Land-use and land-cover change and future implication analysis in Manas National Park, India using multi-temporal satellite data

Pranjit Kr. Sarma[1,*], Bibhuti P. Lahkar[1], Sonali Ghosh[2], Abhijit Rabha[3], Jyoti P. Das[1], Naba K. Nath[1], Santanu Dey[1] and Namita Brahma[1]

[1]Aaranyak, 50 Samonway Path (Survey), P.O. Beltola, Guwahati 781 028, India
[2]Social Forestry Division, Kokrajhar 783 370, India
[3]Conservator of Forests (Wildlife), Forest Department, Rehabari, Guwahati 781 008, India

The Manas National Park is an important conservation area in the Bhabhar and flood plain ecosystem of Northeast India. Satellite imageries of 1977, 1998 and 2006 were analysed to detect the change in habitat types with the help of remote sensing and geographic information system tools. Results indicate landscape-level changes in the vegetation and overall habitat quality within the Park. There is a substantial increase in savannah grassland (74.6%) accompanied by decline in alluvial grasslands (46.8%) from 1977 to 2006. A total of 20.47 km^2 has also been encroached during this period. Water sources in the Park have declined and there has been a significant shift towards a drier and woodland type of vegetation. These land-use changes were a result of non-implementation of habitat management/manipulation activities that are a prerequisite for supporting viable populations of specific endangered animal species in a given Protected Area. In this communication, we recommend a set of habitat management activities for restoration of key habitats in Manas.

Keywords: Habitat management, land-cover, land-use, remote sensing, satellite imagery.

ANTHROPOGENIC changes in land use and land cover are being increasingly recognized as critical factors influencing global change[1]. While land cover and land use are often assumed to be identical, they are rather quite different. Land cover may be defined as the biophysical earth surface, while land use is often shaped by human, socio-economic and political influences on the land[2]. Remote sensing (RS), integrated with Geographic Information System (GIS), provides an effective tool for analysis of land-use and land-cover changes at a regional level. The geospatial technology that combines the technology of RS and GIS holds the potential for timely and cost-effective assessment of natural resources. The techniques have been used extensively in the tropics for generating valuable information on forest cover, vegetation type and land-use changes[3–8]. Therefore, we have used RS and GIS to study land-use and land-cover change in Manas National Park (MNP), considering that the area remained almost inaccessible during the long period of insurgency and no database relating to habitat management is available. It is also a suitable site that could be studied on a spatial and temporal scale, to clearly look at the impact of natural and anthropogenic changes in the last 30 years. Although a few perceptible and obvious changes such as the local extinction of some faunal species, including the Great Indian one-horned rhinoceros (*Rhinoceros unicornis*) and the swamp deer (*Cervus duvauceli ranjitsinhi*) are noticeable, the extent of loss of habitat and other threats are a few of the problems that we have attempted here to find solutions by studying the landscape on a temporal scale.

MNP (26°35′–26°50′N and 90°45′–91°15′E) is located at the foothills of the Bhutan Himalayas in the Baksa and Chirang districts of the Bodoland Territorial Areas District (BTAD), Assam (Figure 1). It was declared a National Park (NP) in 1990, with an area of 519 km^2. The Park also forms the core area of the Manas Tiger Reserve, which has an area of 2837 km^2. Altitude within the Park ranges from 50 to 200 m amsl. In the northern side, the forests are contiguous with those in the Royal Manas and the Black Mountain National Park in Bhutan, thus forming a large area of undisturbed landscape under the Northeast Brahmaputra Valley (9A) bio-geographic zone[9]. It enjoys a tropical climate with rainfall between 3000 and 4000 mm annually[10]. MNP is known for its spectacular scenery and a variety of habitat types that support a wide variety of flora and fauna. At the time of its declaration as NP and later a World Heritage Site in 1985, it was perhaps one of the few Protected Areas (PAs) to harbour as many as 21 scheduled species as listed[11] under the Wildlife (Protection) Act, 1972. Ethnic disturbances in the recent past have caused severe lapses in the management of the NP and resulted in local extinction of several species, including the Great Indian one-horned rhinoceros and has made others such as the highly endangered pygmy hog (*Sus sulvanius*) and Bengal florican (*Houbaropsis bengalensis*) vulnerable (A. R. Rahmani *et al.*, unpublished). Increasing human population in the fringe areas had led to encroachment and illegal hunting and tree-felling within the PA. Even now, people residing in the buffer areas are in many ways dependent on the Park for their livelihood, such as livestock grazing, and fodder and fuel wood collection. Therefore, the urgent need of the hour is to regulate and control the anthropogenic pressure.

