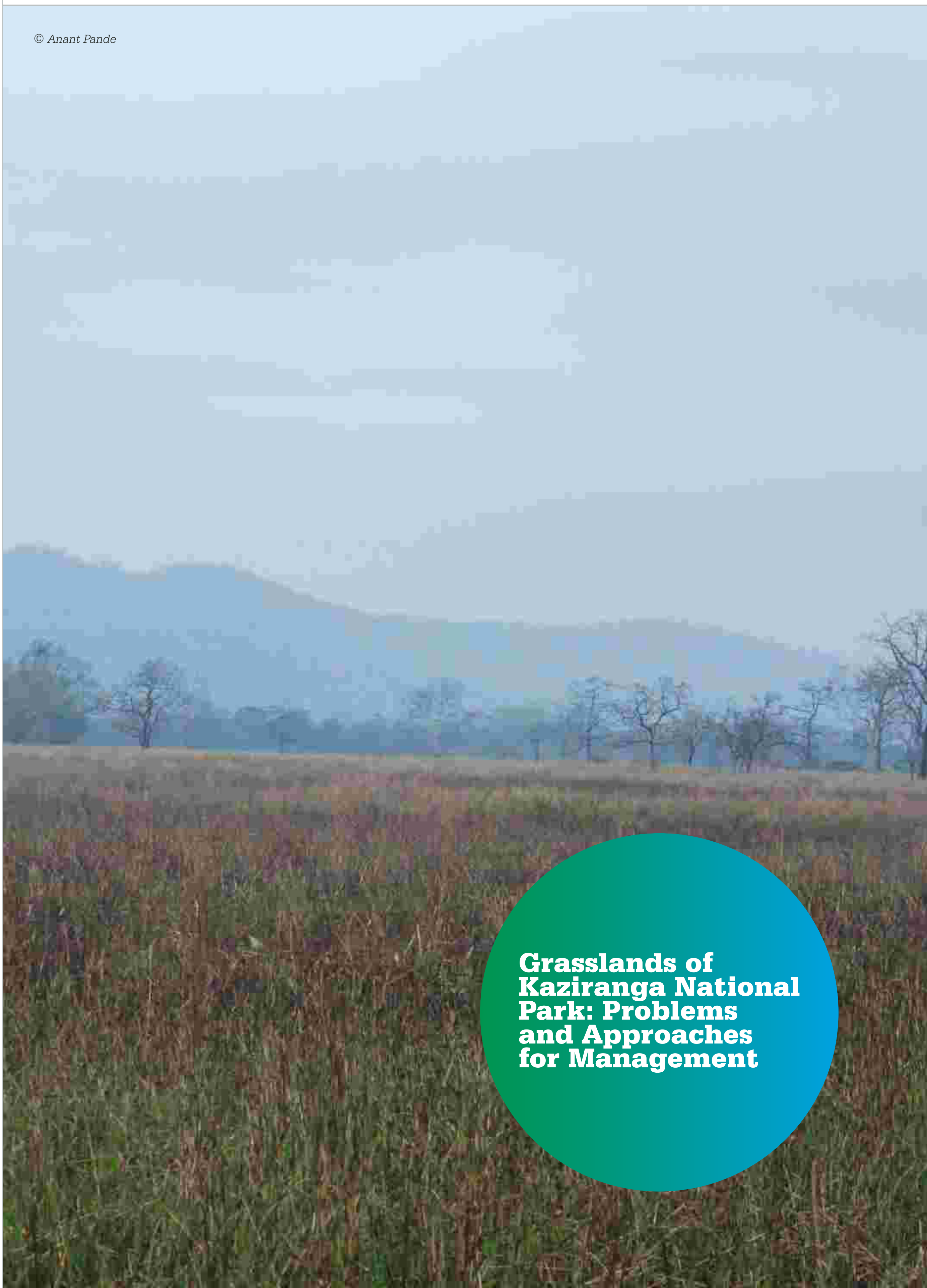

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# Grasslands of Kaziranga National Park: Problems and Approaches for Management




