LPI).

To assess landscape patterns, each metric must have the same spatial resolution (Cushman et al., 2008); changing the spatial resolution will result in a more inaccurate landscape assessment. To quantify and monitor a huge database of landscape features, landscape complexity must be defined (Papadimitriou, 2009). A variety of criteria define landscape characteristics, each with a different level of relevance depending on the classification category. As a result, the metrics used in this study were chosen to identify characteristics at various levels and to be studied to estimate forest cover change using landscape metrics.

*Class Area (CA):*

It is a landscape composition metric that identifies a specific patch type in the landscape. The class area is absolute area covered by each patch type. If a single patch type covers the entire landscape area then the class area (CA) equals the total landscape area (TA).

$$CA = \sum_{j=1}^{n} a_{ij}\left(\frac{1}{10{,}000}\right) \quad (1)$$

Where,

$a_{ij}$ = area ($m^2$) of patch ij.

*Percentage of land (PLAND):*

It represents the proportion of the landscape that is composed of the corresponding atch type. PLAND quantifies the relative ratio of each patch type in the landscape. It equals the sum of the area ($m^2$) of all patches of the corresponding patch type, divided by the total landscape area ($m^2$), and multiplied by 100 (to convert to percentage)

$$PLAND = P_i = \frac{\sum_{j=1}^{n} a_{ij}}{A}(100) \qquad (2)$$

Where,

$P_i$ = proportion of the landscape occupied by patch type (class) i.

$a_{ij}$ = area (ha) of patch ij.

A = total landscape area (ha).

*Edge Density (ED):*

The sum of the lengths (m) of all edge segments, divided by the entire landscape area (sq. m), and multiplied by 10,000 for the conversion into the hectares.

$$ED = \frac{\sum_{k=1}^{m} e_{ik}}{A}\left(\frac{1}{10000}\right) \qquad (3)$$

Where,

$e_{ik}$ = total length (m) of edge in landscape involving patch type (class) i; includes landscape boundary and background segments involving patch type i.

A = total landscape area ($m^2$).

*Largest patch index (LPI):*

The largest patch index (LPI) shows percentage of the largest patch area in each class and helps to understand the fragmentation in the study area. When the corresponding patch type is small, LPI approaches 0 values, whereas when the entire landscape is formed up of a single patch type, it equals 100 values. The area of the largest patch divided by the total landscape are multiplied by 100.

$$LPI = \frac{\max_{j=1}^{n}(a_{ij})}{A}(100) \qquad (4)$$

Where,

$a_{ij}$ = area (ha) of patch ij.

A = total landscape area (ha).

## Results and Discussion

*Panchgani plateau*

The PLAND describes the percentage of land covered by each LULC category (Table 2). Since 1999, the amount of land covered by dense vegetation has decreased. It has decreased from 6.7 % in 2006 to 3% in 2015. The area under forest has been decreased since last two decades of the study period. It has occupied by agriculture and settlement, which have been increasing over the period. The dense vegetation categories have been increased from 1115.4 ha. (1989) to 1599.4 ha in 1999 at Panchgani plateau and again it reduced up to 1146.4 ha in 2006 and decreased converted in results of 503.3 ha in 2015. The Open vegetation category occupied the most land in 2006, but by 2015, it had decreased to 1800 ha. In the category of scrubland, the area covered in 2006 was higher than in 2015 (Figure 2). A significant increase in the area occupied by agricultural and settlement has occurred since 1989 (Table 2). The decrease in the land after 2006 is depicted by the open vegetation and scrub land category. Between 2006 and 2015, the area occupied by agriculture and settlement increased significantly.