The landscape of MNP was extensively surveyed using transect data sampling techniques from October 2005 to October 2006. A total of 55 transects were walked to cover roughly more than 10% of the total geographical area. Ground-truthing was carried out using an e-trex Global Positioning System (GPS) receiver. A total of 330 GPS

*For correspondence. (e-mail: pranjit@aaranyak.org)

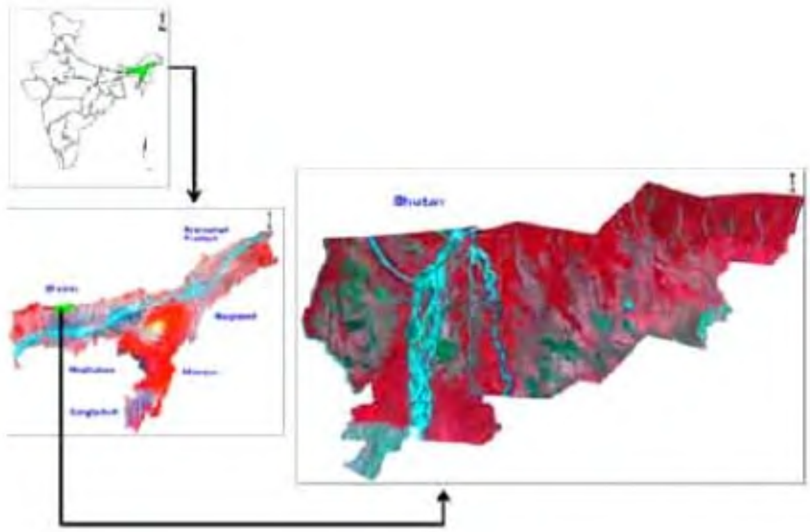

Figure 1. Location map of Manas National Park.

Table 1. Satellite data used for the study

Data type	Path/row	Date of acquisition
Landsat TM	147/42	8 February 1977
IRS IB LISS III	110/53	16 February 1998
IRS ID LISS III	110/53	12 February 2006

points were collected from different vegetation types as visualized in the field. From each GPS location the following information was recorded: (a) latitude and longitude, (b) elevation, (c) type of vegetation and (d) details of habitat characteristics within its vicinity. For change detection we used three satellite imageries of 1977 (LANDSAT TM), 1998 (IRS 1D LISS III) and 2006 (IRS 1D LISS III; Table 1). The 1 : 50,000 Survey of India topographical sheets 78J/13, 78J/14, 78N/1 and 78N/2 were utilized in the preliminary processing of satellite data. A false colour composite (FCC) was generated using the different bands of the satellite data. The satellite imagery was rectified or geometrically corrected using ground control points (GCPs) obtained from topographical sheets and the GPS points collected from the field. Points such as the intersection of roads, river junction, etc. were identified on the topographic sheets as GCPs. Using polynomial equation the scene was geometrically corrected and georeferenced into latitude/longitude coordinate system using polyconic projection system. The pixels were re-sampled using the maximum likelihood algorithm and the study area was extracted from the scene using Park boundary maps in ERDAS Imagine 9.0 software. Sub-pixel image to map registration accuracy was achieved through repeated attempts. Histogram matching was done to correct the radiometric differences, if any. Using GCPs, training sets were generated for different land-cover and land-use types and the image classified based on a combination of visual and digital classification schemes. Finally the three satellite imageries falling in different dates were superimposed to detect changes in land use over a period of time. The output resolutions of the classified images were at 23 m.

The entire study area was classified and the following land-use/land-cover types were obtained (Figure 2).

Woodland: This comprises of tree species mostly belonging to semi-evergreen forest and moist mixed deciduous forest. The semi-evergreen forest is represented by *Pterospermum acerifolium*, *Dysoxylum binectariferum*, *Phoebe goalparensis*, *Amoora wallichi*, *Sterospermum personatum*, *Chukrassia tabularis*, *Duabanga grandiflora*, *Michelia champaca*, *Linnea coromandelica* and *Sterculia villosa*, while the moist mixed deciduous forest is represented by *Bombax ceiba*, *Lagerstroemia flosreginae*, *Careya arborea*, *Terminalia bellerica* and *Gmelina arborea*, among others. The area under this category is 233.31 km^2 and it is distributed mostly in the northern part and in the extreme south-west of the Park.