## Abstract

The flood plains of Ganga and Brahmaputra Rivers are well known for their unique grasslands. Frequent flooding and changes in pattern of channels accompanied by extensive erosion and deposition of sediment generates ideal conditions for such grasslands. The world famous Kaziranga National Park, located in the floodplains of Bramhaputra, represents typical wet grasslands. About 64% of the park area is occupied by tall grasses (61%) and short grasses (3%). Predominantly, tall grass species such as *Saccharum spontaneum, Imperata cylindrica, Saccharum bengalense* are present in low lying areas; *Vetiveria zizanioides* prefers upland areas, whereas *Phragmites karka* and *Themeda arundinacea* prefer the marshy areas. However, changing flood regime, siltation, fire coupled with invasion of *Mimosa invisia* are affecting, vegetation composition and suitability of the habitat for the native fauna adversely. In view of the changing landscape and taking into account the present ethnic diversity, anthropogenic pressure and presence of endangered large mammals in the par, there is a need to conserve and protect this natural heritage in a holistic manner. The present paper describes the vegetation dynamics of the grassland habitats in the park and provides, management recommendations to combat the issues affecting the grasslands.

***Keywords :*** Kaziranga National Park; Management issues; Tall grasslands; Vegetation dynamics; Weed invasion

## Introduction

Grasslands are ecosystems dominated by vegetative component comprising herbaceous species (Coupland 1979). While expansion of agriculture, human settlement and land use changes have resulted in conversion of highly productive grasslands for agriculture and artificial pastures (White et al., 2001; Suttie et al., 2005; Yang et al., 2015); invasion by woody perennials has resulted in drastic changes in the functional ability of these ecosystems (Gioria and Osborne 2014). Hygrophilous or tall wet grasslands are considered as wet savannahs adapted to very wet climate. Ecosystem that serves as habitat for a number of threatened fauna, obligate to grasslands of various types of tropical grasslands, hygrophilous grasslands in the flood plains of Ganga and Bramhaputra Rivers are of special interest due to their high primary productivity and ability to withstand frequent fire and flood.

The hygrophilous grasslands have evolved along the river courses where large seasonal variation in rainfall results in flooding and the overspills from the river flows into the surrounding plains (Krafter et al., 1992). Regular flooding, gravel and mud shifting, formation of oxbow lakes, nutrient rich woods and meadows are the characteristic features of a dynamic floodplain ecosystem (Bayley, 1995; Bissels et al., 2004). The riverine tall wet grasslands of Ganga and Brahmaputra in the foothills of the Himalaya are typical example of floodplains ecosystem in India (Kumar and Subudhi 2013). These floodplains are developed on river deposited silt and often dominated by pure dense stands of 6-8m tall perennial grasses and form a dynamic complex with interspersed woodland and swamps. High water table, annual flooding, high level of moisture availability and the synergistic influence of annual grassland fires are characteristics of this complex ecosystem (Lehmkuhl, 1994; Peet et al., 1997).

The flood banks of Brahmaputra River is characterized by its enormous volume of sediment load leading to continuous changes in channel morphology, rapid bed aggradations and bank line recession and erosion (Sarma and Basumallick, 1980; NRSA, 1980; Naik et al., 1999; Mani et al., 2003). The river has braided channel along its course in the alluvial plains (Goswami et al., 1999). The lateral changes in channels cause severe erosion along the banks leading to a considerable loss of good fertile land each year (Bhakal et al., 2005; Sarma et al., 2007). Bank oscillation also causes a shifting of outfalls of its tributaries that brings newer areas under waters (Kotoky et al., 2005; Das and Saraf 2007). High floods result

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in large scale breaches of the existing embankments bringing vast areas under flood inundation. Stream-bank erosion further damages infrastructure causing significant problems in adjusting water-discharge and represent up to 80- 90% of the sediment load in streams and rivers (Simon and Rinaldi 2000). Total maximum daily sediment load is a significant source of sediment and nutrient pollution affecting the water quality, vegetation composition and fish spawning habitat adversely. Despite of the destructive nature of floods, new habitats are created such as fish spawning areas, crane roosting habitats (Johnson 1994; Flosi et al., 1998), irregular banks as habitat for invertebrates, fish, and birds and substrate for the establishment of riparian vegetation (Florsheim et al., 2008; Miller and Friedman 2009).

