Management of Forests in India for Biological Diversity and Forest Productivity

A New Perspective

WII-USDA Forest Service Collaborative Project

Grant No. FG-In-780 (In-FS-120)

Volume VI

Terai Conservation Area (TCA)

Harish Kumar
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भारतीय वन्यजीव संस्थान
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Project Overview

Background

The Wildlife Institute of India-U.S. Forest Service Collaborative Project entitled "Management of Forests for Biological Diversity and Forest Productivity – A New Perspective" was conceived in 1992 and formally approved by the Government of India in 1995. An Memorandum of Understanding was signed between the parties for this project under the Indo-US Scientific Collaboration on Science and Technology on November 24, 1995 with a sanctioned grant of Rs. 13,455,000 (USIF). The project evolved from the earlier collaboration of the US Forest Service (USFS) and the Wildlife Institute of India (WII) on a project in the Satpura Hills of Central India.

The project is first of its kind in India to address the primary mandate of forest managers in the country to sustain forest biodiversity. The National Forest Policy (NFP) of 1988 by recognizing the maintenance of biological diversity in forests as the principle mandate was materially different than the previous NFP passed in 1952. It is obvious that the traditional forest management approach had to undergo a major shift in emphasis and strategies. The shift in traditional training for budding foresters needed to be inseparable from changes that must happen in the field. Both were under review in India at the time of project initiation. This project was, thus, expected to play a significant role in demonstrating the integration of science and management in a planning process that establishes the complementary roles of protected areas and the large surrounding landscapes of managed forests in maintaining forest-based biological activity.

In view of the above, the principal aim of the project was to demonstrate an approach to achieving integration of concerns in India for biological diversity, forest based products, and their sustained flow in support of technological, economic and social benefits to urban and rural sector lifestyles. To accomplish this, the project set forth the following six objectives that addressed ecological assessment in "conservation areas" that included relatively undisturbed forest ecosystems, managed forests with current forestry interventions under a variety of harvest systems, and intervening matrix landscapes that support subsistence and related market based rural economies.

Project Objectives

- Assess, document, and map the kinds, extent and distribution of plant and animal diversity in selected "conservation areas" through rapid survey methods.
- Use existing status and habitat relationships information to set up baseline habitat relationships information system.
- From stand-to landscape-level perspectives, evaluate the impact of existing forestry practices and use of forest-based resources by local people, including methods of harvests and collection, fires, operation of varied concessions and rights on micro habitat elements, key habitats, species, communities, the overall forest productivity and diversity.
- Rapidly assess the social and economic systems of surrounding villages in terms of varied land use and forest resource dependency, including raising and grazing of domestic livestock, other vocations, skills, economy, and markets. These will be seen in relationship to forest systems. Threats to ecological harmony and economical status of people will be documented.
- Use modern ecological concepts to develop practical management tools and practices for bringing about harmony within and between forest and village systems through sustainable land use practices that make social and economic sense. Document problems and threat mitigation prescriptions, and develop site specific field guides to management.
- Conduct workshops and seminars to share experiences, disseminate knowledge, and begin the process of training scientists and managers.

Project Sites

The project was field based at four conservation areas (CA) that covered some 15,500 sq km of forested and nonforested matrix areas representing a variety of biogeographic patterns in wild plant and animal communities, forestry practices, ethnic human societies and their forest based cultures, economies and tradition, and the range of administrative realities. Each of the CAs included select Protected Areas (PAs) – National Parks or Wildlife Sanctuaries; Managed Forests (MFs), and the intervening matrix of other Government, community or private lands so as to constitute a larger delineated landscape. The four CAs were the Anaimalai Conservation Area (ACA) in south India; Garo Hills Conservation Area in the north east India (GCA); Satpura Conservation Area (SCA) in Central India; and Terai Conservation Area (TCA) in the foothills of Himalaya and on the India-Nepal border.

Project Partners

The Project engaged in early 1996 five field researchers with varied backgrounds in Forestry and Life Sciences. They were given orientation training, then posted at the chosen CA with full logistical support from field line personnel at established field stations and camps. In addition, a Co-Investigator (CI) among the participating WII faculty and a counterpart USFS scientist were assigned to each CA. Besides the scientists and managers from WII and the USFS, senior decision-makers from the respective forest departments supported the team of personnel to conduct the work envisaged under the project. Accordingly, the Principal Chief Conservator of Forests and Chief Wildlife Wardens of the five States (Tamil Nadu, Meghalaya, Madhya Pradesh, Maharashtra, and Uttar Pradesh) fully supported the project. Further, the collaborating Institution i.e. the Indira Gandhi National Forest Academy (IGNFA) identified and pledged the services of two senior faculty members for the cause of the project, each of whom has been a line forest officer prior to their assignment at the IGNFA. In all, nearly 40 people from the WII, USFS, collaborating institutes, and the state forest departments were involved in project.

Project Planning Workshop

A Planning Workshop for the project was conducted at WII, Dehra Dun on June 10-12, 1996. The workshop objectives were to increase understanding of the overall project and to gain the support of the key stakeholders. The individual CA descriptions and the critical issues to be addressed were written for each CA. A specific action plan was to be developed for each CA along with the programme of work to accomplish the identified tasks over the project period. Appropriate coordination structure, monitoring and evaluation efforts were identified. Mr. Tom Darden, Dr. Martin Prather and Mr. Elton Thomas representing the US Forest Service, Mr. G.K. Gupta and Mrs. Usha Kapur representing FERRO, New Delhi, participated in the workshop. The other participants included faculty from WII (17) and IGNFA (3), and managers from the field representing ACA (1), GCA (4), SCA (4) and TCA (1). The proceedings were prepared and provided to the participants and circulated to others separately. The Planning Workshop facilitated the development of a framework of actions during the project period and coordination mechanisms.

Project Approach

The work programme for the project was charted in the Planning Workshop, attended by representatives of all the partners in the project. It is worth mentioning that the wildlife science is of recent origin in India. There is excellent scientific information on plant and animal taxonomy but weak information on species-habitat relationships or species biology. There are no central databases, and retrieval of local information is not easy as automation in data bases is just beginning. One of the most important steps to be taken at the outset was to ascertain, collate, and review the kind and spread of information - maps, unpublished data, research publications, and working plans of agencies. Indents for maps and imageries were decided on the basis of what was available. The ACA, SCA, and TCA had the advantage of a few researchers having worked on some endangered vertebrates, plant communities, and human social systems. Except for GCA, the rest of the three sites had excellent documented forest management histories and current plans.

The project aimed at incorporating modern ecological concepts into a framework applied to CA-specific guides for managers that synthesized technical information and provided strategies for achieving synergy between ecology and forest based economies. Further, the project planned to incorporate project principles, guide books, and management strategies into a managerial training.

Field Work – The Data Realms

Broadly four data realms – ecological, socio-economic, management, and administrative (mechanism of programme delivery through multi-agencies) - were visualized as critical components for each of the project sites. Sampling strategies were challenging since the project dealt with large landscapes. Established techniques were used to investigate the components under each of the realm appropriately:

- The **ecological** realm considered the status and distribution patterns of plants and animals. Those under special focus included plant species of economic and cultural importance, animals that are culturally important, and those plants and animals that are endangered, threatened, endemic and rare. Elements under threat of illegal exploitation were integral to the foregoing. Besides the species, plant communities of conservation importance, sensitive and key sites and systems were included.

  Past and current forestry practices, including silvicultural systems and marking rules, were evaluated for their impact on forest composition and structure, including impacts on special and unique micro-habitats such as snags and logs. Fuel wood collection was integral. There was a much better understanding of silvicultural treatments and their broad impacts on vegetation dynamics than for the species, locations, ecology, productivity, sustainability, and harvest systems of non-timber forest produce. Medicinal plants were of special concern.

- The **socio-economic** realm investigated the relationships between the people and forest based resources. Local people were considered as key players in mitigation and sustainability. This realm has a fluid interface with the ecological data realm as people's interest and activities meld ecological and economic concerns. People's lifestyles and their influences both on the people themselves and on forest systems were also investigated through standard techniques *viz*., questionnaires, household surveys, rapid assessment and micro planning.

  Livestock rearing, grazing and the articulating influences, likewise fuel wood collection constitute very long-term pressures on the forests. Agricultural practices within enclave villages and among peripheral villages are directly related to the nature of pressures on the forests. For example, cropping pattern, crop-depredation by wild herbivores, livestock predation by wild carnivores, injuries and death of humans as a result of encounters with wild animals were major issues of study. Poaching is another activity that has complex linkages. Mining, quarrying, collection of sand, use of water from streams and water holes were also included as a part of the information base development.

- The **management** realm included understanding and interpreting the impacts of infrastructure development (e.g. roads, fire lines, water holes, hides, etc) and current management practices.

- The **administrative** realm of information includes all management processes for conservation or human development of the region, thus includes multiple agencies and their programmes. The programme targets and dimensions can be varied – from local rural interest through activities of national interest. Information was collected on objectives, mechanisms of delivery, and the outputs of these socio-economic programmes of the Government and private sectors especially evolved for the inhabitants of villages in the forest.

Project Accomplishments

Generating ecological and land use maps to fit the project objectives was a necessity for all sites. Each CA stratified the area based on significant forest/ vegetation/habitat types, and established a system of randomly placed transects to assess vegetation structure, composition, distribution, and frequencies of plants of conservation and economic importance. While tree and shrub communities were addressed in detail, the grass and herb communities were addressed in terms of key assemblages and sensitive sites, except in the TCA where tall riverine grasslands and upland dry grasslands constituted significant ecosystems.

Assessments were made on plots of varying sizes placed at regular intervals on the transects. Along with plants, distribution and abundance of larger vertebrates were recorded by indirect evidences with the plots and sightings along the transects. TCA also used a modified experimental design to assess grassland by testing established intervention practices of prescribed burning, harrowing, and grass cutting in different combinations across grass communities. GCA adopted a system of existing natural and man-made trails in an extremely challenging field situation.

Following were the major outputs:

- **Resource Maps** - The project has been able to generate resource maps for all the four sites using the remote sensing and GIS technologies. A spatial data base has been, thus, created for each CA incorporating different layers viz., drainage, administrative/management units, land use/land cover, vegetation, animal distribution, villages, and infrastructure.
- **Baseline Information** – The project has significantly contributed in providing a baseline information on the floral and faunal diversity, land use, historic development, socio-economic condition, wildlife – people conflict, etc. The project has also addressed different biotic pressure in each of the sites.
- **Wildlife Habitat Relationships (WHR)** – A large number of vertebrate species representing the four sites and those unique to each CA based on a species selection criteria were short-listed. The project provided a detailed description on each in each CA and in the overall WHR database.
- **Capacity Building** – The capacity building of the frontline staff was an integral component of the project. New training curricula in the training module for the Post-Graduate Diploma Course in Wildlife Management were formulated for the frontline staff of the forest departments, especially related to habitat assessment and habitat management. A new approach to planning integrated disparate management units (e.g., PAs, MFs, matrix) at hierarchical spatial scales ranging from the CA to the region. These approaches have also been appropriately incorporated in the continuing education courses for middle and senior level forest managers and planners. Changes are also brought about in the training module for wildlife management at the IGNFA. A new course is being developed for forest working plan officers that will be built upon the learning from the project. The chapters on assessment of biodiversity, wildlife and habitat management planning in the draft National Working Plan Code, 1999, were largely based on the learning emerging from this project.
- **Study Tour for the Indian Delegation** - A 13-member Indian delegation visited USA on a study tour from July 24, 1999 to August 7,1999. The delegation included five faculty members from the Institute and eight field managers representing the four project sites across five Indian States. The program was jointly prepared and coordinated by Mr. Tom L. Darden and Dr. Hal Salwasser of the USFS, with support by Dr. James R. Stevenson, US Foreign Agricultural Service. The group visited two important regions – the Southern Appalachian Region on the east coast and the Sierra Nevada Region in the State of California and Nevada on the west coast. Visits to different National Forests, wilderness areas and conservation areas were organized. The counterpart US scientists also joined the visiting group during their field visits to different areas and participated in the workshop and project review. In addition to the field visits to different demonstration areas, workshops were also organized at Asheville, NC and the Institute of Forest Genetics (IFG), Placerville, CA. Several resource persons from the USFS, US National Park Service, and the University of California, Davis were invited during the workshops/field visits to provide their technical inputs. The delegates also visited the Department of Forestry Science in University of California, Davis.

Making large-scale ecological assessments on hierarchical scales to address management were central to the study tour. The experience gained in the process was ploughed into the presentations and field demonstrations. The entire experience was extremely relevant to the emerging situation of planning in India and addressed the vital areas of training, research, monitoring, planning and management. Apart from the field visits, the visiting group was paced through different approaches to integrated forest management using the concept of large landscape/conservation areas. Emphasis was laid on different tools and methods for forest and wildlife inventories, habitat assessment, timber management, endangered species management, management of forest insects epidemics, wildlife habitat relationships, fires, recreations, visitor management, ecological monitoring and some significant research especially on the spotted owls in the Pacific Northwest. Several opportunities were also provided for cultural exchange. The visiting delegations also made presentations based on their field/research works on respective Indian sites and related the experience to the element of the study tour conducted.

- **Management Guide -** The project has ultimately provided a new way of thinking about managing for biodiversity at the landscape scale, by taking into account all types of lands, across multiple spatial scales for multiple wildlife species and resource management needs. The project has provided an insight for the conceptual framework, the scientific basis, specific procedures for analysis and operations, and evaluation of select demonstration areas, about how to integrate resource assessment and management for biodiversity at the landscape level.

- **Information Dissemination** – Right from the beginning the project has yielded a substantial information in the form of technical annual reports or specific compilations. The project has significantly contributed in developing a spatial database. The field managers have extensively used the information generated in the preparation/ revision of management plans or planning other strategies/proposals. It is evident in the first management plan written for the Dudwa Tiger Reserve (De, 2001) and proposal for the establishment of an Elephant Reserve in the State of Meghalaya. Three Ph.D. dissertations are expected from the project. Researchers of the project have been making research presentations during the Annual Research Seminar organized by the Institute wherein a large number of field managers, scientists, decision-makers participate. The project plans to provide an electronic version of the report for its wider use by the scientific community as well as the field practitioners.

Organization of the Report

The final products of the project include a six volume management guide. The volumes have been produced in collaboration and intense interactions among four full time researchers, the US team of scientists, participating WII faculty, field managers of four project field sites and representative faculty from collaborating institution – IGNFA.

The Volume I addresses the conceptual and scientific basis of the approach, and would be of use to any manager or researcher entrusted with such an approach anywhere. Volume II is on wildlife habitat relationships and includes a framework for how to evaluate multiple wildlife species simultaneously, and narrative summaries of life histories of 184 wildlife species selected to represent various criteria of rarity, endemism, management focus, habitat associations and others. Volumes III to VI are intensive case studies of four "Conservation Areas" selected across India to represent a great diversity of ecological conditions, CA histories, cultural situations, and management challenges.

Lessons Learned

The four conservation areas studied in this project differed markedly in ecological conditions, socio-economic situation, and management issues. Equally diverse were the arrays of key stressors on the native flora and fauna, and in the management opportunities for improving conditions for native plant and animal diversity and human communities. Many useful lessons have been learnt from the project, principally the need to think broadly across major landscape areas when managing for native species and communities. This includes the need to coordinate data, analyses and management across different land ownerships and allocations. Cumulative effects in buffer areas or zones of influence outside existing protected areas, or even along international borders, are also to be taken into account when developing site-specific management plans. Also, an integrated resource management approach at all spatial scales is seen as the best way to avoid conflicts in resource use and to plan for appropriate ways to conserve biodiversity in managed forests.

Specifically, following is a gist of overall guiding principles and lessons learned from this project :

- *Think* broadly across major landscape areas
- *Integrate* management plans across administrative boundaries and between forest and wildlife resource areas
- *Consider* cumulative effects of all activities
- *Think* in hierarchical spatial scales
- *Use* local knowledge and needs in the conservation strategy
- *Consider* a fuller array of flora and fauna
- *Consider* ecosystem and anthropogenic processes and the ecological roles of organisms

The study categorised stressors into five main groups: (1) stressors associated with resource consumption, (2) stressors associated with use of non-consumptive resource amenities, (3) stressors associated with transportation and habitation infrastructures, (4) stressors associated with effluents, and (5) stressors associated with other human activities having impact on the resources.

Specific management opportunities related to reducing or eliminating the occurrence and adverse effects of the various stressors listed above can be summarized across the four conservation areas are follows:

- Management opportunities and recommendations in managed forests
- Management opportunities and recommendations for identifying natural conditions and native biodiversity
- Management opportunities and recommendations in riparian areas
- Management opportunities and recommendations for roads and transportation systems
- Management opportunities and recommendations for tourism
- Management opportunities and recommendations for protecting rare and locally-distributed species and ecological communities
- Management opportunities and recommendations for conservation of wide-ranging species
- Management opportunities and recommendations on collection and poaching of species
- Management opportunities and recommendations on participation by local people
- Management opportunities and recommendations on research and monitoring

Further, basic ecological understanding also is necessary to modernise silvicultural systems by moving them from a focus simply on the production of wood and other human goods and services, to the production of both human and ecological goods and services by restoring or maintaining diversity and viable forest ecosystems. The transition from old to "new forestry" will be critical for integrating PAs and MFs to meet ecological goals described for conservation areas. The transition likely will require a period of adjustment of attitudes and experimentation with new methods, such as use of adaptive management approaches.

Chapter 1

Introduction

1.1 The Preamble – Conservation Challenges

The geographic areas that feature natural and cultural attributes considered by society to be of high material, cultural, historical, spiritual or ecosystem value have always been given special protection by the various government and communities (Miller, 1999). Such areas are being increasingly designated all over the world. Moreover, with impetus of the Convention on Biological Diversity (CBD) recent conservation policies, strategies and guidelines have emphasized the maintenance of healthy, productive and diverse ecosystems (Davey,1999; Marcot,1992; Salwasser, 1995). This is a necessity for the continued well being of human societies and to the land itself.