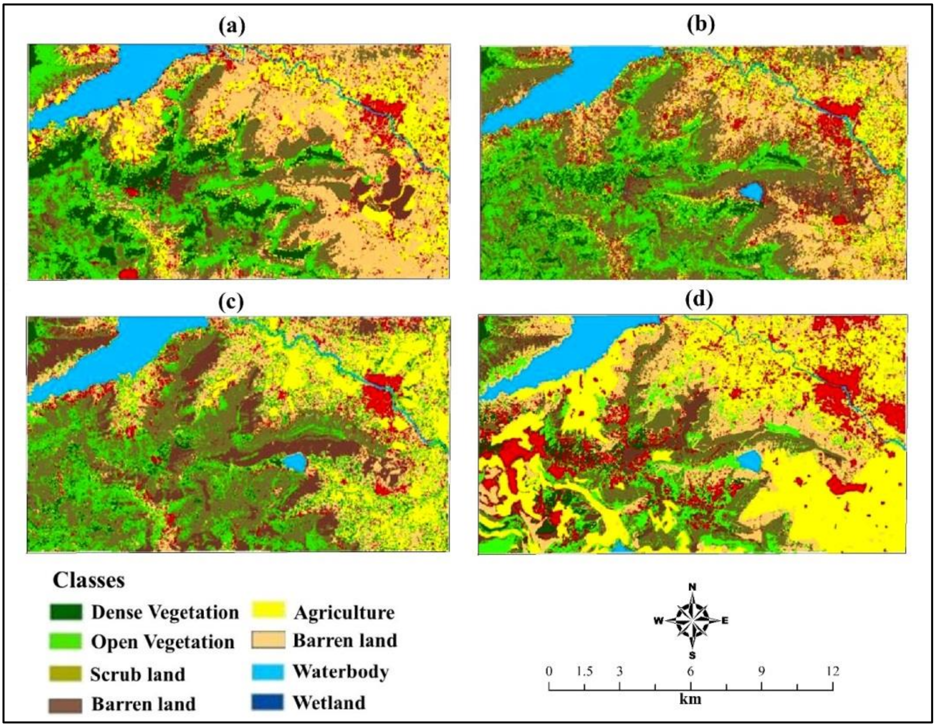


**Figure 2. LULC of Panchgani Plateau: a. 1989 b. 1999 c. 2006 d. 2015**

Between 1989 and 2006, the edge density of dense vegetation, open vegetation and scrubland categories increased, and then significantly decreased in 2015 (Table 3). The largest patch index indicates the proportion of the class area occupied by the largest patch. It describes the decline in vegetation type over time, resulting in forest fragmentation (Figure 3). The findings of this study imply that increasing agricultural, fallow land and settlement (built-up areas) are the primary drivers of forest fragmentation in Panchgani plateau. At the same time the study region is extremely susceptible due to irresponsible tourism activities, infrastructure construction, inappropriate land use, and forest fires. It is also vulnerable to changes in forest cover and increased forest fragmentation. The available habitat is declining due to fragmentation and forest loss caused by conversion to agriculture and other land uses.

**Table 2. Class Area and Percentage of Land of Panchgani plateau**

| Class Name | Class Area (ha) | | | | PLAND (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1989 | 1999 | 2006 | 2015 | 1989 | 1999 | 2006 | 2015 |
| Dense Vegetation | 1115.4 | 1599.4 | 1147.4 | 503.3 | 6.5 | 9.4 | 6.7 | 3 |
| Open Vegetation | 3084.2 | 2806.6 | 3295.1 | 1803.9 | 18.1 | 16.5 | 19.3 | 10.6 |
| Scrub Land | 4836.2 | 2608.8 | 4776.1 | 1987.5 | 28.4 | 15.3 | 28 | 11.7 |
| Barren Land | 1402 | 505.6 | 866.5 | 702.9 | 8.2 | 3 | 5.1 | 4.1 |
| Agriculture | 2666.3 | 2583.5 | 2042.1 | 5269.7 | 15.6 | 15.2 | 12 | 30.9 |
| Fallow land | 1569.1 | 4624.5 | 2575.6 | 3557.7 | 9.2 | 27.1 | 15.1 | 20.9 |
| Settlement | 1764.7 | 1226.4 | 1116.1 | 2320.8 | 10.4 | 7.2 | 6.5 | 13.6 |
| Water body | 609.6 | 1092.7 | 1228.6 | 901.7 | 3.6 | 6.4 | 7.2 | 5.3 |