The grassland habitats along Brahmaputra are highly threatened due to excessive agricultural expansion. Even within Protected Areas such as Kaziranga National Park (KNP), grassland habitats are prone to conversion into woodlands or degradation due to invasion by exotic aggressive weeds. In this paper we describe the issues concerned with management of grassland habitats of KNP with special reference to tall wet grasslands.

## Study area

### *Kaziranga National Park*

Kaziranga landscape is formed by complex of sprawling grasslands, numerous water bodies and woodlands that make an ideal mix of habitats for a variety of flora and fauna. KNP and its six additions are situated in three civil districts namely Golaghat, Nagaon and Sonitpur in the state of Assam. The park is located between 26°30' N to 26°50' N and 92°50' E to 93°41' E coordinates bounded by the Brahmaputra river on the north and Karbi Anglong hills on the south covering an area of 859.4 $km^2$ that includes 429.93 $km^2$ area of KNP vide Govt. Notification No.FOR/WL/722/48/45, dated 11-02-1974 with effect from 01-01-74 and the areas vide subsequent notifications as six additions. National Highway (NH) 37 passes along the southern boundary of the national park. The lithic formation represents grey silt and fine to medium sands which form the recent composite floodplain with numerous meander scars and scrolls. The climate of the national park is subtropical monsoon type differentiated into three seasons viz. summer, monsoon, and winter. The winter season spans between November and February and characterized by mild and dry conditions with a temperature range of 5 - 25°C. During this season, the wetlands called 'beels' and water channels (nallahs) get dried up (Mathur et al., 2005). The hottest months are July and August with maximum temperature going up to 35°C.

Mean annual rainfall is 2,220 mm mostly during the months of June to September. Because of rise and fall of water table of the Brahmaputra River, the park gets submerged due to the unique flooding pattern of the Brahmaputra River. Due to back flow of river 'Mora Diffolu' from the west, large areas in western range are submerged initially, making an ideal condition for development of short grass areas along the water bodies. Nearly 100 km bank-line of Brahmaputra has many openings at different elevations from east to west that facilitates rising of the waters of the river into the park replenishing the water bodies and then spilling to the grassland areas and the adjoining high grounds depending upon the level of water and its duration in the main river. In the final stage, when flood peaks rise above the floodplain surface, the overtopping of bank-line results into heavy inflow of excess water of the river into the park. This situation, if prolonged, creates high flood condition resulting in heavy damage to infrastructure and wildlife and also results in migration of some animals to the elevated and forested regions outside the southern border of the park. In this migration process, mortality due to vehicle hit on NH 37 and drowning when trapped in floating vegetation also occurs. The ecological and biological process in the evolution and development of the riverine floodplain ecosystem of this park is also influenced by the oscillatory character of Brahmaputra River under riverine and fluvial processes.

This floodplain is also dotted with wetlands locally known as beels, which harbour varieties of flora and fauna. The major vegetation types of KNP comprise of five forest types or biomes viz., (1) Eastern wet alluvial grasslands (4D / 2S2), (2) Assam alluvial plains semi-evergreen forests (2B/C1a), (3) Tropical moist mixed deciduous forests (3C3), (4) Eastern Dillenia swamp forests (4D/SS5) and (5) Wetlands (Champion and Seth, 1968).Water bodies cover about 6% of the park area (Table 8.1). The park harbours about 440 plant species, 35 species of mammals, 480 species of birds, 60 species of reptiles, 24 species of amphibians, 42 species of fishes and 491 species of butterflies. However, recurrent flood, erosion and alluvial deposition are resulting in establishment of early succession species such as *Imperata cylindrica, Phragmites* and *Saccahrum* in low lying areas and *Vetiveria zizanioides* on the elevated ones (Khatri and Barua 2011).

Maximum area of the park is occupied by tall grasses followed by woodlands and short grass area. About 64% area of the Kaziranga National Park (KNP), particularly the western part, is occupied by the grasslands that include both tall grasses and short grasses. Rowntree (1954) classified the grasslands of Assam into two associations, i.e. (i) *Imperata - Saccharum –Themeda* type; and (ii) *Alpinia – Phragmites- Saccharum* type. The former develops on higher well drained lands whereas the latter develops on recent alluvium of rivers and flood plains, where *Bombax* and *Albizzia* are common tree associates. Tall grasslands consists mainly *Saccharum* spp., *Saccharum ravennae, Arundo donax, Phragmites karka, Imperata cylindrica, Neyraudia reynaudiana* etc. These grasses occupy the newly formed areas along the river course and wetlands but mixed sometimes with *Tamarix dioica*.