The word "Conservation" implies wise sustainable resource use. Whilst the conservation of biological diversity or biodiversity calls for maintaining the variety and variability of life and associated ecological processes. Maintaining biodiversity entails addressing resources at various biological levels *viz*., genetic, species, population, community, ecosystem and landscape. Every element of biological diversity has some economic and ecological value (Noss, 1990; Hunter, 1990 and 1999; Darden and Marcot, 1995; Naveh, 1995; Biodiversity Guidebook, 1995). In recent years, several new tools and approaches have been described for the conservation of biodiversity. Salwasser (2001) has provided strengths and weaknesses of single species, multiple species and ecosystem management approaches to conservation.

A network of biogeographically representative wildlife Protected Areas (PAs) has been recognized as a means of conservation (McNeely, 1994; Dudley *et al.*, 1999 Green and Paine, 1999). Following other countries, a large number of protected areas (PAs) comprising National Parks (NPs) and Wildlife Sanctuaries (WLS) has been established in India (Rodgers and Panwar, 1988; Rodgers *et al.*, 2000). Miller (1999) has described seven significant obstacles *viz*., initial criteria employed for selection of protected areas, size, shape, landscape linkages, organizational support, and inadequate capacity and investments faced by protected areas that limit their capacity to meet growing demands for their full array of benefits and values.

1.2 The Holistic Approach

Protected areas are becoming increasingly isolated as surrounding natural habitat is converted to human-dominated and incompatible land uses (McNeely, 1994; Schellas and Shaw, 1995). This process of reducing the size of previously larger ecosystems and habitats is threatening the biological integrity of ecosystems and the survival of some far-ranging or critical wildlife species. Because this wild land conversion is often in part a product of people seeking to meet their basic development and subsistence needs, efforts have shifted from a confrontational approach between protected areas and local people to an approach that seeks to meet both conservation and development needs. Protected areas therefore, need to be part of broader regional approaches to land management. The landscape or bioregional management approach has been used to describe extensive areas of land and water that include protected areas and surrounding lands, preferably complete watersheds (McNeely, 1994; Freezailah, 1995; Miller, 1999; Scott *et. al.*, 1999).

Integrated management of the whole landscape, including forests allocated for timber production, is now both a social and an ecological necessity. Wildlife protected areas must of course still be seen as the jewels in the crown of any nation's endowment of natural resources. However, with the degree of land use change and population pressure on most protected areas, other forest lands must also provide much of the substance in the crown. They must, therefore, be managed to provide both immediate sustenance and economic benefits for the dependent communities that live in and near the forests or other wild lands, and the broader range of environmental values and services essential for the future of human kind. Thus, the production or managed forests (MFs) must be managed as a vital complement to protected areas (PAs), so that extensive areas of natural and semi-natural forest are retained to secure as full a complement of biodiversity and options for future generations as is humanly possible. The role of intervening and adjoining private lands including agricultural areas is still important to maintain the quality of corridors or connecting links, and to minimize negative boundary effects, *e.g.* poaching and crop depredation.

1.3 The Major Project

The present study is a part of the major WII-USDA Forest Service collaborative project entitled "Management of Forests in India for Biological Diversity and Forest Productivity – a New Perspective". The principal aim of the project was to demonstrate an approach to achieving integration of concerns in India for biological diversity, forest based products and their sustained flow in support of technological, economic and social benefits to urban and rural sector lifestyles. The project was field based and addressed four sites on distinct geographical locations. Each of the sites included select Protected Areas (PAs – National Park, Wildlife Sanctuary; Managed Forests (MFs); and other government, community or private intervening lands so as to constitute a larger delineated landscape. Each of the sites was designated as a 'Conservation Area (CA)'. The present study specifically deals with the *Terai* Conservation Area (TCA), one of the four sites.

1.4 *Terai* Conservation Area – A Fragile and Diverse Landscape

The *Terai* ecosystem, which the TCA represents, is one of the most threatened ecosystems of India. The region is a vast flat alluvial plain lying between the Himalayan foothills and the Gangetic Plains. It extends through Uttaranchal, northern Uttar Pradesh and Bihar, northwestern Bengal, Assam, and southern Nepal. It forms an integral part of the *Terai*-Bhabhar biogeographic sub-division of the Upper Gangetic biotic province and the Gangetic Plains biogeographic zone (Rodgers and Panwar, 1988).

Once, the *Terai* forests constituted a lush belt of green vegetation in the extensive tract of alluvial Gangetic floodplains. The forest is mainly moist deciduous, dominated by the most valuable Sal (*Shorea robusta*) forests of India. A significant attribute of the sal forest ecosystem is the interspersed swamps, wet tall grasslands, and dry grasslands or 'phanta' variously dominated by *Saccharum spontaneum*, *Saccharum narenga*, *Sclerostachya fusca*, *Imperata cylindrica,* or *Vetiveria zizaniodes.* The high water table, annual flooding and the synergistic influence of traditionally practiced annual burning of grasslands are primary factors defining the characteristics of this tract. The resulting complex woodland - grassland - wetland ecosystem harbours a variety of floral and faunal life, including several charismatic, and obligate species *viz.*, tiger (*Panthera tigris tigris*), great one-horned rhinoceros *(Rhinoceros unicornis*), swamp deer (*Cervus duvauceli duvauceli*), Bengal florican (*Hubaropsis bengalensis*) and hispid hare (*Caprolagus hispidus*). The diversity and biomass of large herbivores in intact *Terai* ecosystem alone equals or exceeds many of the famous wildlife areas of East Africa (Lehmkuhl, 1994). Unfortunately, very little of this productive ecosystem remains intact.

The TCA is the last and best remnant of the *Terai* ecosystem remaining in north India outside Nepal and Assam. De (2001) has described the global to local significance of the protected areas within the TCA, and potentially the nearby managed forests under the landscape management strategy. Global and national values include the conservation of representative biodiversity and endangered species such as the tiger, one-horned rhinoceros, swamp deer, Bengal florican, hispid hare, and swamp partridge. Regional and state significance includes the conservation of the *Terai* forest and grassland ecosystems, watershed and water conservation, endemic tribal peoples ('Tharu'), and ecotourism. Local values include wildlife conservation, ecotourism and related economic activities, non-wood and small timber products for local use, and socio-cultural-religious values.

1.5 Historical Background

Very little information of the history of TCA forests prior to 1861 is known, except that they were under the control of the Raja Khairigarh for hunting reserves and commercial uses (Leete, 1902). Most forests came under government control in 1861 and a Superintendent of Forests, subsequently known as the Conservator of Forests, was appointed for their management. Some forests remained under the private control of local 'Zamindars'. The reserved forests were divided into the North Kheri Forest Division (NKFD) and the South Kheri Forest Division (SKFD) on respective sides of the Sharda River. Scientific management started in 1886 with the development of the first Forest Working Plan. A succession of Working Plans has guided forest management up to the present time (Srivastava, 1993; Srivastava, 2000; and De, 2001). Until 1968 and the establishment of the Dudwa Wildlife Sanctuary, later Dudwa National Park in 1977, all reserved forests in the region were managed for the commercial production of wood products and for the subsistence needs of the local people. Wildlife was considered important, but secondary to the production of wood and forage.

The balance of forest and agricultural lands largely remained stable until the post-independence period after 1947 when large numbers of people were resettled from Pakistan and provided with private forest, grasslands and wetlands to clear or drain. Remaining private forests in the area were reserved after the abolition of the zamindari system in 1952, and agricultural land held by the zamindars was distributed to landless people. Since that time population has increased steadily, 32% during the 1991-2001 period alone (Banthia, 2001), as has the associated subsistence pressures on forest and grassland resources.

Increasing human pressure on natural systems and increased national conservation emphasis on the precious wildlife resources of the area resulted in steps to preserve important wildlife and their habitats. In 1958, the relatively small (16 sq km) Sonaripur Wildlife Sanctuary was established with the aim of protecting a relict population of the swamp deer (*Cervus duvauceli duvauceli)*. The area was increased in 1968 and named Dudwa Wildlife Sanctuary. In 1977 more areas of the NKFD were added to the Sanctuary and the enlarged area was declared Dudwa National Park (DNP) with both core and buffer zones designated. Additional managed forests of the NKFD were added to the buffer zone of DNP in 1991. To further protect swamp deer, part of the SKFD was declared as the Kishanpur Wildlife Sanctuary (KWLS) in 1981. In 1987, DNP and KWLS were brought together under the 'Project Tiger' as Dudwa Tiger Reserve (DTR) under the management of a Field Director. Management of KWLS was transferred to the Field Director of DTR in 1989. The remaining managed forest areas of NKFD and the SKFD are managed separately as regular reserved forests.

1.6 Information Review

Primarily the information on the *Terai* Conservation Area (TCA) comes in the form of various official documents of the Forest Department. These include Forest Working Plans (North Kheri Forest Division – Kakkar, 1964; Chandra, 1973; Gaur, 1982; Srivastava, 1993 and South Kheri Forest Divison - Chandra, 1972; Rizvi, 1980; Pant, 1990; Srivastava, 2000); and Wildlife Management Plan for Dudwa National Park and Dudwa Tiger Reserve (Singh, 1982; De, 2001). These documents provide information mainly on the type and extent of forests, taxonomic checklists (predominantly plants, birds and mammals), past forest management – silvicultural practices, and socio-economic profiles. Singh (1997) has listed 821 species of angiosperms in the flora of Dudwa National Park. It was only during 1980s that the TCA attracted attention of researchers and since then several researches on selected featured faunal species have been undertaken. Prominent among them are: the ecology of swamp deer (Singh, 1984; Qureshi *et al.*, 1991); rhino habitat and monitoring of reintroduced rhinos (Hajra and Shukla, 1983; Sale and Singh,1987; Sinha and Sawarkar,1991); ecology of Bengal florican (Rahmani *et al.*,1990; Sankaran and Rahmani, 1991); study on bird diversity (Javed, 1996); and ecology of Black necked stork (Maheshwaran, 1998). Singh (1985) provided area statistics under different vegetation types based on Landsat – 3 satellite data of November, 1981. Obviously, the focus of these studies was mainly on the biology and ecology of species of concern. Thus, till date the baseline information on the structure, composition and dynamics of forests, grasslands and swamps in a rapidly changing landscape of TCA remained unattended. Likewise, detailed studies on grassland diversity, succession and effect of burning, harvesting and grazing have also lacked.

1.7 The Aim

Keeping in view the above background, following basic questions were posed while formulating the present study in TCA:

? What is the existing knowledge about the plant and animal diversity in TCA, their habitat associations and the status, trends and spatial distribution of habitats and species of particular interest?

? What are the current patterns of spatial heterogeneity at the landscape level? What are the factors (natural, biotic, and of management) responsible for such mosaic and diversity patterns?

? How the spatial mosaic has influenced the distribution of different vegetation communities, species diversity and abundance of species of concern?

? What are the species-specific positive, neutral or negative associations and factors responsible for them? What are the patterns of recruitment, growth and mortality of species of concern?

? How does the burning practices influence grassland diversity, productivity and wild ungulate use?

In a nutshell, the present study aimed to focus on the landscape spatial patterns, their influence on species diversity and also the effect of various grassland burning practices in the *Terai* Conservation area.

1.8 The Objectives

In order to achieve the above aim, the following objectives were set forth for the present study:

? To assess, characterize and map the current landuse and landscape patterns.

? To identify, classify and describe vegetation communities, assess their extent and geographic distribution in the landscape.

? To assess the influence of landscape spatial patterns on habitat and species of particular management interest.

? To assess grassland burning practices *vis-à-vis* plant diversity, productivity, ungulate use and make appropriate recommendations for the management.

1.9 Study Area – Location and Size

The TCA lies in four districts *viz.*, Lakhimpur Kheri, Pilibhit, Shahjahanpur and Bhairach of the State of

Uttar Pradesh and is situated between Latitude N $27^0 49'$ and $28^0 43'$ and Longitude E $81^0 01'$ and $81^0 18'$. The TCA constitutes a spatial heterogeneous landscape of PAs, including Dudwa National Park (DNP) and Kishanpur Wildlife Sanctuary (KWLS), and managed forests (MFs) of North Kheri and South Kheri Forest Divisions within a matrix of private agricultural lands. The major portion of the TCA (~97%) comes under Lakhimpur Kheri (**Fig.1.1**). Dudwa National Park is situated in Nighasan tehsil, Kishanpur Wildlife Sanctuary in Gola tehsil, North Kheri Forest Division in Nighasan and Dhauraha tehsils and South Kheri Forest Division in Gola, Mohamadi and Lakhimpur tehsils. The Indo-Nepal border forms much of the northern border of the TCA, particularly the DNP.

Forest, grassland and wetland areas within PAs and MFs in the TCA encompass 1726.5 sq km, which is equally spilt between PAs (883.7 sq km) and MFs (842.8 sq km) categories. The area of DNP is 490.3 sq km with an adjoining 190 sq km of reserved forests as a designated buffer zone. Revenue agricultural areas ('*Tharu*' villages) of 180 sq km are enclosed within the TCA boundaries. The area of KWLS is 203.4 sq km. The area of NKFD and SKFD are 427.9 sq km and 414.9 sq km, respectively. The landscape assessment area (TCA) including protected areas, managed forests and the agricultural matrix covered 7,896.6 sq km area (**Table 1.1).**

The TCA forests in DNP, KWLS, NKFD and SKFD are under different management objectives and also different administration. DNP and KWLS constituted the Dudwa Tiger Reserve.

1.10 TCA - Physiographic Conditions

1.10.1 Topography

The TCA is on the flat alluvial flood plains of the Suheli, Mohana and Sharda rivers. The general aspect is north-west to south-east. The altitude ranges from 182 m a.m.s.l. in the north to 150 m a.m.s.l. in the south-east. The altitude at Dudwa is 163 m, 183 m at Gauriphanta and 143 m at Mailani.

Table 1.1 - Area Statistics for the *Terai* Conservation Area

Sl.No.	Category	Area (sq km)
A.	***Terai* Conservation Area**	
A.1	**Protected Areas (PAs)**	
	(a)Dudwa National Park (DNP) - Core	490.3
	(b) Buffer Area of National Park	190.0
	(c) Kishanpur Wildlife Sanctuary (KWLS)	203.4
	Sub-Total of Protected Areas	883.7
A.2	**Managed Forests (MFs)**	
	(a) North Kheri Forest Division (NKFD)	427.9
	(b) South Kheri Forest Division(SKFD)	414.9
	Sub-Total of Managed Forests	842.8
A.3	**Total Extent of Forestland in *Terai* Conservation Area (TCA)**	**1,726.5**
B	**Agriculture Area**	**6,170.1**
C	**Total Landscape Assessment Area**	**7,896.6**

1.10.2 Soils

The soils of TCA forests are a recent alluvial formation (Singh, 1965) of the Gangetic Plains. A soil profile showed a succession of sand and loam beds, varying in depth according to the configuration of the ground.

The surface soil is sandy, in more elevated portions and along the high banks of the river to loamy in the level uplands, and clayey in depressions. There is no boulder formation as in Bhabar sal tracts.

1.10.3 River and Water Bodies

Relevance of water in TCA is reflected in the fact that some 20 rivers and numerous streams flow through the PAs alone. The TCA itself is drained by the Sharda and Ghaghra rivers and their tributaries *viz.*, Mohana, Suheli, Ull, Barrachha and Katna rivers.

The Mohana river runs along the north-east boundary, the Ghaghra river along the eastern boundary, and the Gomti river along the southern boundary of the assessment area. The Mohana and Suheli rivers form the natural boundaries of Dudwa National Park, and the Sharda river forms the natural boundary of the North Kheri Forest Division on south, the northern boundary in case of South Kheri Forest Division and the Kishanpur Wildlife Sanctuary.

Flooding rivers inundate large areas of Lowland grasslands for 3-4 months during the monsoon. Flooding rivers and meandering channels have considerable influence on the spatial pattern of the landscape, particularly grasslands and riverine forests. Erosion and accretion elsewhere are inherent dynamic process of the *Terai* ecosystem. Flood waters carry considerable amounts of silt, which is deposited in floodplain grasslands and forests. Shifting of river channels over time has left behind many old channels where numerous seasonal and perennial swamps ('*tals*') or wetlands occur. Some 67 of these *tals* occur in the two PAs (De, 2001).

Prominent perennial *tals* or swamps *viz.*, Khajua, Chhapra, Mutna, Bankey, Bhandara, Kakraha, Amoha, Chhedia, Puraina, Nagra, Bhadi, Churaila, Ludaria, Ranvas, Bhadraula, Teria, Madha, Chaluta and Jhadi widely intersperse in the TCA. Joraha, Nagrol, Nakua and Newra '*nalahs*' (streams) in the DNP and Barachha in Kishanpur Sanctuary and SKFD are the prominent streams in the TCA. These swamps ('*tals*') and streams significantly contribute in making the diverse habitats and they are more or less throughout the TCA. In addition to these perennial swamps, there are many low-lying areas or depressions those retain rain water for some time after monsoon season and provide drinking water to wild animals. Despite the entire area is traditionally water rich by way of interspersed rivers, streams and swamps, several areas face water deficiency in summer season. This deficiency can be mainly attributed due to the enhanced levels of siltation, exploitation of ground water for irrigation of adjoining crop fields and reclamation of swamps in recent decades. In order to overcome this seasonal deficiency, the Forest Department has created a large number of artificial water holes to supplement water supply to wild animals. Supply of drinking water is mainly from tube-wells. Some of the seasonal *tals* or artificial water holes are also being filled through some of the bore wells.