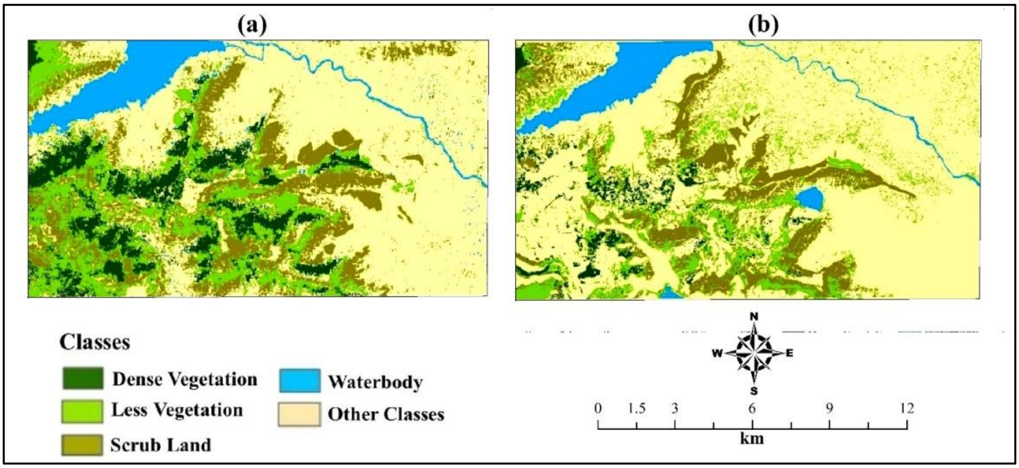


**Figure 3. Forest Fragmentation of Panchgani Plateau: a. 1989 b. 2015**

**Table 3. Edge Density and Largest Patch Index for Panchgani plateau**

| Class Name | ED (ha) | | | | LPI (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1989 | 1999 | 2006 | 2015 | 1989 | 1999 | 2006 | 2015 |
| Dense Vegetation | 16.3 | 29 | 42.3 | 18.6 | 1.3 | 1.3 | 0.7 | 0.2 |
| Open Vegetation | 31.2 | 58 | 113.8 | 73.5 | 7.8 | 4.8 | 5.3 | 0.5 |
| Scrub Land | 46.9 | 51.7 | 136.8 | 46.5 | 11.6 | 2 | 4.2 | 1.9 |
| Barren Land | 17.8 | 8.2 | 43.5 | 17.9 | 1.4 | 0.5 | 1 | 1.1 |
| Agriculture | 23.6 | 57.6 | 89.8 | 54.6 | 2.8 | 2.7 | 2.4 | 10.5 |
| Fallow land | 23.6 | 75.2 | 73.5 | 93.1 | 0.7 | 7.9 | 3.2 | 4.8 |
| Settlement | 39.6 | 53.7 | 61.9 | 73.2 | 0.3 | 0.5 | 0.5 | 1.1 |
| Water body | 13.4 | 8.6 | 19.5 | 4.2 | 1.3 | 5.7 | 5.8 | 4.4 |

*Kas Plateau*

The increasing tourism activity in the Kas plateau is creating threat to the surrounding area. The area of dense vegetation has decreased from 2006 (1957 ha) to 2015 (1523 ha), whereas the area of open vegetation has increased significantly (Table 4). The main reason for this is the increase in patchiness in the area. The percentage of land covered by vegetation is decreasing, from 13% in 2006 to 10.1% in 2015. In 2015, open vegetation increased by 23%, but scrub land dropped slightly (Figure 4) (Table 4).

**Table 4. LULC Class Area and Percentage of land of Kas plateau**

| **Class Name** | **Class Area** (ha) | | | | **PLAND** (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | **1989** | **1999** | **2006** | **2015** | **1989** | **1999** | **2006** | **2015** |
| **Dense Vegetation** | 962.2 | 1548.6 | 1957.6 | 1523.1 | 6.4 | 10.3 | 13 | 10.1 |
| **Open Vegetation** | 2894 | 3712.3 | 2942.2 | 3510.3 | 19.3 | 24.7 | 19.6 | 23.4 |
| **Scrub Land** | 4006.2 | 5741.2 | 4234.8 | 3896.3 | 26.7 | 38.2 | 28.2 | 25.9 |
| **Barren Land** | 2589.4 | 586.6 | 556.5 | 731.2 | 17.2 | 3.9 | 3.7 | 4.9 |
| **Agriculture** | 3736.8 | 1568.6 | 3151.1 | 3033.5 | 24.9 | 10.4 | 21 | 20.2 |
| **Water-body** | 418.5 | 1184.3 | 1540.3 | 1961.6 | 2.8 | 7.9 | 10.3 | 13.1 |
| **Wetland** | 414 | 679.5 | 638.6 | 365.1 | 2.8 | 4.5 | 4.3 | 2.4 |