**Table 8.1.** Land use- land cover statistics of Kaziranga National Park, Assam in different years.

| Land cover type | Percent area cover | | |
|---|---|---|---|
| | (Kushwaha, 1997) | (RFRI, 2011) | (Das et al., 2014) |
| Woodlands | 27.95 | 29.30 | 21.8 |
| Tall grass | 61.01 | 57.00 | 50.6 |
| Short grass | 3.01 | 7.00 | 7.7 |
| Water body ('beels') | 5.96 | 6.00 | - |
| Jia Diffolu | 0.97 | - | - |
| Mora Diffolu | 0.70 | - | - |
| Sand bars | 0.40 | - | - |

## Vegetation dynamics

There are marked seasonal variations in the habitat, the vegetation and the areas of animal concentration in the park mainly between the winter and monsoon seasons. With the advent of winter, the shallow wetlands and streams and the shallow banks around the perennial wetlands starts drying up with simultaneous regeneration and growth of shorter grass species. These are the areas where animals concentrate for grazing immediately after the receding of the monsoon. The tall coarse grasses dry up during December to January and are burnt annually. These burnt sites attract several ungulate species to feed on the partially burnt stems of the reed grasses (Vasu, 2003). As soon as the Park gets a few winter showers, new growth of grasses shoots up in the burnt patches, where the animals concentrate to relish the tender shoots. With gradual increase of the rainfall during the monsoon, the grasses in the burnt patches grow up very quickly resulting in turning up of tender shoots into coarse blades (pers. obs.). As the temperature shoots up, the animals prefer to remain near the water sources, i.e. wetlands and streams. But with setting in of monsoon the shallow wetlands and streams are filled up at first by the rainwater and then by the floodwater leading to gradual movement of animals to higher grounds, which are mainly situated around the woodlands. When more and more areas are submerged by flood water, animals start migrating to the nearby Karbi Anglong Hills and other adjoining areas.

Majority of species in the park have site preferences depending upon the moisture conditions of the soil. *Saccharum spontaneum, I. cylindrica, Saccharum bengalense, Saccharum narenga, Neyraudia reynaudiana, Cymbopogon flexuosus* occur in the newly formed floodplain along the river. *S. spontaneum* (Ekora), the most common, widely distributed and preferred species for the One-horned Rhinoceros grows in elevated areas, which get exposed after being flooded during rains. Borota Kher (*Saccharum bengalense*), Ulu Kher (*I. cylindrica*) occupy comparatively drier areas, while Khagori (*P. karka*) and Meghela (*Saccharum arundinaceum*) are found generally in low-lying damp areas. Nal (*A. donax*) is the species of water logged and marshy places (Vasu 2003). The short grasslands covers about 3% of the park and mostly found in the open areas near the 'beels' which remain inundated during monsoon and dry up during winter supported by loam soils. The woodlands are represented by variety of subtypes or different stages of succession and edaphic variations. Some of the important trees in the park are *Mangifera indica, Delonix regia, Terminalia myriocarpa, Bombax ceiba* and *Ficus* spp.