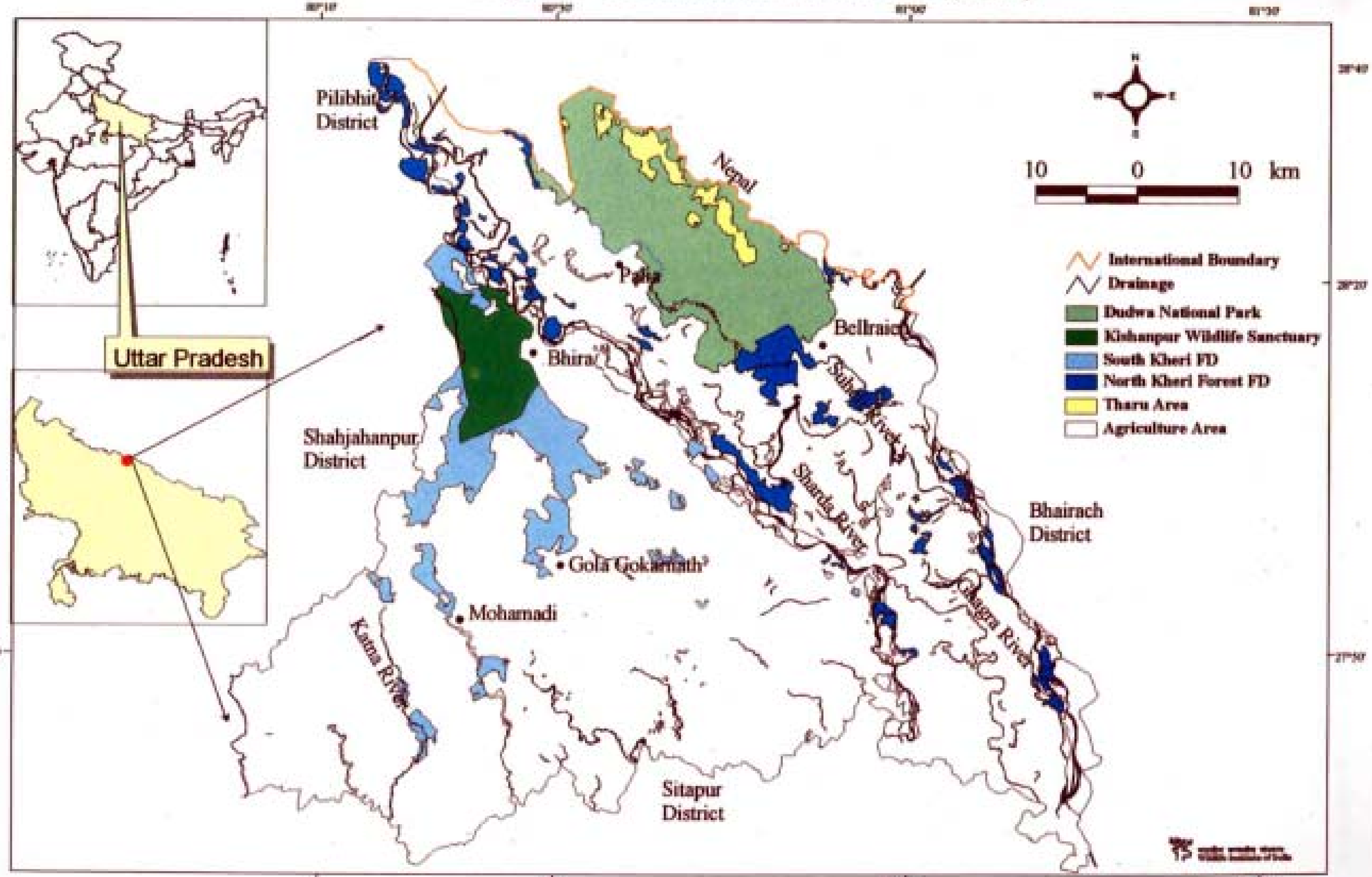
1.10.4 Climate

The climate of the conservation area is a tropical monsoon type. The TCA experiences three distinct seasons: winter (mid October to mid March), summer (mid March to mid June) and monsoon (mid June to mid October). Consultations of old Forest Working Plans for NKFD and SKFD revealed that the climatic data in terms of maximum and minimum temperatures and rainfall used to be collected at atleast 8-10 different meteorological stations located in various forest ranges. The oldest available climatic data dates back to 1936. In addition to this, climatic data in TCA is also being collected by the Revenue Department, Irrigation Department and the M/s Bajaj Hindustan Sugar Mills Limited (BHSML) at select locations. The Forest Working Plans for the period between 1930s and 1970s have incorporated month-wise and year-wise data on those two climatic variables and a trend can be ascertained. The earliest available data on relative humidity is available for the year 1979, collected at the Gola Gokarnath by the M/s BHSML. Recent forest working and wildlife management plans (Pant, 1990; Srivastava, 1993, Srivastava, 2000; De, 2001) also revealed that unfortunately no systematic data on climatic variables is now being collected in different forest range locations and therefore, they have mainly relied on the climatic data obtained from the M/s BHSML for Gola, Mohamdi and Palia stations. The following section provides a gist of recorded values and observed trends relevant to the climatic patterns in TCA.

1.10.4.1 Climatic Pattern

The TCA experiences extremes of temperature and humidity during different seasons. Nights during winter are cold and foggy. Usually fog sets in evening hours after sun set and persists until about middle of the next day. There is heavy dew fall during winter months and the vegetation remains damp. Frosts occur frequently during December to middle of

Fig. 1.1 - Terai Conservation Area (TCA)



February. These are attributed to the general cooling effects of the cold winds that flow down the Sharda valley and are most severe in open grasslands (‘phantas’). **Table 1.2** presents values of mean maximum and minimum temperatures for each decadal period starting from 1959 in the case of Gola Gokarnath station. The month of January is the coldest with mean maximum temperature of 19.6^0C and mean minimum temperature of 8.8^0C. The months of May and June are hottest with the mean maximum temperature rising upto 42.7^0C. The high temperatures during the day time are associated with hot westerly winds. Hot winds blow strongly from the middle of April upto the end of May. These are gradually replaced by easterly winds, which are prevalent during the rainy season. The nights are moderately cool until the beginning of May.

Usually, the onset of monsoon is by the end of June or early July. The monsoon is active during July-August and starts withdrawing by the middle of September. The annual rainfall data for Gola Gokarnath for the past 40 years (1959-1998) was examined and it provided an average annual rainfall value of 1,349 mm. Out of 40-year period, only three years (1965, 1987 and 1989) received less than 50% of the average annual rainfall. The lowest annual rainfall (497 mm) was recorded in 1965 while the highest annual rainfall (1,970 mm) was recorded in the year 1971 (**Fig. 1.2**).

Heavy rain, as much as 254 mm in one day alone was recorded on 20 August, 1963 at Gola. The **Table 1.3** compares values of mean annual rainfall for four decades (1959-1998) for Gola and Mohamdi stations. All values in the case of Mohamdi were relatively lower than Gola.

Nearly 85-90% of the total rainfall is received in four monsoon months (June-September). Usually November and December are the driest months. Small quantity of winter rains are also recorded. The

Table 1.2 - Monthly Values of Mean Maximum and Minimum Temperatures for Gola Gokarnath Over Four Decades

		Temperature °C			
Months		1959-68	1969-78	1979-88	1989-98
Jan	Max.	21.7	23.1	20.9	19.6
	Min.	12.6	8.8	10.2	8.4
Feb	Max.	26.0	28.8	24.1	23.3
	Min.	12.6	9.6	11.6	10.7
Mar	Max.	31.5	35.6	29.8	28.7
	Min.	17.5	13.7	16.8	15.8
Apr	Max.	37.9	41.0	36.5	35.7
	Min.	25.5	20.1	23.3	19.5
May	Max.	40.3	42.7	37.8	40.7
	Min.	26.7	22.7	26.1	23.5
Jun	Max.	38.0	41.9	37.3	38.6
	Min.	27.9	21.2	27.8	27.2
Jul	Max.	34.0	37.2	34.1	33.8
	Min.	26.9	24.4	26.6	22.6
Aug	Max.	33.4	36.6	34.6	34.6
	Min.	26.3	24.0	26.7	26.4
Sep	Max.	33.9	35.4	34.1	34.6
	Min.	25.4	23.3	25.6	24.9
Oct	Max.	32.0	34.8	32.2	32.7
	Min.	21.1	19.4	21.7	21.0
Nov	Max.	27.3	30.3	27.9	28.1
	Min.	14.8	13.0	16.0	16.6
Dec	Max.	22.7	24.7	22.5	22.7
	Min.	10.4	9.0	10.9	10.5

Fig.1.2 - Average Annual Rainfall (mm) for Gola Gokarnath Station for the period 1959-1998

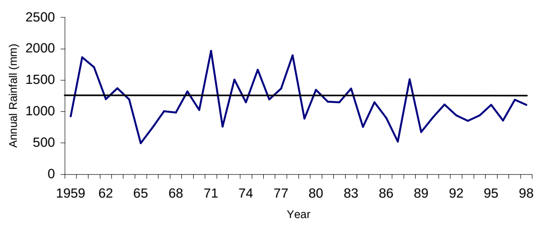


Table 1.3 - Mean Annual Rainfall (mm) for Gola and Mohamdi Stations Over Four Decades

Period	Gola Gokarnath	Mohamdi
1959-68	1,151	861
1969-78	1,386	1,096
1979-88	1,076	813
1989-98	975	952

entire landscape is very humid throughout the year. Values of relative humidity (%) for Gola and Palia stations for the year 1998 are also presented in **Table 1.4**. In general, higher values of relative humidity were recorded in the case of Palia, north of Sharda river while lower values were recorded for Gola, south of Sharda. Highest values of relative humidity were recorded in the month of August while lower values of relative humidity were recorded in summer months.

1.10 Organization of the Report

This report contains seven Chapters. The Chapter 1 deals with the general introduction highlighting the concerns for biodiversity conservation along with multiple forestry objectives, the major research project, the aim, the objectives and also describes the study area. The Chapter 2 describes the landscape perspective and spatial heterogeneity in TCA. The Chapter 3 presents an assessment on the plant diversity in different vegetation types, constituent areas, regeneration status of species of concern and a comparison of PAs and MFs. The Chapter 4 highlights habitat use pattern by featured faunal species of TCA and their conservation concerns. The Chapter 5 deals with an experimental trial on grassland burning practices and their effect on grass production and ungulate use. The Chapters 2 to 5 also incorporate corresponding details of methodology used to achieve the objectives of relevant theme presented in the respective Chapter. The Chapter 6 describes the social and economic situation in TCA. The Chapter 7 discusses the present study adopting a holistic approach to evaluate the conservation implication *vis-à-vis* the key stressors and the current socio-economic conditions in TCA. This Chapter concludes the study by presenting specific future management needs. The Chapter 7 is followed by a list of references.

Table 1.4 - Values of Monthly Average Rainfall (mm) and Relative Humidity (%)

Month	Monthly Average Rainfall (1989-98)		Relative Humidity(%) 1998	
	Gola Gokarnath	Mohamdi	Gola Gokarnath	Palia
Jan	15.0	17.2	74.3	92.0
Feb	26.0	26.4	65.7	92.9
Mar	11.4	9.6	67.5	90.6
Apr	8.0	6.5	57.2	75.8
May	19.5	20.1	50.0	88.0
Jun	89.5	87.1	53.2	69.0
Jul	282.2	289.9	77.0	90.6
Aug	314.4	296.4	78.8	94.5
Sep	150.0	154.8	68.2	90.2
Oct	33.1	29.0	62.1	87.1
Nov	5.7	4.2	54.7	90.6
Dec	13.5	9.9	49.8	89.1

Chapter 2

The Landscape and Forest Spatial Heterogeneity

2.1 The Landscape Perspective and Spatial Heterogeneity

A landscape is a heterogeneous land area composed of a cluster of interacting stands (patches) or ecosystems that are repeated in similar form throughout (Forman and Godran, 1986). Landscapes reflect the totality of physical, ecological and geographical entities, integrating all natural and human induced patterns and processes (Naveh, 1987). Landscapes are not merely structurally unique in composition, function and spatial pattern. They are also dynamic.

Heterogeneity is an inherent character of every landscape. Heterogeneity may be defined as the uneven, non-random distribution of objects (Forman, 1995), and the analysis of this pattern is of fundamental importance to understanding most ecological processes and the functioning of complicated systems such as landscapes. Heterogeneity and diversity are two related concepts, whereas diversity describes the different quantities of the patches, heterogeneity represents the spatial complexity of the mosaic (Farina, 1998).

Three different types of heterogeneity according to spatial, temporal and functional components have been described. The spatial heterogeneity can be defined as the complexity and the variability of a system in space (Li and Reynolds, 1994). This may be seen as a static or dynamic pattern (Kolasa and Rollo, 1991). Temporal heterogeneity has a meaning similar to spatial heterogeneity, but is measured as a variation at one point in space for different times. Functional heterogeneity is the heterogeneity of ecological entities (distribution of individuals, populations, species and communities).

Forest landscapes are rich in spatial heterogeneity from a variety of causes, including the environment, biotic interactions and disturbance and succession. Spatial patterns can have a strong influence on population dynamics and ecosystem processes including the spread of disturbance. Human activities have had a profound effect on forest structure and pattern. In managed forest landscapes, logging patterns often result in reduction in patch sizes and increase in edge (Spies and Turner, 1999). The structure and composition of landscape, as well as changes in them, influence the distribution, abundance and dynamics of different species (Morris, 1987; Weins, 1986; Andern *et al.,* 1997; Tomar, 1998).

Dunning *et al.* (1992) have described a landscape framework for understanding how species are distributed across a complex mosaic of habitat patches or the ecological processes that operate at the landscape level. The composition of habitat types in landscape and the spatial pattern of these habitats are two essential features that are required to describe any landscape. As such, these two features (composition and pattern) affect the following four ecological processes that can influence population dynamics and community structure:

- **Landscape Complementation:** Landscape complementation occurs when two required patch type occur in close proximity within a landscape and then support a larger population than do landscapes in which these habitats are far apart;
- **Landscape Supplementation:** Landscape supplementation means that the population in a small focal patch may be increased if the patch is located in a portion of the landscape that contains similar patches in proximity for additional resource requirement;
- **Source/Sink Relationships:** The source/sink relationships occur when the relatively productive patches serve as source of emigrants, which disperse to less productive "sink" patches; and
- **Neighbourhood Effect:** The neighbourhood effect illustrates ability of an organism to use the resources in adjacent patches depending

upon the nature of boundaries between the patches and to some degree, the shape and size of focal patch itself.

Understanding the dynamics and heterogeneity of natural forest landscapes has thus become very important as management objectives for forests increasingly emphasize the maintenance of biological diversity. Using natural or semi-natural ecosystems as a template for management is quite challenging, require understanding not only of the patterns of forest change, but also the processes that underlie them (Spies and Turner, 1999). Forest fragmentation is one of the most severe processes to reduce biodiversity.

2.2 Forest Fragmentation

The decline of forests is a global concern due to the pace and magnitude of its conversion to other uses. Several studies have focused on the fragmentation process as a central issue in landscape ecology and conservation planning (Wilcove *et al.,* 1986; Saunders *et al.,* 1991; Thomas *et al.,* 1997; Wiekham *et al.,* 2000). Most ecological studies of forest fragmentation have been undertaken from the perspective of the impact of habitat loss and isolation on specific taxa, whereas a fewer studies address the human factors that contribute to forest fragmentation.

The negative influence of fragmentation has been well documented on several species of plants and animals, and on ecological processes (Andren, 1994). Fragmentation takes account of both the loss and geographical isolation of habitat and associated populations. After extinction from an isolated patch the probability of recolonization strongly depends on the distance of fragments from the main core, where animals persist, and on the quality of the surrounding habitat. Edge sensitive species (interior species) can decline in abundance as habitat is broken up into small pieces with relatively more edge than in large intact patches. Large or wide-ranging species that require correspondingly large or well connected areas, such as large predators disappear with potential outbreaks of species such as deer, which in turn impact forage plants and other animals that depend on them. Such cascading effects key starting point for further environmental degradation and disturbance (Farina, 1998).

The increase in forest fragmentation as a general trend in natural habitats has created small and isolated habitats/fragments or patches containing fewer species then surrounding woodlands. The reduction of species has been attributed to the high rate of extinction in small patches. In that case, the persistence of populations in a heterogeneous environment can be ensured only by emigration and immigration. The risk of local extinction and the probability of recolonization mainly depend on the ability to maintain local populations or exchange of individuals. The success of colonization depends on many factors, such as the capacity to disperse. These populations are generally considered as components of a metapopulation with sub-populations that are connected by movement (immigration – emigration of individuals) or a population of populations (Levins, 1970; Gilpin and Hanski, 1991). Fragmentation is often interpreted by the general framework of the island biogeography theory (MacArthur and Wilson, 1967). The metapopulation concept is strongly related to island biogeography, considering both colonization and extinction as fundamental processes.

Factors, *viz.,* corridors, connectivity, presence of ecotones and the metapopulation structure are considered important when fragmentation is studied at a landscape scale. Fragmentation appears as a continuum process, and according to a landscape perspective, matrix and patches are the elements that have to be used when considering a landscape, fragmented or not. Fragmentation is perceived in different ways by different species, and even for the same species it may be different according to the season.

2.3 Landscape Characterization

Conservation strategies can be evolved using target species, populations and communities at patch, landscape and regional scales. Farina (1998) has described five common requirements for individual species *viz.,* (a) size of habitat patch (grain size); (b) homogeneity of patches (grain evenness); (c) distribution of habitat patches (grain dispersion); (d) matrix surrounding patches; and (e) connectivity between patches. The grain size of patches is species specific. Different species have different sensitivities to five common requirements/characters. The conservation programmes in agricultural landscapes are challenging and increasing with the heavy impact of technology in recent decades. The aim is to maintain or restore biodiversity by reversing the effects of habitat fragmentation, *viz.,* increasing habitat areas and connectivity of fragmented sub-populations. Conservation in disturbed landscapes in which the mosaic heterogeneity has been depressed by human activity may require a new disturbance regime. Prescribed fire is one of the most used management tools to ensure heterogeneity in wet tall grasslands (Rodgers, 1986; Deb Roy, 1986; Lehmkuhl, 1989; Bell and Oliver, 1992; Peet, 1997). Although fire is relatively inexpensive tool this practice can be difficult to handle when the managed areas are of limited size and creation of a mosaic is unrealistic.