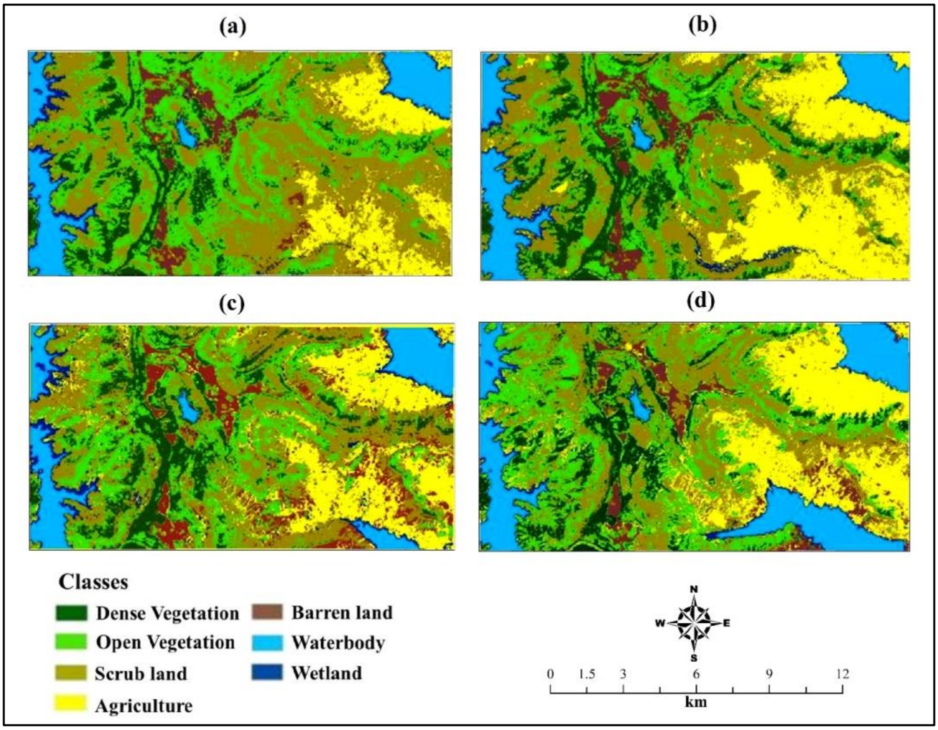


**Figure 4. LULC of Kas Plateau: a. 1989 b. 1999 c. 2006 d. 2015**

Between 1989 and 2006, the edge density of dense vegetation and scrubland categories increased, and then significantly decreased in 2015. From 1989 to 2015, there has been a steady increase in the category of open vegetation and also increase in agriculture category in the Kas Plateau (Table 5). The number of patches in the agriculture category has increased, followed by dense vegetation. If the number of patches for a specific category increases, the area is shown to be fragmented (Figure 5).

**Table 5. Edge density and Largest patch index of Kas plateau**

| Class Name | **ED** (ha) | | | | **LPI** (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | **1989** | **1999** | **2006** | **2015** | **1989** | **1999** | **2006** | **2015** |
| **Dense Vegetation** | 19.7 | 37.9 | 56.1 | 50.4 | 1.5 | 1.9 | 3.4 | 3.3 |
| **Open Vegetation** | 57.1 | 94.8 | 106.4 | 125.6 | 3.4 | 5.7 | 2.2 | 6.9 |
| **Scrub Land** | 58 | 112.6 | 142.2 | 111.1 | 11.1 | 21.5 | 7.8 | 10.3 |
| **Barren Land** | 56 | 16.3 | 16.5 | 20.7 | 1.1 | 0.8 | 0.7 | 1 |
| **Agriculture** | 57 | 25.4 | 62.1 | 72.8 | 7.8 | 4.3 | 12.4 | 7.3 |
| **Water-body** | 4.8 | 3.7 | 5 | 5.9 | 1.2 | 3.3 | 3.8 | 4.5 |
| **Wetland** | 9.7 | 26.8 | 40.9 | 19.3 | 0.7 | 0.7 | 0.6 | 0.5 |