Species of *Imperata, Phragmites* and *Saccharum* are considered the early succession species of this floodplain and occupy the low lying areas of the park under fluvial action and flooding. This association also develops in woodlands when periodic flooding ceases and soils stabilize. *Phragmites karka – Imperata cylindrica* assemblage is generally favoured by extreme wet and marshy condition, whereas *Phragmites karka – Sacchrum narenga – Imperata cylindrical* assemblage occupy relatively lower end of the moisture gradient. Shorter perennial grasses such as *Imperata cylindrica* and *Vetiveria zizanioides* occupy generally drier and well drained elevated area with better developed soils but mixed sometimes with scattered trees or shrubs (Khatri and Barua 2011; Kumar and Subudhi, 2013). *S. spontaneum* has been observed to colonize the river banks after the retreat of monsoon floods (Dinerstein, 2003).Though natural disturbances determine the forest dynamics and affect the tree diversity at local and regional scales (Attiwill, 1994; Sheil, 1999), the anthropogenic disturbances contribute in regulating the regeneration dynamics, structure and floristic composition of grasslands (Ewel et al., 1981; Horn and Hickey, 1991). Fire is an important anthropogenic factor in KNP that stimulates the growth of many palatable and nutritious grass species preferred by the grazing ungulates. The annual flooding replenishes the soil with nutrients and allows regeneration of flood adapted species (Loeb et al., 2009; Manral et al., 2012). These key factors operate in tall wet grasslands at the landscape level creating a mosaic of seral stages that are exploited by the resident ungulate (Banerjee 2001). The changes in structural attributes of the grassland are also related to disturbance regimes (Cannon et al., 1994; Wright 2005). Decreased grassland area at the expense of tropical deciduous



and tropical semi-evergreen forests and development of two new forest types viz., tropical evergreen and moist deciduous forests are the recent changes in vegetation dynamics of KNP (Medhi and Shaha 2014). Decline in area of wetlands under sedimentation and silt deposition and its conversion into grassland followed by invasion of *Mimosa* species are also influencing the vegetation composition and dynamics of the park.

## Problems of grassland management

A number of fresh water lakes (beels), marshy areas, seasonally inundated lowlands and a large number of riverine sandbars and islands were, till recently, an ideal wetland ecosystem of the Brahmaputra floodplain. However, the devastation of these wetlands started with the arrival of water hyacinth a century ago. Extensive growth of this weed leads to eutrophication by slowing down water movement and depositing debris at the bottom of the water bodies. The anthropogenic factors such as large scale deforestation in the hilly catchments practice of shifting cultivation, and human intervention in the river system like encroachment in the floodplains, and destruction of natural wetlands cause degradation of wetlands. The floods in the region have also made a quantum leap after the massive earthquakes of 1897 and 1950, both of magnitude 8.7 on the Richter scale. As usual such earthquakes generate large quantities of sediment that enter the river system as sludge and disturb the normal regime over a period of several decades (World Bank, 2006). Gradual silt deposition and rising of the riverbed affect run-off from the catchment areas during the monsoon (Bhatt, 2013).

## Changes in grasslands area

The grassland associations include mono-specific stands of tall grass viz., *S. spontaneum* (4–6 m), *S. bengalense, S. narenga* and *Themeda arundinacea* (5–7 m) or mixed sometimes with short grass species such as *I. cylindrica, Chrysopogon aciculatus, Eragrostis* spp. etc (Dinerstein and Price 1991; Dinerstein 2003). The short grasses usually occur at elevated area with relatively less moisture and are intensively grazed by the rhinos and other herbivores or sometime mixed within tall grasslands. KNP is losing its area due to river action every year particularly from the northern boundary, though the points of erosion changes with the change in the river course (Gilfellon et al., 2003). The gravity of the situation can be judged from the fact that the estimated area of the park in 1998 was only 40,790 ha against the notified area of 42,993 ha in 1974. Though sometimes the areas eroded earlier are restored by heavy silt depositions, but recent estimate indicates a loss of about 11.7% core area of the park due to erosion of Brahmaputra (Das et al., 2014). Thus, loss of area due to erosion is a part of ecosystem processes in the floodplains of Brahmaputra. To check this phenomenon, erosion control structures were erected along the bank-line. However, these structures are affecting the flow of excess water from the river into the floodplains (KNP) which in turn upsets the ecosystem functions that help in creating a variety of habitats suitable for different flora and fauna species and their assemblages. Hence, a better understanding of the flooding pattern and corresponding processes in ecological framework is required in order to take immediate steps for erosion control. The recent six additions to KNP which includes the river in the park northern boundary and river islands (Chapories) has helped in restoring lost habitats due to erosion to a great extent. Land cover change analysis during 1990 to 2009 indicates conversion of 0.38 % short grass area into 'beel' (Table 8.2).