Fahrig and Merriam (1994) and Farina (1998) have described the following three elements of landscape spatial structure:

(i) **Patch characteristics (size, shape and quality)** – Larger patches have a higher persistence of a population. The edge effect and the predator ratio can be influenced by the patch size and shape. The size of a patch *per se* is not enough to characterize the degree of persistence of local populations, because two patches of the same size but with different edge amounts and shapes can support populations differently. Patch quality is also equally important e.g. the presence of old and soft wood trees can increase the persistence of cavity nesting birds.

(ii) **Spatial Configuration** – The spatial arrangement of patches in a landscape is extremely important. The position of habitat patches in a hostile matrix seems more important than the dispersal routes. It is also important to understand the landscape dynamics or the rate of spatial change. Landscapes that are prone to abrupt and rapid changes will greatly influence the populations.

(iii) **Proximity and Corridors** – The distance of a patch or a group of patches from others is an important variable in mosaic analysis. The presence of connectivity or corridors linking patches or different local populations is also an essential component.

2.4 TCA – A Featured Landscape

The diverse and productive *Terai* ecosystem witnessed a massive change during the country's post independence era as a result of abrupt changes in landuse policy, settlement of refugees, uncontrolled expansion of agriculture and the associated large-scale reclamation/conversion of grassland and swamp habitats, heavy deforestation, enhanced resource dependence and factors like fire, livestock grazing and flash floods. These factors greatly reduced the once extensive *Terai* into smaller fragments.

The TCA being the last, largest representative of the Indian *Terai* ecosystem has also undergone several transformations during the past 8-10 decades, mainly through: (i) the long history of forest management including timber felling, raising of plantations, (ii) habitat management practices *viz.,* grass harvesting, annual burning of grasslands, weed control, water management, habitat restoration through protection; and (iii) frequent flooding and changes in river course.

The resultant combined effect of above abrupt landuse changes and management practices thus, provided an opportunity to study the existing mosaic of spatial pattern and their ultimate effect on vegetation diversity, animal use and various ecological relationships.

2.5 The Methodology

The methodology adopted for the assessment of forest spatial heterogeneity in TCA is presented below. Whilst Chapter 3 and Chapter 4 include methods used for the assessment of resultant vegetation diversity and habitat use pattern by focal species.

2.5.1 Field Reconnaissance and Review of Literature

As stated earlier, the present study formed a part of the 7-year (1996-2002) major WII-USDA Forest Service Collaborative Project. The field reconnaissance and preliminary assessments in TCA were carried out during 1996-1997. Extensive consultations with field managers and review of available official documentation (mainly, forest working plans and wildlife management plans) and other literature – research papers and research dissertations were carried out prior to the field reconnaissance and this was later followed by visits to different field sites in TCA. This effort facilitated in getting the first hand impression of the floral and faunal diversity, field complexities and realities. During the preliminary assessment period, relevant Survey of India (SOI) toposheets, forest thematic maps and remotely sensed data IRS IB LISS II were obtained and intensively used as reference material for getting acquainted with the study area. Combination of traditional field assessments and modern techniques *viz.*, application of remotely sensed data and Geographical Information System (GIS) was thus made for the present study.

2.5.2 Landscape Heterogeneity and Characterization

The false colour composites (FCC) of IRS IB LISS II sensor of January, 1997 were used to assess the landscape heterogeneity and characterisation. LISS II sensor has spatial resolution of 36.25m x 36.25m. Bands used for generating standard FCC were green, red and infrared i.e. 2,3 and 4. The study area (TCA) was covered in 16 FCCs of geocoded data on 1:50,000 scale. The corresponding SOI toposheet Nos. 62D/6,7,8,10,11,12,14,15,16; 63A/1,5,9,13; 62H/3,4 and 63E/1 were used to delineate the landscape boundaries covering two protected areas (Dudwa National Park and Kishanpur Wildlife Sanctuary), two managed forests (North and South Kheri Forest Divisions), and intervening private agricultural lands and the preparation of a base map of TCA. Permanent features like roads, railway lines and rivers were marked on the base map. The field reconnaissance allowed recognizing and relating various vegetation and landuse cover types to their tonal variation on the satellite images. Intensive ground validation was undertaken to develop an interpretation criteria for stratifying forest into different vegetation types. Based on the image properties and the ground feature relationships, an interpretation key was developed (**Table 2.1**).

The image elements considered for interpretation were tone, texture, pattern, physiography, location and association. Desired ground validation work was undertaken in predetermined and representative sites. The interpretation key and field knowledge was used for extending the interpretation and to prepare the landuse/vegetation type map of the conservation area in GIS domain using ARC/INFO 8.0.2 software. Broadly, the visual interpretation process for landuse and vegetation mapping was used as described by Ravan and Roy (1997) and Tomar (1998).

Table 2.1 – Interpretation Key For Landuse/Vegetation Classes in TCA Using IIRS 1B LISS II Data Band Combination 2, 3 and 4 on 1:50,000 Scale and Ground

Sl. No.	Tone	Texture	Pattern	Physiography/ Location	Vegetation/ Landuse Type	Prominent Species
A	**Forests**					
1	Bright red to medium red	Smooth to medium	Regular	Mainly on old alluvial plain and 'damar' (upland) areas	Dense Sal Forest (>60%)	*Shorea robusta, Mallotus philippensis, Syzygium cumini, Terminalia alata, Ehretia laevis*
2	Medium red to dull red	Medium	Ranging between regular and irregular	Occurs on high/low alluvial areas	Moderately Closed Sal Forest (40-60%)	*Shorea robusta, Mallotus philippensis, Syzygium cumini, Terminalia alata, Miliusa velutina*
3	Red with blackish tinge	Coarse	Irregular	Occurs on low alluvial areas	Open Sal Forest (<40%)	*Shorea robusta, Mallotus philippensis, Millusa velutina, Syzygium cumini* with occasional gap plantations of *Tectona grandis*
4	Bright to medium red	Medium to coarse	Irregular	On gentle slopes, old river terraces and around grasslands	Sal Mixed Forest	*Shorea robusta, Mallotus philippensis, Syzygium cumini, Lagerstroemia parvifolia* with plantations of *Tectona grandis*
5	Dark brown with bluish tinge	Coarse	Regular	Occurs as interspersed patch in grasslands areas	*Chandar* Sal Forest	*Shorea robusta, Mallotus philippensis, Bauhinia racemosa, Bridelia squamosa, Syzygium cumini*

Contd....

Table 2.1 Contd....

Sl. No.	Tone	Texture	Pattern	Physiography/ Location	Vegetation/ Landuse Type	Prominent Species
6	Red to tan	Coarse	Irregular	Along river, streams, mainly Suheli, Jauraha and wet depressions	Tropical Semi-Evergreen Forest	*Syzygium cumini, Ficus racemosa, Mallotus philippensis, Trewia nudiflora, Schleichera oleosa*
7	Brownish red with greenish tinge	Coarse	Irregular	Mostly on uplands and in peripheral areas adjoining rivers	Moist Mixed Deciduous Forest	*Mallotus philippensis, Syzygium cumini, Ficus racemosa, Trewia nudiflora, Dalbergia sissoo*
8	Medium red	Medium to coarse	Irregular	Along perennial rivers *viz.* Suheli, Ull, Barachha, and Katna	Tropical Seasonal Swamp Forest	*Syzygium cumini, Mallotus philippensis, Barringtonia acutangula, Trewia nudiflora, Ficus racemosa*
9	Light to medium brown	Medium to coarse	Irregular	In low lands along major rivers *viz.* Sharda and Ghagra	Khair & Sissoo Forest	*Acacia catechu, Dalbergia sissoo, Bombax ceiba, Haldina cordifolia*
10	Bluish to yellow	Coarse	Irregular	On river islands along Sharda and Ghagra rivers	*Tamarix* scrub	*Tamarix dioica, Saccharum spontaneum, Phragmites karka, Typha angustifoila*
11	Yellow to red with black tinge	Coarse	Irregular	Along the road, railway lines and clear felled sal forests	Plantations	*Tectona grandis, Eucalyptus citriodora*
B	**Moist Sal Savannah**					
12	Light grey to greenish yellow	Fine to medium	Regular	Upland areas	Upland Grassland	*Imperata cylindrica, Desmostachya bipinnata, Saccharum spontaneum*
13	Light to dark bluish grey	Medium to fine	Regular	In low land areas and along fresh alluvial of Suheli, Ull, Sharda and Ghagra rivers	Lowland Grassland	*Sclerostachya fusca, Saccharum narenga, Phragmites karka, Saccharum spontaneum*
C	**Wetlands**					
14	Dull greenish blue	Fine	Regular	In depressions and low lying areas	Swamp	*Nelumbo nucifera, Hydrilla verticillata, Oryza sativa, Nymphaea nouchali*
15	Light blue with variation in depth	Fine	Regular	Natural course of Mohana, Suheli, Sharda and Ghagra rivers	River	-
16	White	Fine	Regular	Along the banks of Mohana, Sharda and Ghagra rivers	Sandy bank	-
D	**Agriculture**					
17	Brilliant red-sugarcane; other crops – greenish blue to light pink	Medium to coarse	Irregular	Alluvial plains, Mosaic of regular geometrical shapes of croplands	Agriculture	Sugarcane, Rabi crops (Wheat, Mustard)

2.5.2.1 Landscape Metrics

Landscape ecology allows to study the effect of landscape pattern on ecological processes (Turner, 1989). The most common method for quantifying landscape patterns is to capture information of a particular spatial pattern into a single variable. Such variables are commonly referred to as landscape metrics or landscape indexes.

The smallest sampling unit used in remote sensing and raster data referred as picture element or pixel is basically used in all analysis. A contiguous cluster of homogeneous pixels constitutes a 'patch'. Several patch types together constitute a typical landscape. These patch types are hereby designated as the landuse/vegetation types or 'classes'. The landuse/vegetation type (classes) map generated for TCA based on the above described methodology using remotely sensed data formed basic vital input for deriving landscape metrics.

A wide variety of landscape metrics and several software programmes to calculate them have been described (O'Neill *et al.,*1988; Turner, 1989; Cullinan and Thomas, 1992; Frohn, 1997; Miller *et al.,*1997; Ravan and Roy, 1997; Tomar, 1998; Farina, 1998; McGarigal and Marks, 1994,1995).

Software FRAGSTATS*ARC version 3.02 was used in the present study. FRAGSTATS, a spatial pattern analysis programme for quantifying landscape structure is in wider use (McGarigal and Marks, 1994 and 1995). FRAGSTATS quantifies the areal extent and spatial distribution of patches (i.e., polygons on map coverage) within a landscape. An evaluation copy FRAGSTATS*ARC – v 3.0.2 (November 19, 2001) – Landscape Structure Analysis and Spatial Pattern Analysis for ARC/INFO freely available on website was downloaded and installed in a Sun Microsystem Ultra – 5. The operating system Solaris 7 and file inputs in ARC/INFO 8.0.2 were used. FRAGSTATS computed several statistical indices or metrics for the landscape mosaic under consideration. Indices thus, obtained mainly characterized: (i) each patch in the mosaic; (ii) each patch type (class) in the mosaic; and (iii) the landscape mosaic as a whole. The developers of this software have appropriately cautioned about the application and interpretation of different metrics in the absence of adequate understanding of various concepts and exact meaning of each metric before it is used. Thus, only relevant, meaningful and easily interpretable in the present context and to various phenomenon in the landscape under consideration have been actually used in describing the results and discussion. These selected metrics are summarized below:

In general, every patch in the landscape (or class) was counted. FRAGSTATS does not sample patches from the landscape, instead it censused all patches in the entire landscape. Many of the patch indices have counterparts at the class and landscape levels e.g. instead of considering a single patch, the programme considered all patches of a particular type for the corresponding class indices. Likewise, many of the landscape indices were derived from patch or class characteristics. Consequently, many of the class and landscape indices were computed from patch and class statistics by summing or averaging over all patches or classes. Class indices represented the spatial distribution and pattern within a landscape or a single patch type (landuse/vegetation type); whereas, landscape indices represented the spatial pattern of the entire landscape mosaic, considering all patch types simultaneously. In addition to the above standard patch, class and landscape indices, relevant metrics for each of the constituent areas i.e. DNP, KWLS, NKFD and SKFD as well as two PAs (DNP and KWLS) and MFs (NKFD and SKFD) combined were also computed by suppressing or merging relevant portions during the analysis.

2.5.2.1.1 Measures of Patch Characteristics

FRAGSTATS computed several simple metrics representing patch size, shape, edge and core area. The patch size or area (AREA) of each patch comprising a landscape mosaic is the single most important and useful piece of information contained in the landscape. Patch area has a great significance of ecological utility. Patch size alone can influence the floral and faunal composition, productivity and dynamics. Therefore, patch size information has been greatly used to model species richness, patch occupancy and species distribution patterns in a landscape given the appropriate empirical relationships derived from field assessments (Ambuel and Tenpala, 1983; Robbins *et al.*, 1989; Forsman *et al.,* 1984; Tomar, 1998; Johnson and Lawrence, 2001; Naugle *et al.,* 2001, Hinsley, 2000; Vos *et al.,* 2001).

Class area (CA) a measure of landscape composition described how much of the landscape is comprised of a particular patch type, Several vertebrate species specialize on a target patch type (habitat) exists within the landscape. Lehmkuhl and Raphael (1993) have described that the late-seral forest area might be a good index of habitat suitability within landscape wherein the size of spotted owl home ranges. Total landscape area (TA) defined the extent of the landscape. TA was used in computation of several class and landscape level metrics. The landscape similarity index (LSIM) represented the per cent of the landscape occupied by the same patch type. The largest patch index (LPI) at the class and landscape levels denoted the percentage value of total landscape area occupied by the largest patch.

Subsequent to patch size, patch perimeter and amount of edge were considered other useful variables. Patch perimeter measured the perimeter of each patch composing a mosaic. The perimeter to area ratio provided patch shape. Several metrics have been in use to characterize patch shape. Total amount of edge in a landscape is important to many ecological phenomena. Early wildlife management efforts were focussed on maximizing edge habitat because it was believed that most species favoured habitat conditions created by edges and that the juxtaposition of different habitats would increase species diversity (Leopold, 1933). However, it is now widely accepted that edge effects must be viewed from an organism centered perspective because edge effects influence organisms differently; some species have affinity for edge, some are unaffected, and others are adversely affected as they are dependent upon forest interior conditions (Laurance, 1991; Laurance and Beirregaard, 1997). FRAGSTATS also computed several indices those quantify landscape configuration in terms of the complexity of patch shape at the patch, class and landscape levels. The shape index (SHAPE) measured the complexity of patch shape compared to a standard shape i.e. a circular standard shape index is minimum for circular patches and increases as patch become increasingly non circular. The shape index was also applied at the class and landscape levels as well. Mean shape index (MSI) measured the average patch shape or the average perimeter to area ratio for a particular patch type (class) or for all patches in the landscape (McGarigal and Marks, 1995).

The area-weighted mean shape index (AWMSI) of patches was calculated by weighting patches according to their size. Large patches were weighted more heavily than smaller patches in calculating the average patch shape for the class or landscape. The landscape shape index (LSI) measured the perimeter-to-area ratio for the landscape as a whole on the basis of 'average' patch shape indices. The other basic type of shape index computed was based on the fractal dimension. A fractal is an object that has fractional dimensions and which at a changing scale of resolution shows self-similarity (Mendelbrot, 1977 and 1982; Farina, 1998). In other words, a fractal is a shape made of parts similar to the whole in some way. FRAGSTATS calculated the fractal dimension (FRACT) to characterize individual patches. The mean patch fractal dimension (MPFD) was calculated on the basis of fractal dimension of each patch. The values of area-weighted mean patch fractal dimension (AWMFPD) were also obtained at the class and landscape levels by weighting patches according to their size, similar to the area-weighted mean shape index.

The software also computed several metrics on core area at the patch, class and landscape levels. Core area is defined as the area within a patch beyond some specified edge distance or buffer width. In the present study, a buffer width of 100 m from the edge was considered appropriate for the diversity of focal species in the landscape. All computations for the core area metrics were thus made using this width. The core area metrics reflected both landscape composition and landscape configuration. Core area has been found to be a much better predictor of habitat quality than patch area for the forest interior specialists (Temple, 1986). Unlike patch area, core area is affected by patch shape. Thus, while a patch may be large enough to support a given species, it still may not contain enough suitable core area to support the species. Metrics *viz.,* Core area (CORE) at the patch level, total core area (TCA) at the class and landscape levels, and core area per cent of landscape (C% LAND) at the class level were computed. The latter index quantifies the core area in each patch type as a percentage of total landscape area. For organisms having strong affinity with patch interiors, this index provides a better measure of habitat availability than its counterpart. The core area indices integrate into a single measure the affects of patch area, patch shape and edge effect distance. Thus, although they quantify landscape composition, they are affected by landscape configuration. The total core area at the class level also signifies the habitat fragmentation, because fragmentation affects both habitat area and configuration. Further, each patch may actually contain several disjunct patches of suitable interior habitat. FRAGSTATS, thus provided the number of core areas (Disjunct) in each patch (NCORE), as well as the number in each class and the landscape as a whole (NCA). Values of core area index (CAI) at the patch level and the total core area index (TCAI) at the class and landscape levels quantifying core area for the entire class or landscape as a percentage of total class or landscape area, respectively were also obtained.

In addition, several other indices as measures of variability among patches in core area size were computed and used in characterization of the landscape.