Savannah grasslands: This type of grasslands is dominated by tall grasses such as *Narenga porphyrocoma*, *Imperata cylindrica*, *Phragmites karka*, *Arundo donax*, *Saccharum spontaneum*, *Themeda arundinacea*, *Saccharum procerum* and *Vetiveria zizaanioides*, that are interspersed with tress such as *B. ceiba*, *Dillenia indica* and *L. flosreginae*. The total area under this category is 161.98 km^2. This land cover type is distributed in the northeastern part as well as the southern boundary of the Park touching the villages.

Alluvial grassland: The area under this category is 44.49 km^2. This land-cover type is scattered all over the Park. It is characterized by pure patches of grasslands and

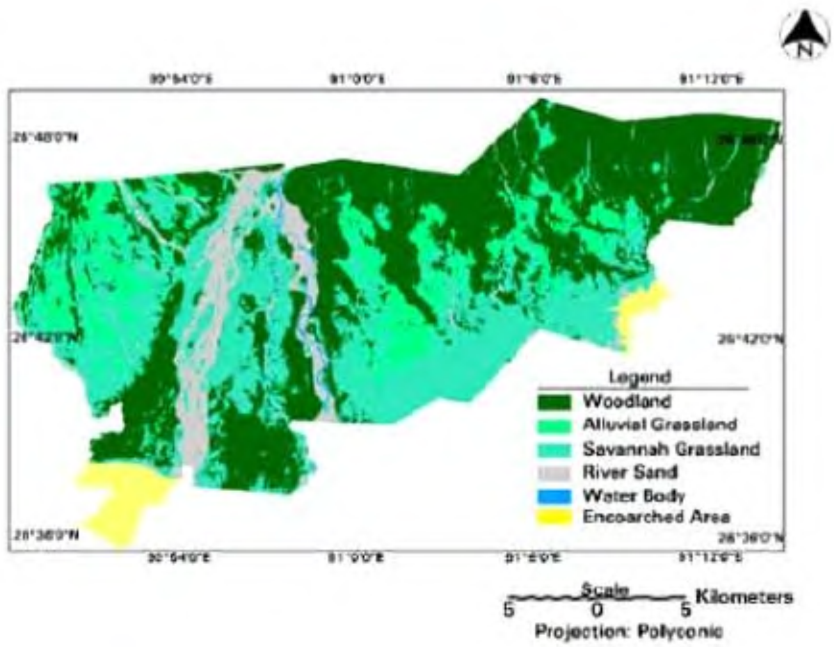

Figure 2. Land-use map of MNP as in 2006.

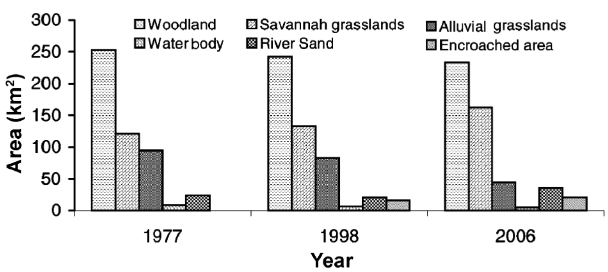

Figure 3. Land-use changes in MNP.

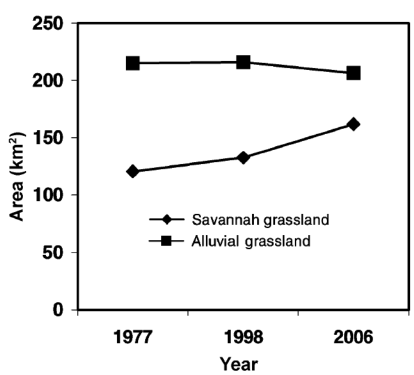

Figure 4. Pattern change of grasslands in MNP.

presence of water during the rainy season. These alluvial grasslands have been critical to the survival of mega herbivores such as the rhinoceros and swamp deer in the past.