**Table 8.2.** Land use- land cover statistics of Kaziranga National Park, Assam in different years.

| | 1990 | | 2009 | |
|---|---|---|---|---|
| **Land cover classes** | **Area (ha)** | **Percentage (%)** | **Area (ha)** | **Percentage (%)** |
| Short grassland | 7706.97 | 9.1 | 9313.09 | 11.0 |
| Tall grassland | 25529.03 | 30.3 | 20320.09 | 24.1 |
| River | 17993.52 | 21.3 | 11907.17 | 14.1 |
| Tropical deciduous forest | 3525.78 | 4.2 | 4104.32 | 4.9 |
| Tropical evergreen forest | 7899.83 | 9.4 | 11395.84 | 13.5 |
| Braided Bar | 18797.32 | 22.3 | 25066.63 | 29.7 |
| Wetland (beel) | 2895.67 | 3.4 | 2240.98 | 2.7 |
| **Total** | **84348.12** | **100** | **84348.12** | **100** |



The short grassland areas and 'beels' area are interchangeable to some extent i.e when water level recedes in the 'beels' short grassland area increases, whereas a reverse trend has been observed when water level increases during the floods (Kushwaha et al., 2000a, b). The conversion of tall grassland to short grassland area (3.6 %) and 'beel' (1.3 %) could be considered as a positive change since Rhinos and the other herbivores forage extensively on the short grassland areas. A 6.2% reduction in tall grassland areas due to expansion of forested areas has been observed indicating an overall decrease on grassland areas. Though, the conversion of tall grass to short grass (3.6 %) and 'beel' (1.3 %) could be considered as a positive change, but reduction in tall grasslands was because of the expansion of forested areas into grasslands. Further, conversion of tall grassland areas to tropical deciduous forest accounted for 0.9 % and tropical semi-evergreen forest for 1.2 % that has resulted in reduced grassland areas. Increase in the other forest classes has also been observed, i.e. tropical evergreen (4 %) and moist deciduous (0.7 %). In addition, invasion of *Mimosa diplotricha* and *M. invisa* in short and tall grassland areas has also reduced the grassland areas. However, this data slightly differ with that of Das et al., (2014), where these authors reported 50.6% area of the park under grassland, followed by 21.8% under forests and 7.7% area under short grasses.

## *Siltation*

The areas under river and 'beel' in KNP are declining from 21% and 3.4% in 1990 to 14% and 2.6% in 2009, respectively. Decreased in area under 'beels' are due to sedimentation and silt deposition and its conversion into short grassland (0.4%) and tall grassland (0.6%) areas (Medhi and Shaha 2014). Sedimentation along the riverbanks also adds nutrients to the ecosystem, which increases the net primary productivity (Khatri and Barua, 2011; Chitale et al., 2012).

## *Increasing pollution load*

Regular flooding and silt deposition replenishes the soil with nutrients and allows regeneration of hygrophilous species (Loeb et al., 2009; Manral et al., 2012). Increased silt deposition and nutrient addition in tall wet grasslands results in a mosaic of seral stages. However, high enrichment of cadmium (Cd) and chromium (Cr) along the road side soils of KNP and their accumulation in the biological system of the park needs attention. The origin of these heavy metals was observed from both geogenic and anthropogenic sources (Devi et al.,, 2015). The accumulation of other heavy metals such as iron (Fe) and nickel (Ni) was also observed maximum in the smooth bark surfaces of *Trema orientalis* and *Tectona grandis*, whereas the concentration of cobalt (Co) and copper (Cu), manganese (Mn) and Cr, lead (Pb) and Cd were observed high in bark surfaces of *Streblus asper, Mangifera indica* and *Lagerstroemia* spp.