2.5.2.1.2 Measures of the Spatial Arrangements of Patches

FRAGSTATS computed several metrics characterizing the spatial arrangement of patches based on their types, number, density, dominance and evenness. These metrics basically quantified landscape composition as they are not spatially explicit measures. Forest fragmentation leads to high patch density and affects corridors of pollination, species dispersal, movement and migration and multiplication (Tomar, 1998; Farina, 1998; McGarigal and Marks, 1995). Number of patches (NP) of a particular habitat type also influence a variety of ecological processes. For example, the number of patches may determine the number of sub-populations in a spatially dispersed population, or metapopulation for species exclusively associated with that habitat type. A patch type that is highly subdivided is presumed to have more resistant to the propagation of disturbance (e.g. disease, fire, etc.) and thus more likely to persist in a landscape than a patch type that is contiguous (Franklin and Forman, 1987). A landscape with a greater number of patches is thus recognized to have a finer grain; that is, the spatial heterogeneity occurs at a finer resolution. Patch density (PD) expressed number of patches in a unit area. The density of patches in the entire landscape mosaic serves as a good heterogeneity index because a landscape with greater patch density would have more spatial heterogeneity.

Diversity measures have been widely used in a variety of ecological implications. FRAGSTATS computed three diversity indices as a measure of richness and evenness. Richness refers to the number of patch type present, evenness refers to the distribution of area among different types.

2.5.2.1.3 Measures of Distance and Spatial Intermixing

The distance of a patch or a group of patches from others and their spatial intermixing are important parameters in mosaic analysis. Distance means energy loss for moving and increased predation risk (Farina, 1998). Distance also means connectedness and connectivity. Interspersion is a measure of the spatial intermixing of habitats/landuse and is computed in a nonspecies-specific manner (Lyon, 1983). Juxtaposition is the measure of proximity of the vegetation type and thus, a species-specific measurement. Association of natural and man made vegetation types can be evaluated through juxtaposition. FRAGSTATS computed a interspersion and juxtaposition index (IJI) that is applicable at both the class and landscape levels. Each patch was evaluated for adjacency with all other patch types; like adjacencies are not possible because a patch can never be adjacent to a patch of the same type. Patch insularity is a function of many things, including distance between the patch and its nearest neighbour, age of the patch or its duration of isolation, connectivity of the patch with neighbours (e.g., through corridors), and the character of intervening landscape. The permeability of a landscape for some organisms may depend on the character of the intervening landscape. The degree of contrast between the focal habitat patch and the surrounding landscape may influence dispersal patterns and survival and thus, indirectly affect the degree of patch isolation. Dunning *et al*. (1992) has described four possibilities of the use of resources in adjacent patches by organisms (**see section 2.1**).

2.5.2.1.4 Patch Distribution

FRAGSTATS computed several metrics characterizing each patch in a class or landscape. Values of Patch Area (Area_HA) were used to understand patch distribution in pre-determined patch area classes, adopting the usual presentation style of distribution of trees in standard girth classes. Number of patches were segregated in different patch area classes for select forest and non-forest classes, constituent areas, forestland, and the overall landscape. Eight patch area classes *viz.,* <=50 ha, >50-100 ha, >100-250 ha, >250-500 ha, >500-1,000 ha, >1,000-2,000 ha, >2,000-3,000 ha, and >3,000 ha were constituted to distribute all patches deciphered in the landscape as well as only in the forestland. Likewise, five patch area classes *viz.,* <=10 ha, >10-25 ha, >25-50 ha,

>50-100 ha, and >100 ha were pre-determined for segregating patches of grasslands, swamps and plantations.

2.6 The Results

The following section describes landuse/land cover types and forest spatial heterogeneity in the assesed landscape.

2.6.1 Landuse/Land Cover Types

The TCA constituted a spatial heterogeneous landscape (7,896.6 sq km) of forest – grassland – wetland complex within a matrix of sparsely distributed habitations and their extensive agricultural land. The landuse/land cover map generated for the TCA using the satellite data of January, 1997 is given in **Fig. 2.1** while the landuse pattern is presented in **Table 2.2**.

Ten different forest types including plantations and seven non-forest categories (two type of grasslands, scrub, swamp, river, sandy bank and agriculture with sparsely located habitations) were identified and delineated based on the satellite data and ground validation. Five different Sal (*Shorea robusta*) forest types *viz.,* Sal (>60%), Sal (40-60%), Sal (<40%), Sal Mixed and *Chandar* Sal were deciphered. Four other prominent forest types were: Moist Mixed Deciduous, Tropical Semi-Evergreen, Tropical Seasonal Swamp and Khair and Sissoo (*Acacia catechu* and *Dalbergia sissoo*) forests. Grasslands were classified in two types: (i) Upland grasslands – well drained grasslands which does not retain rain water and thus, drier in nature; and (ii) Lowland grasslands – tall, wet grasslands in lowlands those are seasonally wet or remain marshy for several months following monsoonal flooding and also in marsh (water-logged all year round) like situation. A separate category of *Tamarix* scrub dominated by *Tamarix dioica* shrub was recognized on scattered islands in Sharda and Ghagra rivers. The Tropical Seasonal Swamp forests occurred along streams and tributaries of river Sharda. Several interspersed swamps were also mapped.

Landuse/land cover pattern assessed for the entire landscape, forestland, each constituent area (DNP, KWLS, NKFD and SKFD), and a comparison between two PAs and two MFs combined are described in the following section, one by one for each of the category.

2.6.1.1 Landscape

The forestland including the above deciphered forest types with interspersed grasslands, scrubs, swamps, rivers and plantations within two PAs (DNP and KWLS) and two MFs (North and South Kheri Forest Divisions) covered 1,726.5 sq km or 25.8% of the landscape. The landscape matrix including several small towns and villages alongwith their agricultural area occupied 5,861.9 sq km or 74.2% of the landscape. The **Table 2.2** presents a comparative account of actual area covered and percentage proportion of each of the identified forest and non-forest type categories in the landscape and also in the forestland (PAs and MFs) which was under the control of U.P. Forest Department.

It is evident that very little productive natural ecosystem – forests, grasslands and swamps have remained intact in the TCA which was otherwise famous till recent past for contiguous, dense forests and lush tall wet grasslands. Enhanced human presence during the post independence period resulting from the settlement of immigrants and the implementation of various developmental schemes have caused the area to become more conveniently accessible. Large scale conversion of natural forests/grasslands and reclamation of swamps for agricultural purposes have led to disappearance of forests and other natural vegetation in this vast landscape. More and more areas are being brought under the plough. Thus, the landscape possessed a meager 14% land under different forest types those too with a long history of management. Grasslands and swamps occupied only 2.8% and 0.5% of the landscape, respectively. Whilst extensive plantations of teak (*Tectona grandis*) and *Eucalyptus citriodora* covered 1.7% of the landscape.

2.6.1.2 Forestland

While considering the forestland only, that was under the control of UPFD, different forest types occupied 73.0% of the forest area. Out of this, different five Sal (*Shorea robusta*) forest types covered 44.5% of the forestland. Among five Sal types, Sal with >60% canopy, Sal with 40-60% canopy, Sal with <40% canopy, *Chandar* Sal, and Sal Mixed were deciphered. For the convenience, former three types are hereby referred as dense Sal, moderately closed Sal, and open Sal , respectively.

Table 2.2 - Landuse/Landcover Types in TCA

Sl. No	Landuse/Landcover Types	Area (sq km)	% Area of TCA	Area (sq km) in Forested Tract	% Forested Tract
A	**Forests**				
1	Dense Sal (>60%) Forest	91.0	1.2	91.0	5.3
2	Moderately Closed Sal (40-60%) Forest	281.4	3.6	281.4	16.3
3	Open Sal (<40%) Forest	348.3	4.4	348.3	20.2
4	Sal Mixed Forest	17.4	0.2	17.4	1.0
5	*Chandar* Sal Forest	28.6	0.4	28.6	1.7
6	Moist Mixed Deciduous Forest	160.0	2.0	160.0	9.3
7	Tropical Semi-Evergreen Forest	10.8	0.1	10.8	0.6
8	Tropical Seasonal Swamp Forest	43.2	0.6	43.2	2.5
9	Khair and Sissoo (*Acacia catechu* and *Dalbergia sissoo*) Forest	119.1	1.5	119.1	6.9
10	*Tamarix* Scrub	25.3	0.3	25.3	1.5
11	Plantations	132.3	1.7	132.3	7.7
Sub Total of Forests		**1,257.4**	**16.0**	**1,257.4**	**73.0**
B	**Grasslands**				
12	Upland Grassland	55.9	0.7	55.9	3.2
13	Lowland Grassland	166.0	2.1	166.0	9.6
Sub Total of Grasslands		**221.9**	**2.8**	**221.9**	**12.8**
C	**Wetlands**				
14	Swamps	39.2	0.5	12.3	0.7
15	Rivers	169.9	2.2	50.4	2.9
16	Sandy Banks	346.3	4.4	74.6	4.3
Total of Forests-Grasslands-Wetland Complex		**2,034.7**	**25.9**	**1,616.6**	**93.7**
D	**Agriculture**				
17	Agriculture	5,861.9	74.2	109.9*	6.3
Grand Total (Entire Landscape as well as only Forestland)		**7,896.6**	**100.0**	**1,726.5**	**100.0**

* 109.9 sq km forestland in the landscape was found encroached and under cultivation.

The Moist Mixed Deciduous, Tropical Semi-Evergreen and Tropical Seasonal Swamp forests occupied 9.3%, 0.6% and 2.5% area of the forestland, respectively. Plantations covered 7.7% of the forested tract. Interspersed grasslands (Upland and Lowland) together represented 12.8% of the forestland. The Upland and Lowland grasslands occurred in 1:3 ratio. Rivers and swamps together occupied 3.6% of the forested tract. Sandy banks devoid of any vegetation occurred along rivers covered 4.3% of the forestland. Forestland to the extent of 109.9 sq km or 6.3% was found actually encroached and under cultivation.

2.6.1.2 Constituent Areas

Landuse/land cover pattern in each of the constituent areas (DNP, KWLS, NKFD and SKFD) is presented in **Table 2.3**. The values of forest cover in four constituent areas ranged from 41.8% (NKFD) to 90.6% (SKFD). The forestland to the extent of 109.9 sq km or 25.7% of the forest area was found encroached and being cultivated in the case of NKFD. Forests in DNP and KWLS occupied 79.3% and 80.3% area, respectively. The extent of plantations was maximum, being 20.1% in SKFD, followed by

Fig. 2.1 - Landuse/Landcover Types in Terai Conservation Area (TCA)

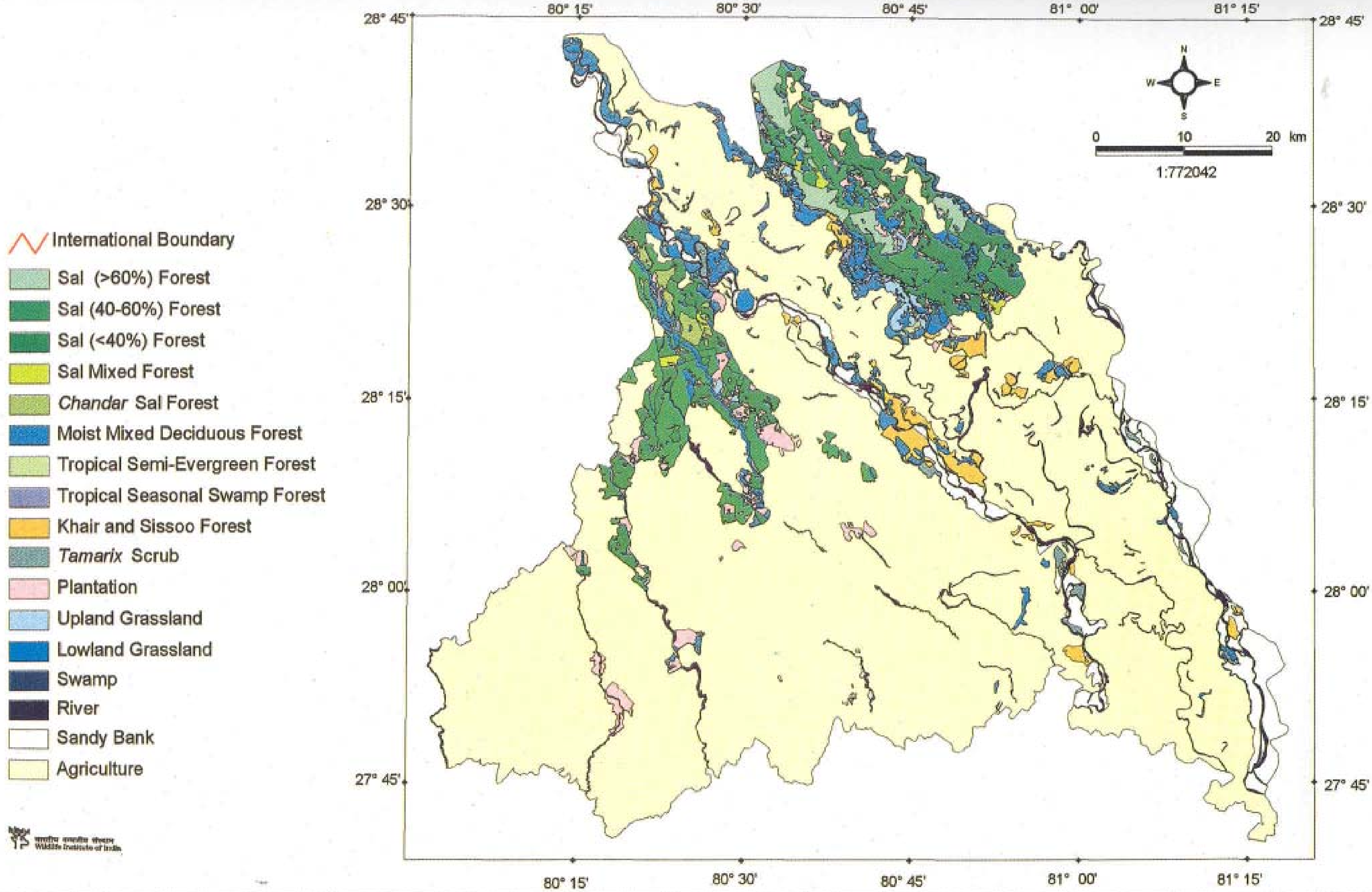


Table 2.3 - Landuse/Land Cover Pattern in Each Constituent Area (DNP, KWLS, NKFD and SKFD) and Forested Tract in TCA

Landuse/Land cover Types	DNP*		KWLS		SKFD		NKFD		Forested Tract	
	sq km	%	sq km	%	sq km	%	sq km	%	sq km	%
A. Forests										
Dense Sal (>60%) Forest	91.0	13.4	-	-	-	-	-	-	91.0	5.3
Moderately Closed Sal (40-60%) Forest	129.5	19.0	56.7	27.9	95.1	23.0	-	-	281.4	16.3
Open Sal (<40%) Forest	176.0	25.9	48.5	23.8	117.0	28.2	6.8	1.6	348.3	20.2
Sal Mixed Forest	10.3	1.5	7.1	3.5	-	-	-	-	17.4	1.0
Chandar Sal Forest	-	-	22.2	10.9	6.4	1.5	-	-	28.6	1.7
Moist Mixed Deciduous Forest	58.1	8.5	8.3	4.1	18.5	4.5	75.2	17.6	160.0	9.3
Tropical Semi-Evergreen Forest	10.8	1.6	-	-	-	-	-	-	10.8	0.6
Tropical Seasonal Swamp Forest	20.5	3.0	6.3	3.1	10.6	2.6	5.7	1.3	43.2	2.5
Khair and Sissoo (*Acacia catechu* and *Dalbergia sissoo*) Forest	9.4	1.4	-	-	29.5	7.1	80.2	18.7	119.1	6.9
Tamarix Scrub	-	-	2.5	1.2	15.0	3.6	7.8	1.8	25.3	1.5
Plantations	33.7	5.0	11.8	5.8	83.5	20.1	3.3	0.8	132.3	7.7
Sub Total of Forests	**539.3**	**79.3**	**163.4**	**80.3**	**375.6**	**90.6**	**179.0**	**41.8**	**1,257.4**	**73.0**
B. Grasslands										
Upland Grassland	43.2	6.3	1.4	0.7	9.6	2.3	1.7	0.4	55.9	3.2
Lowland Grassland	81.9	12.0	30.0	14.8	19.4	4.7	34.7	8.1	166.0	9.6
Sub Total of Grasslands	**125.1**	**18.3**	**31.4**	**15.5**	**29.4**	**7.0**	**36.4**	**8.5**	**221.9**	**12.8**
C. Wetlands										
Swamps	5.5	0.8	1.5	0.7	0.1	0.0	5.3	1.2	12.3	0.7
Rivers	9.9	1.5	2.8	1.4	3.3	0.7	34.4	8.0	50.4	2.9
Sandy Banks	0.5	0.1	4.3	2.1	6.9	1.6	62.9	14.7	74.6	4.3
Total of Forests – Grasslands – Wetland Complex	**680.3**	**100.0**	**203.4**	**100.0**	**414.9**	**100.0**	**318.0**	**74.3**	**1,726.5**	
D. **Agriculture**										
Agriculture	-	-	-	-	-	-	109.9**	25.7	109.9*	6.3
Grand Total (Each Constituent Area)	**680.3**	**100.0**	**203.4**	**100.0**	**414.9**	**100.0**	**427.9**	**100.0**	**1,726.5**	

*Also includes 190.0 sq km of reserved forests (north and south buffer).
**109.9 sq km forested land in the landscape was found encroached and under cultivation.

5.8% in KWLS and 5.0% in DNP. The NKFD had the lowest area under plantations, being 0.8%. This lowest value can be attributed to the fact that majority of the plantations raised in NKFD were of *Acacia catchu*, *Dalbergia sissoo* and other miscellaneous species and as such extensive plantations could not be separated from the Khair and Sissoo forest. Gaur (1982) in the forest working plan for NKFD has documented that the extent of natural forest was just 14.5% while plantations of Khair and Sissoo alone occupied 20.2% land of the entire Forest Division. Encroached and leased forestland covered 17.8% while unproductive area under rivers, firelines, roads, etc. constituted 14.4% of the NKFD.