Waterbody: The area under waterbodies (numerous small wetlands and rivers) is 3.94 km^2. The waterbodies are mostly distributed towards the southern boundary near the Bansbari Range, as is typical in a Bhabhar–Terai formation.

River sand: The area under this category is 35.82 km^2. River sand banks devoid of any vegetation are mainly concentrated around the dried river bed of Manas. The change in course by the rivers Beki and Manas along with excessive siltation during the rainy season have resulted in the expansion of such areas.

Encroached area: The area under this landuse type is 20.47 km^2. It is distributed in two major area at the extreme southwest and extreme southeast part of the Park.

As it is clear from Figure 2, there have been crucial alterations of land-use pattern within the Park from 1977 to 2006 (Table 2 and Figures 3–5). An area of 20.05 km^2 has been deforested within the Park boundary during these years, out of which 15.33 km^2 has been deforested in the southwestern part of the Park, whereas 4.72 km^2 has been encroached in the eastern-most part. Initially the settlers around the Park were only grazing and collecting minor forest produce from the fringe areas. Gradually with the deterioration in law and order, the important timber-yielding species were removed and the cleared area used for encroachment and illegal farming. At present, these areas are still under occupation. The alluvial grasslands, which was a major habitat for several species such as the pygmy hog, Bengal florican, swamp deer, hog deer, rhinoceros and elephants, has reduced drastically (46.8%; Figure 4). The major causes of decline are silta-

Table 2. Land-use changes in Manas National Park (km^2)

Land-use class	Area (km^2) 1977	1998	2006	Net change (km^2) 1977–1998	1998–2006
Woodland	253.1	242.18	233.21	–10.92	–8.97
Savannah grasslands	120.86	132.84	161.97	+11.98	+29.13
Alluvial grasslands	94.38	83.21	44.37	–11.17	–38.84
Waterbody	8.88	6.67	4.99	–2.21	–1.68
River sand	23.74	20.52	35.97	–3.22	15.45
Encroached area	0	15.54	20.47	+15.54	+4.93