## Biological Changes in Grasslands

### *Invasion of weeds*

One of the major threats besides poaching is infringement of invasive species in the grassland and wetland habitats. This reduces the availability of suitable forage species to meet the requirements of Rhino and other the mega herbivores. *Mimosa invisa, Chromolaena odorata, Mikania micrantha, Ipomoea carnea* and *Lantana camara* are some important alien species in Rhino habitats (Lakher et al., 2011). About 43% of KNP area is at varying degree of risk from of invasion by two species of *Mimosa* belonging to the family Mimosaceae, i.e. *M. diplotricha* and *M. invisa* (Vattakkavan et al., 2002; RFRI, 2011). Both species are straggling herbs seen climbing to the top of several meters high elephant grasses. The quick growing herb not only destroys the grasses, but it hampers the free movement of wild animals also. Mimosin, a harmful toxin present in this species are known to affect herbivore population particularly ruminants (Mathur et al., 2005). *Mimosa* invasion started in the grasslands of the Baguri Range (western range) of the park in the mid-1990s and later spread all over the park. This issue of invasive species particularly by Mimosa spp. was highlighted around 2001–02. The spread of *Mimosa* spp. is mostly through dispersal of seed which is facilitated by vehicular movements and annual flooding coupled with high soil moisture condition and favourable temperature for its growth and regeneration in the park (Lucia et al., 2004; Chauhan and Johnson 2008) which is indicated by its high regeneration status ranging between 270 and 780 individuals per sq meter (RFRI, 2011).

### *Grazing by domestic Livestock*

There is always an active interaction between KNP and the landscapes surrounding it for maintaining the flows of organisms, water, nutrients, and energy. Land use change occurring in surrounding areas of the park affects the dynamics of the park (DeFries et al., 2005). People also settle along with their cattle on the sandy areas bordering the park after the flood recedes leading to increased grazing pressure on the park resources. In general, communities living in and around the park are financially poor and rely on the local ecosystem for fuel wood, fodder, water, grazing and other ecosystem services. Highly variable resource use patterns as a function of caste/ethnic group, educational level, socioeconomic and immigration status of households, and location with respect to the park and wildlife corridors have



significant impact on conservation and management of the park (Srivastava 2007). There is an urgent need for regional-scale land use planning for the surrounding park areas and human-dominated landscapes to balance conservation goals with livelihood needs for fuelwood, fodder and other ecosystem services.

## Conservation Strategies

A century old effort in protection and *in-situ* conservation has made the grasslands flora and fauna of KNP to sustain in such a manner that one of the largest assemblages of flora and fauna can be seen here. The prominent among the mega-fauna are the Great Indian one horned. Rhinoceros (*Rhinoceros unicornis*), the Asiatic wild buffalo (*Bubalus bubalis*), the Asian elephant (*Elephas maximus*), the swamp deer (*Rucervus duvaucelii ranjitsinhi*) and the tiger (*Panthera tigris*). However, high variation in attitudes and awareness as a function of ethnic group, educational level, and socio-economic status, indicates the need for economic interventions within some communities. Further, the predicted land use/land cover (LULC) map of Kaziranga-Karbi Anglong corridor indicates an expansion of agricultural and plantation areas. An estimate indicates that only 25.66% of the present dense forest and 20.72% of open forest will remain by 2030, while areas under agriculture and plantation will increase by 33.91 and 5.33%, respectively (Sharma and Sarma, 2014). A highly localized development schemes and participatory approaches to resource management at the village level, coupled with greater efforts at education will be more appropriate to achieve conservation and development goals (Heinen et al., 2009).

## Grassland management

To understand the changes in land use practices, identifying the processes that led to degradation and factors governing the rehabilitation processes is essential. Maintaining a higher level of herbage mass by promoting highly adaptable and palatable grasses optimize plant biodiversity and enhance productivity (Wang et al., 2011). Annual burning is being practiced as a tool for habitat management for both upland and lowland grasslands for quite some time and through this management practice provides new forage to wild herbivores. The fire helps in the maintenance of grasslands by arresting succession from grassland to forests, increases productivity of grasses and provides high quality forage. The burning also enhances visibility facilitating anti-poaching surveillance to counter methods of poaching adopted by organized gangs of poachers (Vasu 2002). Because of probable change in grassland composition, a detailed study on tall and short grasslands and the impact of annual burning on the grassland habitats is required. Identifying the factors leading to the creation of short grasslands and evolving strategies to reduce the stocking of ungulate in some of the Ranges of the park is the required for increased efficiency. Preparation of high grounds should be done in such a way that they do not affect the drainage pattern and wetlands. Identifying some inviolate areas within the park where fire and other human interventions can be minimized and the effect of protection can be compared by periodic monitoring, restoration of water bodies, channels and the maintenance of the corridors will enhance efficient management of the park.