The DNP harboured all major forest and grassland types, except *Chandar* Sal forest and *Tamarix* scrub those were absent. On the contrary, dense Sal and Tropical Semi-Evergreen forest types confined to DNP only and represented 13.4% and 1.6% area, respectively of the national park. The maximum extent, being 43.2 sq km or 77.2% of the Upland grasslands of TCA occurred in DNP. Likewise, almost 50% of the Lowland grasslands also occurred in DNP. *Tamarix* scrub was absent in DNP.

The KWLS had the maximum extent of *Chandar* Sal forests. Dense Sal, Tropical Semi-Evergreen, and Khair and Sissoo forest types were absent in KWLS. The KWLS also harboured the maximum extent of Sal Mixed forest, being 3.5% among the four constituent areas. The relative proportion of the Lowland grassland was also maximum in KWLS.

The dense Sal and moderately closed Sal forest types were absent in the managed forest north of Sharda river i.e. NKFD. However, open Sal occurred in NKFD. Its area proportion in NKFD was the least, being 1.6% amongst the four constituent areas. Likewise, *Chandar* Sal, Sal Mixed, Tropical Semi-Evergreen forest types were conspicuous in absence in NKFD. On the contrary, the maximum extend of Khair and Sissoo and Moist Mixed Deciduous forests was recorded in NKFD among the four constituent areas. Thus, NKFD harboured half of the Moist Mixed Deciduous forests and almost two third of Khair and Sissoo forests, those recorded in TCA. The actual area and percentage proportion of Swamps, Rivers and Sandy banks was highest in NKFD. This was due to the fact that forest patches of NKFD were located all along the Sharda and Ghagra rivers.

Dense Sal, Sal Mixed, and Tropical Semi-Evergreen forest types were absent in SKFD. The forests in

SKFD were mainly characterized by moderately closed Sal and open Sal forests and extensive plantations. A small extent of *Chandar* Sal also occurred in SKFD. The SKFD was relatively rich in Khair and Sissoo forests when compared to two PAs. The maximum extent and percentage proportion of *Tamarix* scrub was recorded in SKFD. In contrast to the NKFD, swamps were absent in SKFD while only a small proportion of this managed forest was traversed by rivers. Nearly two third (63.1%) of plantations recorded in TCA occurred in SKFD.

2.6.1.4 Comparison of PAs and MFs

The landuse/land cover pattern in two PAs and two MFs combined was compared (**Table 2.4**). The area extent of two PAs (883.7 sq km) and two MFs (842.8 sq km) was more or less same with slightly higher area in the case of PAs. Forests in the case of two PAs including plantations covered 79.5% areas whilst different forests occupied 65.8% area of two MFs. Three forest types *viz.,* dense Sal , Sal Mixed and Tropical Semi-Evergreen forests were absent in two MFs. Different Sal forest types alone covered 61.3% area of two PAs while on the contrary the extent of various Sal forests in two MFs was just 37.9%. Two MFs together represented the higher proportion of Moist Mixed Deciduous forest, being 11.1%, while two PAs had only 7.5% area under this forest type. The entire small extent of Tropical Semi-Evergreen forest being 10.8 sq km in TCA was confined to DNP. Two PAs had greater proportion (3.0%) of the Tropical Seasonal Swamp forest than two MFs (1.9%). Only small extent of Khair and Sissoo forest, being 1.1% was registered in the case of two PAs while two MFs represented higher proportion (13.0%) of this forest type. In fact, more than 90% area of the Khair and Sissoo forest type occurred in two MFs. The area

Table 2.4-Comparison of Landuse/Landcover Patterns in PAs and MFs

Landuse/Landcover Types	Actual Area in PAs (sq km)	% Area of Two PAs	Actual Area in MFs (sq km)	% Area of Two MFs
A. Forests				
Dense Sal (>60%) Forest	91.0	10.3	-	-
Moderately Closed Sal (40-60%) Forest	186.3	21.1	95.1	11.3
Open Sal (<40%) Forest	224.5	25.4	123.8	14.7
Sal Mixed Forest	17.4	2.0	-	-
Chandar Sal Forest	22.2	2.5	6.4	0.8
Moist Mixed Deciduous Forest	66.3	7.5	93.7	11.1
Tropical Semi-Evergreen Forest	10.8	1.2	-	-
Tropical Seasonal Swamp Forest	26.8	3.0	16.3	1.9
Khair and Sissoo (*Acacia catechu* and *Dalbergia Sissoo*) Forest	9.4	1.1	109.8	13.0
Tamarix Scrub	2.5	0.3	22.8	2.7
Plantations	45.5	5.1	86.8	10.3
Sub Total of Forests	**702.7**	**79.5**	**554.7**	**65.8**
B. Grasslands				
Upland Grassland	44.6	5.0	11.2	1.3
Lowland Grassland	111.9	12.6	54.1	6.4
Sub Total of Grasslands	**156.5**	**17.6**	**65.3**	**7.7**
C. Wetlands				
Swamps	7.0	0.8	5.4	0.6
Rivers	12.9	1.5	37.7	4.5
Sandy Banks	5.0	0.6	69.8	8.3
D. Agriculture				
Agriculture	-	-	109.9*	13.0
Grand Total	**883.7**	**100.0**	**842.8**	**100.0**

* 109.9 sq km forestland (NKFD) in the landscape was found encroached and under cultivation

covered under plantations was nearly double in the case of two MFs.

Two PAs had 17.6% of their area covered by two types of grasslands while the two MFs had its only 7.7% area under grasslands. Nearly 3/4th area of the Upland grasslands occurred in two PAs alone. Likewise, two PAs also possessed almost 2/3rd area of the Lowland grasslands.

The extent of Swamps in two PAs combined was slightly higher, being 0.8% while Swamps covered just 0.6% area of two MFs. Two MFs had bulk (~94%) area of the Sandy banks while Sandy banks occupied just 5.0 sq km area or 0.6% area of the two PAs.

The Dudwa NP had the enclaved agriculture and habitations of 'Tharu' tribals. Agricultural area and habitations together formed the revenue land. Similarly villages and their agricultural lands in the case of KWLS and SKFD also formed the part of revenue land. Encroachment of forestland to the extent of 25.7% was recorded in the case of NKFD and such encroached forestland was under plough.

2.6.2 Spatial Heterogeneity and Landscape Metrics

The spatial complexity of the *Terai* Conservation Area assessed at three scales *viz.,* overall landscape, vegetation type (class) and the individual patch level is described below one by one.

2.6.2.1 Landscape Level

The landscape metrics were first computed for TCA. Later, in order to have a better picture of spatial complexity in the case of forestland alone which was actually surrounded by a vast matrix of agriculture, the forestland only was clipped while computing different metrics. A comparison between two PAs and MFs combined was also made in a similar manner.

2.6.2.1.1 Area Metrics

The Largest Patch Index (LPI) quantified the percentage of total landscape or constituent area comprised by the largest patch (**Table 2.5**). The values of LPI ranged from 3.6% (MFs) to 30.4% (TCA). This reflected that a contiguous block of agriculture occupied 30.4% of the landscape. The largest patch of any one class in the case of DNP covered 9.8% area of the national park. The lowest value of LPI in the case of two MFs reflected that patches in the two managed forests were of relatively smaller size.

Table 2.5 - Area Metrics at the Landscape Level

Landscape Constituent Areas	Total Area (sq km)	Largest Patch Index - LPI (%)
TCA	7, 896.6	30.4
Forestland	1, 726.5*	4.5
PAs	883.7	7.5
MFs	842.8*	3.6
DNP	680.3	9.8
KWLS	203.4	8.7
SKFD	414.9	6.3
NKFD	427.9*	6.9

*109.9 sq km forestland in the landscape was found encroached and under cultivation

2.6.2.1.2 Patch Density, Patch Size and Variability Metrics

As such, the number of patches (NP) ranged from 100 to 1,084 for the overall landscape and other constituent areas (**Table 2.6**). This variation is also probably due to difference in actual area of each constituent unit. TCA had the maximum number of patches, being 1,084 while KWLS had the minimum number of patches (100). The greater number of patches in a landscape denotes a finer grain; that is, the spatial heterogeneity occurs at a finer resolution. Comparing two PAs, DNP had the higher number of patches, being 393 than 100 patches in the case of KWLS. Two PAs had greater number of patches than two MFs together. Although the number of patches in a landscape may be fundamentally important to a number of ecological processes, however, it conveyed no information about area, distribution, or density of patches. Nevertheless, number of patches is probably most valuable basis for computing other, more interpretable, metrics.

Patch density (PD) expressed number of patches on a per unit area basis. The values of PD varied from 0.1 patches/sq km to 0.7 patches/sq km. The lowest value was obtained in the case of TCA indicating contiguous vast agriculture area (matrix). The

Table 2.6 - Patch Density, Patch Size and Variability Metrics

Landscape/ Constituent Areas	Number of Patches (No.)	Patch Density - PD (# /sq km)	Mean Patch Size-MPS (sq km)	Patch Size Standard Deviation - PSSD (sq km)	Patch Size Coefficient of Variation - PSCV (%)
TCA	1, 084	0.1	7.3	83.7	1, 149.1
Forestland	899	0.6	1.8	4.8	265.8
PAs	493	0.6	1.8	5.2	292.1
MFs	453	0.6	1.6	3.1	192.0
DNP	393	0.6	1.7	5.6	324.3
KWLS	100	0.5	2.0	3.4	166.6
SKFD	243	0.6	1.7	3.6	209.2
NKFD	211	0.7	1.5	2.4	159.9

maximum value (0.7 patches/sq km) obtained in the case of NKFD can be attributed to the fact that smaller, isolated forest fragments of NKFD had varying patches representing various vegetation classes (forest types). The greater patch density in the case of NKFD thus, expressed more spatial heterogeneity. Otherwise, four constituent areas obtained more or less the same value of PD (**Table 2.6).**

The Mean Patch Size (MPS) is a function of the number of patches in the landscape or an index of habitat fragmentation. The values of MPS in present assessment varied from 1.5 sq km (NKFD) to 7.3 sq km (TCA). The lowest value of MPS in the case of NKFD could be explained owing to its smaller forest fragments while the highest value in the case of TCA can be attributed due to extensive contiguous crop fields. Although, MPS was derived from the number of patches, it did not convey any information about how many patches were present. Moreover, MPS represented the average condition. Variation in patch size thus, may convey more useful information. FRAGSTATS has computed two of the simplest measures of variability – standard deviation and co-efficient of variation. The Patch Size Standard Deviation (PSSD) is a measure of absolute variation; it is a function of mean patch size (MPS) and the difference in patch size among patches. The values of PSSD obtained in the case of TCA was 83.7 sq km while values among four constituent areas and other landscape units varied from 2.4 to 5.6 sq km. High value of PSSD in the case of TCA denoted greatly varying patch sizes while relatively lower values in the case of four constituent areas and other considered landscape units conveyed uniformly sized patches. Although, PSSD expressed information about patch size variability, it ignored the mean patch size.

The Patch Size Coefficient of Variation (PSCV) measured relative variability about the mean. The values of PSCV varied from 159.9% (NKFD) to 1,149.1% (TCA). These values clearly indicated that patches in the landscape (TCA) were actually much more variable in size than in NKFD. Higher values (324.3%) of PSCV in DNP than KWLS (166.3%) also indicated that patches in DNP were more variable in size than KWLS. Likewise, while comparing two PAs and two MFs combined, higher value, being 292.1% of PSCV in the case of PAs revealed that patches in PAs were more variable in size than in two MFs.

2.6.2.1.3 Edge Metrics

Edge metrics represent the amount of edge or degree of edge contrast at the patch, class and landscape levels (**Table 2.7**). Edge metrics thus, represent landscape configuration. Total amount of edge in a landscape is important to many ecological phenomena. Total Edge (TE) denoted absolute measure of total edge length of a particular patch type (class type) or of all patch types (landscape level). The values of TE (**Table 2.7)** ranged from 365.8m/km (KWLS) to 6,011.0 m/km (TCA). This index is of lesser utility while comparing the overall landscape or individual constituent areas as they greatly varied in size. Instead Edge density (ED) removed this constraint and quantified edge to a per unit area basis that facilitated comparison among overall landscape and constituent areas of varying size as in the present case. The values

Table 2.7 - Edge Metrics

Landscape/ Constituent Areas	Total Edge Length - TE (m/km)	Edge Density - ED (m/sq km)
TCA	6, 011.0	761.2
Forestland	2, 839.1	1, 756.4
PAs	1, 738.7	1, 967.0
MFs	1, 106.9	1, 511.3
DNP	1, 372.9	2, 018.9
KWLS	365.8	1, 794.8
SKFD	532.3	1, 283.8
NKFD	551.1	1, 732.7

of ED greatly varied from 761.2 m/sq km (TCA) to 2,018.9 m/sq km (DNP). The highest value of ED, being 2,018.9 m/sq km in the case of DNP than KWLS (1,794.8 m/sq km) indicated the greater edge length per unit area or finer resolution in the former. Likewise, the higher value of ED in the case of NKFD (1,732.7 m/sq km) than SKFD also indicated finer resolution in NKFD. Two PAs combined had greater image resolution than two MFs. The lowest value of ED, being 761.2 m/sq km in the case of landscape (TCA) clearly indicated lower resolution or lesser edge on the account of contiguous agricultural patch.

2.6.2.1.4 Shape Metrics

FRAGSTATS computed different metrics those quantified landscape configuration in terms of the complexity of patch shape at the patch, class and landscape levels (**Table 2.8**). Important ecological processes or inter-patch processes *viz.,* small mammal migration, woody plant colonization and animal foraging strategies have been shown to influenced by patch shape and size (Buechner, 1989; Hardt and Forman, 1989; Forman and Godron, 1986). FRAGSTATS computed shape index on the basis of perimeter – area relationships. The shape index (SHAPE) measured the complexity of patch shape compared with a circular standard; shape index is minimum for circular patches and increases, as patches become increasingly non-circular. The shape index was computed at the class and landscape levels. The Mean Shape Index (MSI) measured the average patch shape, or the average perimeter-to-area ratio. The percentage values of MSI varied from 1.8 to 2.0. FRAGSTATS also computed Area-Weighted Mean Shape Index (AWMSI) of patches at the class and landscape levels by weighting patches according to their size. The values of AWMSI varied from 2.3 (SKFD) to 4.2 (TCA). The MSI and AWMSI were based on the average patch characteristics. Alternative to this, the FRAGSTATS computed the Landscape Shape Index (LSI). This index measured the perimeter-to-area ratio for the landscape as a whole. The LSI quantified the amount of edge present in a landscape of the same size and no internal edge. The values of Landscape Shape Index (LSI) calculated using total edge length (TE) varied from 7.2 (KWLS) to 19.9 (forestland in TCA). The value of LSI obtained for the landscape (TCA) was 19.1. Higher values of LSI in the case of TCA as well as forestland indicated divergence from a regular shape. Lower values of LSI in the case of KWLS, SKFD and MFs indicated a move towards a more regular shape. Two other shape indices *viz.,* Mean Patch Fractal Dimension (MPFD) and Area Weighted Mean Patch Fractal Dimension (AWMPFD) based on a fractal dimension were also computed. Surprisingly, values of MPFD and AWMPFD computed for TCA and other constituent areas were more or less same i.e. 1.2 to 1.3. This can be attributed to the inherent limitations as described by McGarigal and Marks (1994).

Table 2.8 - Shape Index

Landscape/ Constituent Areas	Landscape Shape Index Calculated Using TE - LSI	Mean Shape Index - MSI (%)	Area Weighted Mean Shape Index - AWMSI	Mean Patch Fractal Dimension - MPFD	Area Weighted Mean Patch Fractal Dimension - AWMPFD
TCA	19.1	2.0	4.2	1.3	1.2
Forested Tract	19.9	1.9	3.1	1.3	1.2
PAs	16.5	1.9	2.9	1.3	1.2
MFs	11.5	1.8	2.7	1.3	1.2
DNP	14.8	1.9	3.2	1.3	1.3
KWLS	7.2	1.8	2.4	1.3	1.3
SKFD	7.4	1.8	2.3	1.3	1.3
NKFD	8.7	1.9	3.1	1.3	1.3

2.6.2.1.5 Core Area Metrics

Twelve different indices based on core area at the landscape level were computed. Core area computed in the present case was within a patch beyond 100 m edge distance or buffer width. Core area metrics reflected both landscape composition and landscape configuration. Only select core indices useful in the present context are presented (**Table 2.9**). The values of Total Core Area Index (TCAI) varied from 55.0% (NKFD) to 86.4% (TCA). The lowest value of TCAI, being 55.0% in the case of NKFD reflected the minimum available core area for interior species. This can also be seen in conjunction with the lowest value of the Mean Patch Size (MPS). The higher value of TCAI, being 63.1% in the case of two PAs than two MFs (60.8%) reflected that larger contiguous fragments in the case of PAs possess more core area than scattered, smaller forest fragments as in the case of two MFs. This pattern was also confirmed by values of the Mean Core Area Per Patch (MCA1), Mean Core Area Per Disjunct Patch (CASD1) and Patch Core Area Coefficient of variation (CACV1). These core area indices were basically edge-to-interior ratios like the shape indices presented above. These indices were relative measures and they do not reflect patch size, class area, or total landscape area. Instead they quantified the percentage of available area, comprised of core. For this reason, these indices were better interpreted and reflected true picture of fragmentation in each of the constituent areas *vis-à-vis* their respective corresponding area.