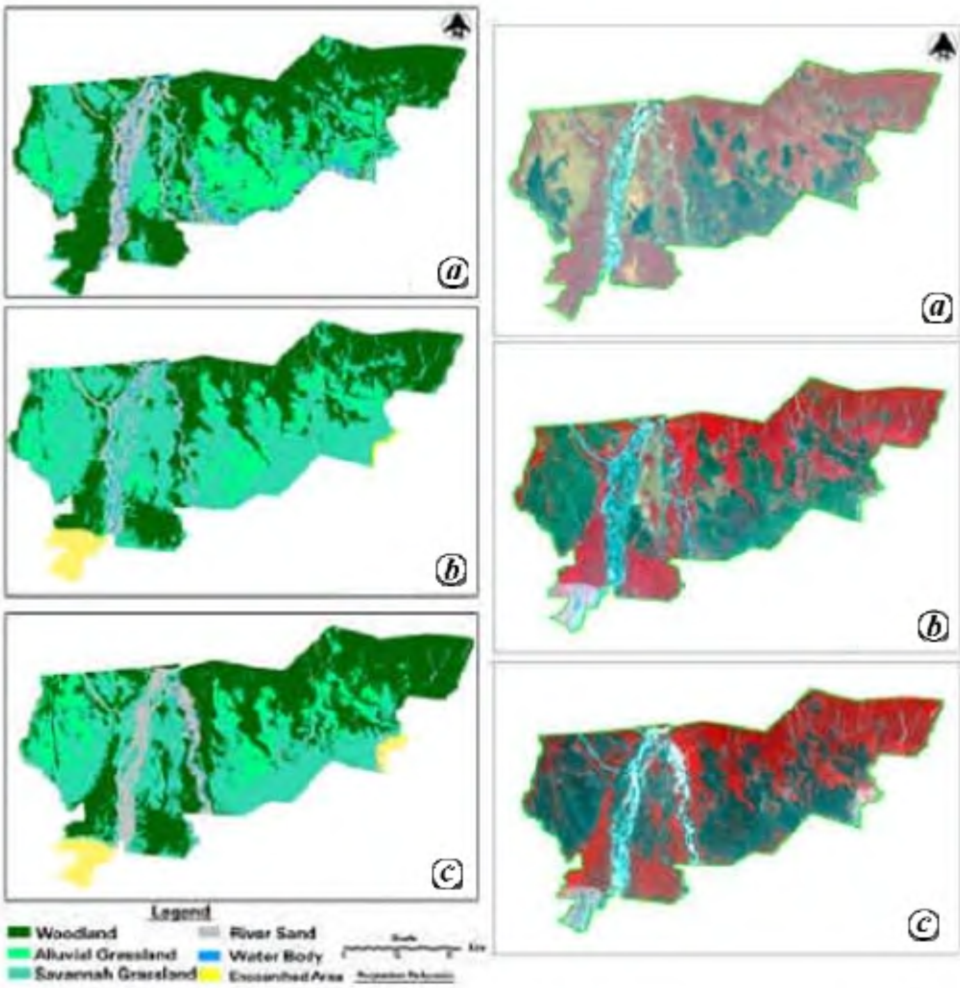

Figure 5. Changes in land-use pattern and land cover as indicated by comparing classified and FCCs over a period of thirty years in MNP. ***a***, 1977; ***b***, 1998, and ***c***, 2006.

tion of existing waterbodies, invasion of exotic weeds like *Eupatorium* sp., *Melastoma* sp., *Lea* sp., marked augmentation of *Bombax ceiba* saplings and or lack of a suitable burning regime in the surrounding savannah grasslands. Records also indicate that during the last decade two disastrous floods (1988 and 2004 respectively) caused considerable damage, which carried vast amount of silt from the upstream and deposited it over the low-lying areas of the Park. No studies till date have examined the influence of floods in this type of land-use alteration. These grasslands are naturally dynamic and subjected to altered flooding regime due to change in the river course and are subjected to additional disturbances from fire, grass collection, grazing, encroachment and agricultural conversion[12–14]. A marked eastward shifting of 4 km by the River Beki was visible. On the other hand, the River Manas was almost dry from Mathanguri onwards.

The woodland area remained almost the same during these years; however, currently the area occupied by mixed moist deciduous forest is trifling (65.61 km^2). Species specific to this type of habitat may face problems. The semi-evergreen forests have greater area coverage (177.02 km^2). These are well protected and intact, lying in the northern part of the Park touching the Indo-Bhutan border. These patches play a crucial role in trans-boundary movement of wild animals.

We provide the following recommendations for proper management.

Alluvial grasslands: The low-lying areas in the Park have been impacted the most due to man-made and natural causes. The already reduced area of these alluvial grasslands must be intensively managed with suitable habitat interventions, so that the desired species composition is attained. The criticality of the situation can be judged from the fact that these areas are now supporting the only remaining three sub-populations of the critically endangered pygmy hog in the world. Studies indicate that they require a suitable mix of short and tall grasslands. As indicated in the study, these grasslands need not be necessarily burnt on an annual basis. If so, then suitable measures need to be taken to ensure a patchy burning regime, so as to provide suitable cover during the time of re-growth of grass. De-siltation of existing waterbodies and removal of aquatic weeds may also be taken up on a priority basis.

Savannah grasslands: Mega-herbivores such as rhinoceros and elephants require large tracts of grasslands interspersed with waterbodies. Manual uprooting of fire-resistant weeds and colonizing trees may be resorted to in some of the intensively managed sites.

Settlement and cultivated areas: It has been observed that more than ten pairs of Bengal floricans have been visiting the Kokilabari Seed Farm, on the eastern boundbary of the Park since the last 5 years. The area is an abandoned seed farm which is now being used for cultivation by the local community. The males are especially visible during the breeding season (March–April), when they become highly territorial, actively performing courtship dances. Like most other bustards, the Bengal florican is also perhaps tolerant to a mix of undisturbed grasslands and cultivation, and this area may turn out to be the most suitable habitat for these birds, if the farming is effectively regulated. While the cultivation period can start just from the monsoon season in July and last till October, the land can be left fallow for the remaining part of the year for the birds to arrive and breed. Suitable eco-tourism benefits can be transferred to the farmers so as to provide an incentive to protect the land.

Combating encroachment and illegal activities: The number of anti-poaching camps needs to be increased and spread out to cover the area adequately. Forest personnel may be suitably equipped with wireless and other such amenities. Awareness camps and conservation and eco-tourism initiatives by the local youth need to be encouraged.

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