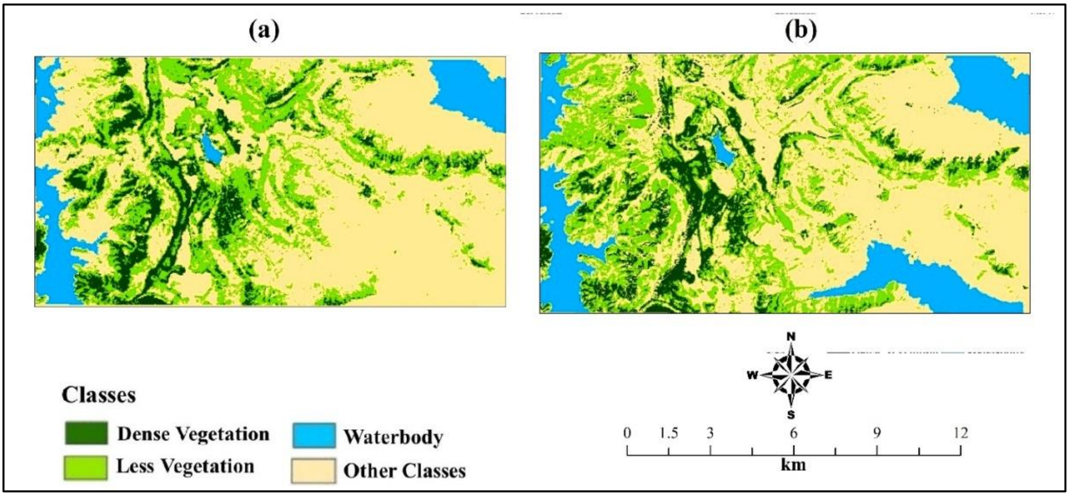


**Figure 5. Forest Fragmentation of Kas plateau: a. 1989 b. 2015**

*Fragmentation in Kas and Panchgani Plateaus*

Kas and Panchgani plateaus are two distinct places with few similarities in elevation, climate, and physiographic conditions with flora and fauna. Both of these locations are well-known tourist destinations. Though Kas and Panchgani plateaus are eco-sensitive zone but still there is a disturbance mainly due to increase in agriculture, water bodies and development activities, which degrade the ecosystem due to forest fragmentation. From the Landsat images, it was depicted that the settlements in the Kas plateau are scattered and sparsely populated. In Panchgani plateau, the wetland area is absent. As compared to Kas Plateau, the Panchgani plateau is more fragmented because of decrease in vegetation cover. Fragmentation in Panchgani plateau is also the result of its popularity as a famous tourist destination. Another reason for fragmentation might be as a consequence of increase in area under agriculture. The area under dense vegetation is only 3% in Panchgani plateau and 10.1% in Kas plateau region whereas the open vegetation is high in Kas plateau (23.4 %) as compared to Panchgani plateau which is 10.6 % respectively. Agricultural land is expanding in the Panchgani plateau (30.9%) as compared to 20.2% in Kas region. The results reveal that the both plateau areas are degrading through fragmentation of natural forest but Panchgani Plateau and its surrounding areas are more fragmented as compared to Kas Plateau region. The conservation effects of the Kas Plateau region have improved.

## Conclusions

Forest fragmentation is associated with a rapid increase in the number of small patches and a decrease in patch connectivity. The study areas are experiencing forest fragmentation due to unplanned tourism activity, farm houses, increasing settlements, expansion of agriculture area, infrastructure development and human encroachment in adjacent area of forest. Increased fragmentation is harmful to biodiversity because forest patches are more widely scattered throughout both plateaus. The comparison between geographical and geological distinct Kas and Panchgani plateau facing the negative impact of human interference and have changed forest cover over the period. It can be depicted that both these areas are under threat for ecological disturbance and especially Panchgani plateau has face more. The spatial configuration pattern of forest fragmentation, as well as how it fluctuates through time and space at the landscape level, should be addressed in conservation policy and land use planning for both the study area and the rest of the world.

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