Table 2.9 - Core Area Metrics

Landscape/ Constituent Areas	Total Core Area Index -TCAI (%)	Mean Core Area Per Patch - MCA1 (sq km)	Patch Core Area Standard Deviation - CASD1 (sq km)	Patch Core Area Coefficient of Variation - CACV1(%)
TCA	86.4	6.3	80.3	1, 277.1
Forestland	62.4	1.1	3.6	320.1
PAs	63.1	1.1	4.1	361.3
MFs	60.8	1.0	2.2	227.8
DNP	62.9	1.1	4.4	404.8
KWLS	63.8	1.3	2.5	194.1
SKFD	65.2	1.1	2.7	246.9
NKFD	55.0	0.8	1.4	174.5

2.6.2.1.6 Diversity Metrics

The Patch Richness (PR) denotes the number of patch type present; it is not affected by the relative abundance of each patch type or the spatial arrangement of patches (**Table 2.10**). The values of PR varied from 11 (NKFD) to 17 (TCA). The lowest value in the case of NKFD was owing to the absence of dense Sal, moderately closed Sal, Sal Mixed, *Chander* Sal and Tropical Semi-Evergreen forest types while TCA also had a vast area under agriculture in addition to 11 forest and 5 non-forest categories as described in the foregoing section on landuse/land cover types. Richness is partially a function of scale. Thus, larger areas are expected to be richer owing to generally greater heterogeneity over larger areas than over comparable smaller areas. In order to overcome this problem, the FRAGSTATS also computed the Patch Richness Density (PRD) which denoted richness to a per unit area basis. The values of PRD varied from 0.2 patches/sq km (TCA) and 6.0 patches/sq km (KWLS). The highest values in the case KWLS reflected greater spatial heterogeneity. Relatively lower value, being 2 patches/sq km in the case of DNP was probably owing to the larger patches of Sal forests in the national park area.

FRAGSTATS computed six indices those quantified diversity at the landscape level. These diversity metrics quantified landscape composition and are influenced by richness and evenness. Like diversity measures extensively used in ecological applications, here richness refers to the number of patch type present while evenness refers to the distribution of area among different types. In other words, former reflected composition while the latter indice reflected structural components of diversity.

The values of Shannon's Diversity Index (SHDI) varied from 1.2 to 2.4. The lowest value was obtained in the case of landscape (TCA) while the highest value, being 2.4 was computed for the forestland. The lowest value in the case of TCA can be attributed to vast disproportionate matrix of agricultural land while the forestland in comparison to individual constituent areas possessed maximum habitat

Table 2.10 - Diversity Metrics

Landscape/ Constituent Areas	PR	PRD (# / km^2)	SHDI	SIDI	MSIDI	SHEI	SIEI	MSIEI
TCA	17	0.2	1.2	0.4	0.6	0.4	0.5	0.2
Forested Tract	16	1	2.4	0.9	2.1	0.9	0.9	0.8
PAs	16	2	2.2	0.9	1.9	0.8	0.9	0.7
MFs	13	2	2.3	0.9	2.1	0.9	1.0	0.8
DNP	14	2	2.1	0.8	1.9	0.8	0.9	0.7
KWLS	13	6	2.0	0.8	1.7	0.8	0.9	0.7
SKFD	13	3	1.9	0.8	1.7	0.8	0.9	0.7
NKFD	11	4	1.9	0.8	1.7	0.8	0.9	0.7

PR - Patch Richness; PRD - Patch Richness Density; SHDI - Shannon's Diversity Index; SIDI - Simpson's Diversity Index; MSIDI - Modified Simpson's Diversity Index; SHEI - Shannon's Evenness Index; SIEI - Simpson's Evenness Index; MSIEI - Modified Simpson's Evenness Index

diversity. The SHDI is more sensitive to richness than evenness. Thus, rare types have a disproportionately large influence on the magnitude of the index. Other diversity indices *viz.,* the Simpson's Diversity Index (SIDI) and Modified Simpson's Diversity Index (MSIDI) also reflected almost similar pattern. The SIDI is relatively less sensitive to richness and place more weight on the common class. The values of Shannon's Evenness Index (SHEI) varied from 0.4 (TCA) to 0.9 (forestland and MFs). The disproportionate representation of extensive agriculture in the case of TCA yielded the lowest value of SHEI while two MFs were relatively more even. The values of Simpson's Evenness Index (SIEI) and Modified Simpson's Evenness Index (MSIEI) also reflected more or less similar pattern for the landscape and individual constituent units. As the evenness index approaches 1, the observed diversity approaches perfect evenness. In general, each constituent area and two PAs and two MFs combined reflected greater evenness. However, two MFs based on value of Simpson's Evenness Index, being 1.0 reflected perfect evenness of constituent classes.

2.6.2.1.7 Contagion and Interspersion Metrics

FRAGSTATS computed the Interspersion and Justaposition Index (IJI) representing patch interspersion and juxtaposition at the class and landscape levels. The IJI was based on "patch" adjacencies. Each patch was evaluated for adjacency with all other patch types; like adjacencies are not possible because a patch can never be adjacent to a patch of the same type (**Table 2.11**). The values of IJI ranged from 68.9% (NKFD) to 80.0% (Forestland). The lower value in the case of NKFD characterized that the patch types were poorly interspersed (i.e. disproportionate distribution of patch type adjacencies) in this managed forest while the higher (80.0%) value in the forestland of TCA resulted from well interspersed patch types.

Relatively higher value, being 79.8% in the case of DNP than KWLS reflected well interspersion of patch types in the former. Even relative higher value of IJI, being 72.5% in the case of TCA revealed that the constituent patch types including agriculture were well interspersed in the landscape than in the case of NKFD.

2.6.2.2 Class (Patch Type) Level

FRAGSTATS computed several metrics at the class (vegetation types) level using vector data for the overall landscape. These metrics thus, explain spatial complexity at the class (Patch/Vegetation Type) level

Table 2.11 - Interspersion and Juxtaposition Metrics

Landscape/ Constituent Area	Interspersion and Juxtaposition Index - IJI
Terai Conservation Area (TCA)	72.5
Forestland	80.0
Protected Areas (PAs)	77.6
Managed Forests (MFs)	78.7
Dudwa National Park (DNP)	79.8
Kishanpur Wildlife Sanctuary (KWLS)	74.2
South Kheri Forest Division (SKFD)	74.4
North Kheri Forest Division (NKFD)	68.9

subsequent to the foregoing description at the landscape level.

2.6.2.2.1 Area Metrics

Metric values of Class Area (CA), Per cent of Landscape (PLAND) and Largest Patch Index (LPI) for different Classes (Patch/Vegetation Types) are presented in **Table 2.12**.

The percentage values of Largest Patch Index (LPI) for various forest classes varied from 0.046% (Tropical Seasonal Swamp forest) to 0.926% (open Sal forest). The largest patch of Lowland grassland represented 0.244% area of the landscape while the largest patch of Upland grassland covered 0.203% of the landscape. A contiguous block of Agriculture covering area as large as 30.4% of the landscape constituted the largest patch.

Table 2.12 – Area Metrics at the Class Level

Vegetation Type	Class Area - CA (sq km)	Per Cent of Landscape – PLAND (%)	Largest Patch Index – LPI (%)
A. Forests			
Dense Sal (>60%) Forest	91.0	1.2	0.390
Moderately Closed Sal (40-60%) Forest	281.4	3.6	0.556
Open Sal (<40%) Forest	348.3	4.4	0.926
Sal Mixed Forest	17.4	0.2	0.061
Chandar Sal Forest	28.6	0.4	0.133
Moist Mixed Deciduous Forest	160.0	2.0	0.191
Tropical Semi-Evergreen Forest	10.8	0.1	0.060
Tropical Seasonal Swamp Forest	43.2	0.5	0.046
Khair and Sissoo Forest	119.1	1.5	0.185
Tamarix Scrub	25.3	0.3	0.056
Plantations	132.3	1.7	0.165
B. Grasslands			
Upland Grassland	55.8	0.7	0.203
Lowland Grassland	165.9	2.1	0.244
C. Wetlands			
Swamps	39.2	0.5	0.059
Rivers	169.9	2.2	1.518
Sandy Banks	346.3	4.4	0.715
D. Agriculture			
Agriculture	5862.2	74.2	30.416

2.6.2.2.2 Patch Density, Patch Size and Variability Metrics

The values of Number of Patches (NP) obtained for various forest and non-forest classes varied from 5 (Sal Mixed forest) to 184 (Lowland grassland). Nine forest types and *Tamarix* scrub covering 14.2% of the landscape had altogether 319 patches (**Table 2.13**). The smallest extent (10.8 sq km) of Tropical Semi-Evergreen forest which occurred in DNP only was constituted by just 12 different patches. Likewise, small proportion of *Chandar* Sal (28.6 sq km) and Tropical Seasonal Swamp forest (43.2 sq km) were constituted by 10 and 43 patches, respectively. Two type of grasslands were constituted by 316 patches. Swamps as such represented only 0.5% of the landscape (**Table 2.12**). However, swamps were scattered in 105 patches. As many as 130 patches of Sandy banks were recorded. Despite the matrix (Agriculture) occupied bulk of the landscape, only 25 patches of this Class were recorded.

The values of Mean Patch Size (MPS) varied from 0.7 sq km (Tropical Seasonal Swamp forest) to 13.0 sq km (dense Sal forest). Only 7 patches of dense Sal forest were recorded in the landscape and the highest value of MPS was obtained for these seven patches. The value of Mean Patch Size in the case of 12 patches of Tropical Semi-Evergreen forest computed was 0.9 sq km. The values of MPS revealed that the Lowland grassland patches were almost half than the average size of Lowland grassland patches. The average patch size of Swamps was just 0.4 sq km. The values of Patch Size Standard Deviation (PSSD) for the various forest and non-forest Classes ranged from 0.9 sq km (Sal Mixed forest) to 509.4 sq km (Agriculture) indicating lowest variability among patches of Sal Mixed forest. This was also confirmed by the lowest percentage value of Patch Size Coefficient of Variation (PSCV), being 25.3% in the case of Sal Mixed forest. The Tropical Semi-Evergreen forest obtained the highest value of PSCV, being, 157.9% confirming that there was a high variability in size of 12 patches recorded for this forest type. In general, values of PSCV for majority of classes were higher

Table 2.13 - Patch Density, Patch Size and Variability Metrics at Class Level

Vegetation Types	No. of Patches – NP (no.)	Patch Density – PD (#/sq km)	Mean Patch Size – MPS (sq km)	Patch Size Standard Deviation – PSSD (sq km)	Patch Size Coefficient of Variation – PSCV (%)
A. Forests					
Dense Sal (>60%) Forest	7	0.001	13.0	10.8	83.4
Moderately Closed Sal (40-60%) Forest	28	0.004	10.1	10.1	100.4
Open Sal (<40%) Forest	31	0.004	11.2	14.7	130.5
Sal Mixed Forest	5	0.001	3.5	0.9	25.3
Chandar Sal Forest	10	0.001	2.9	3.8	132.9
Moist Mixed Deciduous Forest	103	0.013	1.6	2.0	130.1
Tropical Semi-Evergreen Forest	12	0.002	0.9	1.4	157.9
Tropical Seasonal Swamp Forest	65	0.008	0.7	0.7	105.7
Khair and Sissoo Forest	42	0.005	2.8	3.5	123.8
Tamarix Scrub	16	0.002	1.6	1.5	93.6
Plantations	134	0.017	1.0	1.7	171.7
B. Grasslands					
Upland Grassland	132	0.017	0.4	1.5	353.7
Lowland Grassland	184	0.023	0.9	2.3	252.8
C. Wetlands					
Swamps	105	0.013	0.4	0.6	167.1
Rivers	55	0.007	3.1	16.1	521.0
Sandy Banks	130	0.016	2.7	7.2	270.8
D. Agriculture					
Agriculture	25	0.003	234.5	509.4	217.2

than 100% indicating relative variability about the mean in each case. The higher values of PSCV in the case of two type of grasslands in conjunction with number of Patches and Mean Patch Size reflected that both the grassland types had greatly varied and smaller patch sizes. Lower values of PSSD and PSCV in the case of Sal Mixed forest in conjunction with the number of patches and mean patch size reflected its uniformly sized as well as moderately sized patches.

The values of Patch Density (PD) for various classes varied from 0.001 patches/sq km to 0.017 patches/sq km. Lower values of Patch Density (0.001 patches/sq km) obtained in the case of dense Sal, Sal Mixed and *Chandar* Sal forest types in conjunction with Class Area and Number of Patches reflected relatively lower fragmentation of these forest types. Higher values of Patch Density in the case of the Moist Mixed Deciduous, Khair and Sissoo and Tropical Seasonal Swamp forests while seen in conjunction with CA, NP and MPS clearly reflected that these three forest types were highly fragmented and at the same time depicted greater spatial heterogeneity. Likewise, higher values of PD in the case of Plantations, Upland and Lowland grasslands, and Swamps also indicated more spatial heterogeneity of these classes.

2.6.2.2.3 Edge Metrics at the Class Level

FRAGSTATS computed Total Edge Length (TE) and Edge Density (ED) for each class (**Table 2.14**). The values of TE for various forest and grassland classes varied from 75.7 m/km (Sal Mixed forest) to 1,040.7 m/km (Lowland grasslands). Total Edge is an absolute measure of total edge length of a particular patch type (class level). In applications that involve comparing classes of varying size, this index may not be useful. Edge Density (ED) standardizes edge to a per unit area basis that facilitated comparisons among classes of varying size. The values of ED varied from 9.6 m/sq km (Sal Mixed forest) to 131.8 m/sq km (Lowland grassland) among various forest/grassland classes.

These edge indices are affected by the resolution of the image. Higher values of Edge Length and Edge Density thus, denoted that the edges were delineated with greater details or finer the resolution.

Moderately closed Sal, open Sal, Moist Mixed Deciduous forests and Lowland grasslands reflected finer resolution based on their relatively higher values of ED while Sal Mixed, *Chandar* Sal, Tropical Semi-Evergreen and dense Sal forests reflected coarser resolution.

2.6.2.2.4 Shape Metrics at the Class Level

Values of various shape metrics obtained at the class level are presented in **Table 2.15**. The patch shape is evaluated with a circular standard. The Mean Shape Index (MSI) measured the average patch shape or the average perimeter-to- area ratio for each patch type (Class). The values of MSI ranged from 1.5% (Upland grassland) to 2.5% (open Sal forest) indicating a greater habitat edge in the case of later.

Table 2.14 - Edge Metrics at Class Level

Vegetation Type	Total Edge Length – TE (m/km)	Edge Density – ED (m/sq km)
A. Forests		
Dense Sal (>60%) Forest	175.7	22.2
Moderately Closed Sal (40-60%) Forest	707.9	89.6
Open Sal (<40%) Forest	926.3	117.3
Sal Mixed Forest	75.7	9.6
Chandar Sal Forest	89.2	11.3
Moist Mixed Deciduous Forest	677.7	85.8
Tropical Semi-Evergreen Forest	91.7	11.6
Tropical Seasonal Swamp Forest	420.1	53.2
Khair and Sissoo Forest	393.0	49.8
Tamarix Scrub	102.9	13.0
Plantations	717.3	90.8
B. Grasslands		
Upland Grassland	435.7	55.2
Lowland Grassland	1040.7	131.8
C. Wetlands		
Swamps	444.5	56.3
Rivers	2232.8	282.7
Sandy Banks	887.3	112.4
D. Agriculture		
Agriculture	2603.7	329.7

The Khair and Sissoo forest obtained the lowest value of MSI, being 1.6% among different forest types reflecting lower habitat edge. The values of Landscape Shape Index (LSI) were also computed at the class level on the basis of "average" patch characteristics at the corresponding patch type. The values of LSI varied from 5.1 (Sal Mixed forest) to 22.8 (Lowland grasslands) among various forest and grassland types indicating more complex or irregular shape of patches in the case of former. Tropical Seasonal Swamp, Moist Mixed Deciduous and open Sal forests had more complex patches in shape. In contrast, dense Sal and Sal Mixed forest attained lower values of LSI, being 5.2 and 5.1, respectively reflecting more regular shape of patches. The higher values of Area Weighted Mean Shape Index (AWMSI) in the case of Tropical Semi-Evergreen, open Sal forests and two types of grasslands confirmed complex shape of patches belonging to these classes or patch types.

2.6.2.2.5 Core Area Metrics

Several Core Area metrics at the class level were computed. Only select metrics *viz.,* Total Core Area Index (TCA1), Mean Core Area Per Patch (MCAI), Patch Core Area Standard Deviation (CASD1) and Patch Core Area Coefficient of Variation (CACV1) are interpreted and presented in **Table 2.16**. The values of Total Core Area Index (TCA1) varied from 26.0% (Tropical Seasonal Swamp forest) to 81.1% (Dense Sal forest) indicating availability of relatively larger core area in the case of later. Both grassland types also obtained lower values (<50%) of TCAI reflecting lesser available core area for the interior species. Majority of the classes obtained lower values of the Mean Core Area Per Patch (<2.0 sq km) indicating higher fragmentation. Variation in core area per patch was better conveyed through metrics *viz.,* CASD1 and CACV1. The higher values of CACV1 in the case of Tropical Semi-Evergreen, Tropical Seasonal Swamp, Moist Mixed Deciduous forests and Upland grasslands indicated greater variability in core size area per patch. All of the core area indices were result of the interaction of patch size, patch shape, and the specified edge width (100 m in the present case). Thus, availability of smaller core areas per patch and greater variation among them would have severe ecological implications, particularly for the

Table 2.15 - Shape Level Metrics at Class Level

Vegetation Type	Landscape Shape Index Using TE - LSI	Mean Shape Index – MSI (%)	Area Weighted Mean Shape Index - AWMSI
A. Forests			
Dense Sal (>60% Forest	5.2	2.2	2.2
Moderately Closed Sal (40-60%) Forest	11.9	2.3	2.9
Open Sal (<40%) Forest	14.0	2.5	3.5
Sal Mixed Forest	5.1	2.3	2.3
Chandar Sal Forest	4.7	1.7	1.8
Moist Mixed Deciduous Forest	15.1	1.7	2.1
Tropical Semi-Evergreen Forest	7.9	2.1	3.6
Tropical Seasonal Swamp Forest	18.0	2.3	2.8
Khair and Sissoo Forest	10.2	1.6	2.0
Tamarix Scrub	5.8	1.6	1.7
Plantations	17.6	1.7	2.0
B. Grasslands			
Upland Grassland	16.5	1.5	3.0
Lowland Grassland	22.8	1.8	3.3
C. Wetlands	20.0	2.1	2.6
Rivers	48.3	4.6	30.2
Sandy Banks	13.5	1.6	2.1
D. Agriculture			
Agriculture	9.6	2.3	4.1

interior species, larger wild herbivores, predators and habitat obligate species.