## Control of Mimosa invasion

High seed production rate and long seed viability, favourable environmental condition and efficient seed dispersal make the control measures of *Mimosa* spp. very difficult (Chauhan and Johnson, 2008; RFRI, 2011). Although fire is used as control measures to check the invasion, various studies (Triet et al., 2001; Byers et al., 2002; RFRI, 2011) have recommended complete eradication of *Mimosa* spp. from the park area. An effort has also been made by the park management to control the invasive species by way of uprooting, but this process is not continuous and follow-up action is also not adequate. *Mimosa* is present in most of the sectors of the Park which requires constant monitoring and practices to control them in varying extent and intensity. As has been shown by earlier control measures in the park, for complete eradication process, the plant could be completely uprooted rather than cutting from the base to achieve better result. October to early December (time of seed maturation) followed by May to June (regenerated seedlings at the ground) are the best eradication period, i.e. twice a year (RFRI, 2011).

## Management of Beels

For the wetland management, regular monitoring of these wetlands is necessary to sustain both flora and fauna of the park. There should be a desiltation process in planned and phased manner. Monitoring of the wetlands against pollution should also be carried out. To check the ecological linkages and integrity of the available wetlands in the protected area with Brahmaputra and continued sustainability of the wetlands, long termed or periodic monitoring is required.

## Recommendations

The Kaziranga landscape with its unique mosaic of wetlands (beels), grasslands (tall and short) and forests habitat characterize riverine and fluvial processes which represents a spectacular ongoing ecological and biological process due to periodic flooding in the evolution and development of the riverine flood plain ecosystems (UNESCO, 2003). The



landscape is amongst the last surviving floodplains ecosystems of large river systems in the world. The landscape offers one of the largest assemblages of mega herbivores such as one-horned rhinoceros, elephant, Asiatic wild buffalo, swamp deer, sambar etc. in the wild which contributes towards outstanding universal values of Kaziranga and the need to maintain the integrity of its rich biological heritage as world heritage site. Feeding guilds and variety of suitable habitats greatly depends on landscape linkages with adjoining Karbi Anglong hills that provides suitable habitats for elephants in their natural movement range. The barrier effect along the National Highway and disturbances in hills results in restriction in the movement of animals outside the park and increases grazing pressure of the grassland ecosystem. Increasing number of wild buffalos coupled with feral buffalo population is also reflecting visible changes in the tall grassland presence in many areas of the Park. Last decade has witnessed loss of many such areas in western range of the park where this phenomenon is very severe. Management of wild buffaloes based on carrying capacity determined by using their habitat use with respect to rhinos and elephants are urgently required to reduce further loss of juxtaposed tall and short grass combinations. Landscape connectivity with Karbi Anglong hills in the south and river Brahmaputra and its islands in north and connecting forest areas in other adjoining territorial divisions needs to be protected and maintained for long term survival of these mega herbivore assemblages.

Assessment and monitoring along with appropriate action are required for understanding of various processes e.g., rising levels of river bed and the wetlands because of sedimentation and organic matter load from invasion of water hyacinth. Detailed study on tall and short grasslands and impact of the present management interventions in the form of controlled annual burning is required for long-term management of habitat for its suitability for rhinos. This should include identifying the factors leading to the creation of short grasslands and evolving strategies to reduce the stocking of ungulate in some of the areas for increased efficiency. Also since short grasses such as *Hemarthria compressa* are preferred forage species for rhinos (Vasu, 2003), such grasslands especially surrounding the Shola beel in the eastern range need to be monitored and conserved. These grasses could also be promoted to reduce erosion along the banks. There is a need to design a technique aided by constant monitoring and investigation as part of a long term strategy. Concerted efforts are needed to control all invasive species and a better understanding of the causes of their spread to implement pre-emptive measures. Further, the cost and difficulty of eradication increases exponentially with each season of delay. Government agencies, institutions and individuals in rhino bearing areas lack adequate knowledge about the ecological and environmental consequences caused by invasive alien species and how to address it. Hence emphasis should be given to apprise policy makers, managers, conservationists, media and the academic community about this threat. Future microsite planning approach for conservation and development of the area should also consider the high ethnic diversity, high human population densities and grassland land-dependent large mammal populations.

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