2.6.2.2.6 Interspersion and Juxtaposition Metrics at the Class Level

The values of the Interspersion and Juxtaposition Index (IJI) for each of the class were computed (**Table 2.17**). The values of IJI ranged from 52.2% (*Tamarix* scrub) to 88.9% (Lowland grasslands) indicating that Lowland grasslands were relatively well interspersed in the landscape in contrast to *Tamarix* scrubs which were highly restricted to islands of two major rivers i.e. Sharda and Ghagra.

Among different forest types, the Tropical Semi-Evergreen forest obtained the lowest value of IJI, being 56.9% reflecting that this forest class was aggregated in a particular portion of the landscape or highly dispersed. The IJI was affected only by patch type interspersion and juxtaposition and not necessarily by the size, contiguity or dispersion of patches. Higher values of IJI in the case of Tropical Seasonal Swamp (79.8%), and open Sal forests indicated that these classes were relatively well interspersed. *Chandar* Sal, and Khair and Sissoo forests obtained relatively lower values of IJI, being 62.4% and 68.9%, respectively indicating that these two classes were moderately interspersed. Lowest value of IJI, being 39.0% among various forest and non-forest classes was obtained in the case of Swamps, reflecting that they were poorly interspersed in the landscape. This was owing to their proximity to river Sharda. Likewise, the class of Sandy banks obtained lower IJI value of 40.7%, again reflecting their poor interspersion in the landscape instead this class was highly aggregated. The class – Agriculture in TCA obtained 67.8% value for IJI indicating that matrix was moderately distributed in the landscape. This can be attributed to the fact that there was a disproportionate greater distribution of agricultural land in the south of river Sharda.

2.6.2.3 Patch Level

FRAGSTATS computed several metrics at the patch level characterizing each patch in a class or landscape. Since earlier described metrics at the landscape and class levels were mainly dependent upon individual patch characteristics in each class or the entire landscape, values of Patch Area (AREA_HA) only were considered useful for presentation here. Adopting the usual presentation style of distribution of trees in standard girth classes, number of patches were segregated in pre-determined patch area classes for select forest and non-forest classes, constituent areas, forestland and the overall landscape.

2.6.2.3.1 Distribution of Patches in Landscape

Altogether, 1,084 patches belonging to different forest and non-forest classes were delineated in the landscape (**Table 2.18**). **Table 2.18** also provides values of number of patches in each of the identified class, maximum, minimum and mean patch size in sq km. As such, values of number of patches and mean patch size have been earlier presented. However, it was considered appropriate to see the values of patch number and mean patch size in conjunction with the maximum and minimum patch size for each class.

Table 2.16 - Core Area Metrics at Class Level

Vegetation Type	Total Core Area Index – TCAI (%)	Mean Core Area Per Patch - MCA1 (sq km)	Patch Core Area Standard Deviation – CASD1 (sq km)	Patch Core Area Coefficient of Variation – CACV1 (%)
A. Forests				
Dense Sal (>60%) Forest	81.1	10.5	9.6	91.0
Moderately Closed Sal (40-6-%) Forest	75.2	7.6	8.1	106.7
Open Sal (<40%) Forest	74.5	8.4	11.6	138.3
Sal Mixed Forest	60.3	2.1	0.6	29.5
Chandar Sal Forest	71.1	2.0	3.2	156.7
Moist Mixed Deciduous Forest	58.9	0.9	1.4	152.4
Tropical Semi-Evergreen Forest	31.6	0.3	0.5	186.7
Tropical Seasonal Swamp Forest	26.0	0.2	0.3	172.2
Khair and Sissoo Forest	69.4	2.0	2.8	143.7
Tamarix Scrub	62.1	1.0	1.1	108.4
Plantations	54.1	0.5	1.3	241.3
B. Grasslands				
Upland Grassland	39.0	0.2	0.9	530.5
Lowland Grassland	48.0	0.4	1.3	296.5
C. Wetlands				
Swamps	24.3	0.1	0.3	355.5
Rivers	17.6	0.5	2.8	518.2
Sandy Banks	74.2	2.0	6.3	318.7
D. Agriculture				
Agriculture	95.0	222.7	490.5	220.3

Highly variable values of maximum and minimum patch size in each of the forest and non-forest class were noticeable e.g. the maximum patch size in the Lowland grassland was 19.2 sq km while the minimum patch size was just 0.04 sq km. Likewise, the maximum patch size recorded in the case of open Sal forest was 73.1 sq km while the minimum patch size was 0.43 sq km only. Similarly, the maximum patch size in the case of Khair and Sissoo forest was 14.6 sq km while the minimum patch size was 0.04 sq km or 4 ha. The largest swamp was 4.6 sq km in size while the smallest swamp was 0.005 sq km (5 ha) in size.

Distribution of 1,084 patches according to various patch area classes is presented in **Fig. 2.2**. It is evident from the **Fig. 2.2** that 55.1% patches (i.e. 598 patches) in landscape were very small in size i.e. <=50 ha. Only 27 patches or 2.4% patches were larger than 2,000 ha. Distribution of patches in eight patch area classes resulted into a negative curve i.e. number of patches greatly reduced on increase in patch area (ha).

Distribution of forest patches (n=319) only in TCA representing 10 forest types excluding plantations is presented in **Fig. 2.3**. Almost similar distribution pattern as of total patches was observed. Only four forest patches were larger than >3,000 ha. **Fig. 2.4** presents patch distribution of the Upland grassland. Nearly 1/6th Lowland grassland patches were >100 ha in size, otherwise bulk of the grassland patches were smaller in size i.e. <25 ha (**Fig. 2.5**). Nearly 1/3rd of the swamps in TCA were much smaller in size i.e. <10 ha while only 6 swamps were larger than 100 ha (**Fig. 2.6**). In contrast, there were 35 patches of plantations larger than 100 ha in extent (**Fig. 2.7**).

Table 2.17 - Interspersion and Juxtaposition Index at Class Level

Sl. No.	Vegetation Type	Interspersion and Juxtaposition Index – IJI (%)
A	**Forests**	
1	Dense Sal (>60%) Forest	68.8
2	Moderately Closed Sal (40-60%) Forest	76.2
3	Open Sal (<40%) Forest	78.5
4	Sal Mixed Forest	73.4
5	Chandar Sal Forest	62.4
6	Moist Mixed Deciduous Forest	75.3
7	Tropical Semi-Evergreen Forest	56.9
8	Tropical Seasonal Swamp Forest	79.8
9	Khair and Sissoo Forest	68.9
10	*Tamarix* Scrub	52.2
11	Plantations	72.0
B	**Grasslands**	
12	Upland Grassland	78.1
13	Lowland Grassland	88.9
C	**Wetlands**	
14	Swamps	39.0
15	Rivers	51.3
16	Sandy Banks	40.7
D	**Agriculture**	
17	Agriculture	67.8

Fig 2.2 - Distribution of Patches in TCA (n = 1, 084)

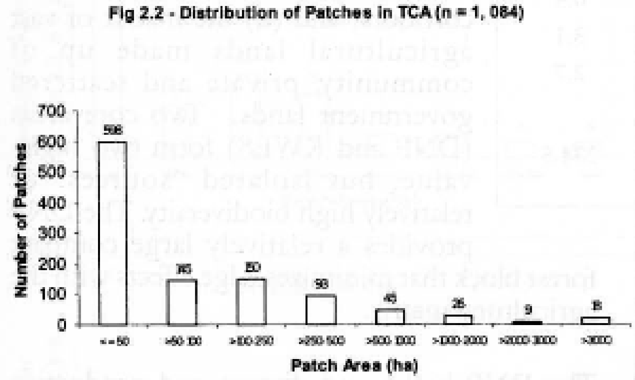


Fig. 2.3 - Distribution of Forest (n=319) Patches inTCA

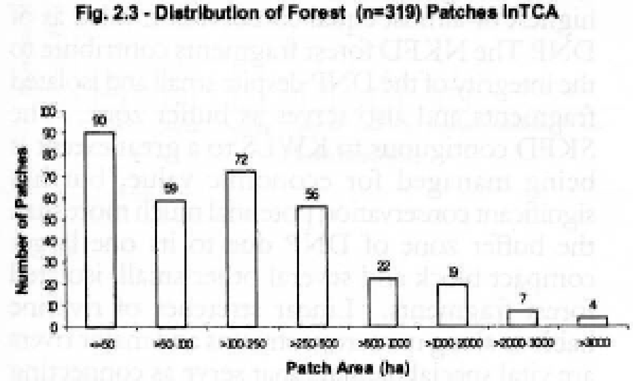


Fig 2.4 - Distribution of Upland Grassland Patches in TCA (n = 132)

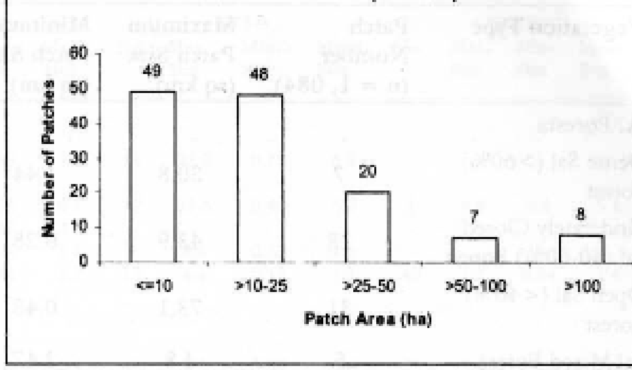


Fig 2.5 - Distribution of Lowland Grassland Patches in TCA (n = 184)

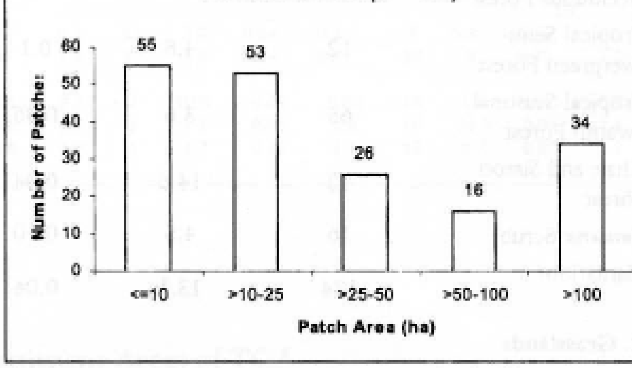


Fig 2.6 - Distribution of Swamp Patches in TCA (n = 105)

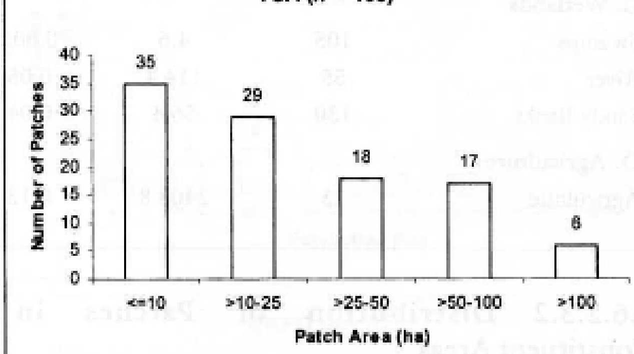


Fig 2.7 - Distribution of Plantation Patches in TCA (n = 134)

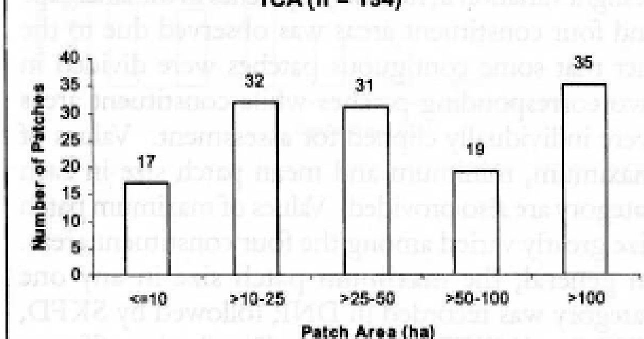


Table 2.18 – Number of Patches in TCA and their Maximum, Minimum and Mean Patch Size (sq km)

Vegetation Type	Patch Number (n = 1, 084)	Maximum Patch Size (sq km)	Minimum Patch Size (sq km)	Mean Patch Size (sq km)
A. Forests				
Dense Sal (>60%) Forest	7	30.8	1.44	13.0
Moderately Closed Sal (40-60%) Forest	28	43.9	0.28	10.1
Open Sal (<40%) Forest	31	73.1	0.43	11.2
Sal Mixed Forest	5	4.8	2.47	3.5
Chandar Sal Forest	10	10.5	0.20	2.9
Moist Mixed Deciduous Forest	103	15.1	0.04	1.6
Tropical Semi-Evergreen Forest	12	4.8	0.1	0.9
Tropical Seasonal Swamp Forest	65	3.6	0.05	0.7
Khair and Sissoo Forest	42	14.6	0.04	2.8
Tamarix Scrub	16	4.5	0.10	1.6
Plantations	134	13.1	0.04	1.0
B. Grasslands				
Upland Grasslands	132	14.5	0.04	0.4
Lowland Grasslands	184	19.2	0.04	0.9
C. Wetlands				
Swamps	105	4.6	0.005	0.4
River	55	114.4	0.05	3.1
Sandy Banks	130	56.4	0.04	2.7
D. Agriculture				
Agriculture	25	2408.8	0.13	234.5

2.6.2.3.2 Distribution of Patches in Constituent Areas

Table 2.19 presents distribution of patches in four constituent areas (DNP, KWLS, NKFD and SKFD). A slight variation in number of patches in the landscape and four constituent areas was observed due to the fact that some contiguous patches were divided in two corresponding patches while constituent areas were individually clipped for assessment. Values of maximum, minimum and mean patch size in each category are also provided. Values of maximum patch size greatly varied among the four constituent areas. In general, the maximum patch size in any one category was recorded in DNP, followed by SKFD, KWLS and NKFD, respectively. Distribution of forest, grassland, plantation and swamp patches in the four constituent areas according to patch area classes is presented in **Figs. 2.8, 2.9** and **2.10**, respectively. The spatial distribution of overall forest patches, each forest and grassland type, swamps, and plantations in TCA are depicted in **Fig. 2.11 to 2.22.**

2.7 Conclusion

The aforesaid description on the landscape level assessment and forest spatial heterogeneity allowed the following conclusion:

- The TCA has four distinct constituent areas or Landscape Management Units (LMU) that forms the basis for integration of disparate forest/wildlife allocations for landscape management so as to achieve multiple forestry objectives including the conservation of biodiversity. These units are: (a) two protected areas (core areas) – Dudwa NP (DNP) and Kishanpur Sanctuary (KWLS); (b) two managed forests (MFs) – North Kheri Forest Division (NKFD) and South Kheri Forest Division (SKFD); (c) linear riverine habitats and connective corridors; and (d) the matrix of vast agricultural lands made up of community, private and scattered government lands. Two core areas (DNP and KWLS) form two high–value, but isolated "sources" of relatively high biodiversity. The DNP provides a relatively large compact forest block that minimizes edge effects with the agricultural matrix.

- The DNP harboured diverse and productive forests and grasslands. The KWLS has the next highest or almost equal conservation value as of DNP. The NKFD forest fragments contribute to the integrity of the DNP despite small and isolated fragments and also serves as buffer zone. The SKFD contiguous to KWLS to a great extent is being managed for economic value, but has significant conservation potential much more than the buffer zone of DNP due to its one larger compact block and several other small, isolated forest fragments. Linear stretches of riverine habitats along numerous streams and major rivers are vital special habitats that serve as connecting

Table 2.19 – Number of Patches in Four Constituent Areas along with their corresponding Values of Maximum, Minimum and Mean Patch Size (sq km)

Vegetation Types	DNP				KWLS				SKFD				NKFD			
	No.	Max. Size	Min. Size	Mean Size	No.	Max. Size	Min. Size	Mean Size	No .	Max. Size	Min. Size	Mean Size	No.	Max. Size	Min. Size	Mean Size
A. Forest																
Dense Sal (>60%) Forest	7	30.8	1.44	13.0	-	-	-	-	-	-	-	-	-	-	-	-
Moderately Closed Sal (40-60%) Forest	9	43.9	3.22	14.4	8	17.7	0.89	7.1	14	26.3	0.28	6.8	-	-	-	-
Open Sal (<40%) Forest	9	66.3	1.73	19.6	8	13.4	1.35	6.1	17	21.6	0.43	6.9	1	6.8	6.8	6.8
Sal Mixed Forest	3	4.8	2.47	3.4	2	3.7	3.40	3.6	-	-	-	-	-	-	-	-
Chandar Sal Forest	-	-	-	-	7	10.5	0.49	3.2	4	3.5	0.20	1.6	-	-	-	-
Moist Mixed Deciduous Forest	36	10.6	0.05	1.6	5	2.8	0.81	1.7	17	4.4	0.13	1.1	49	5.7	0.04	1.5
Tropical Semi-Evergreen Forest	12	4.8	0.10	0.9	-	-	-	-	-	-	-	-	-	-	-	-
Tropical Seasonal Swamp Forest	34	3.6	0.05	0.6	7	1.8	0.11	0.9	18	2.3	0.09	0.6	7	1.5	0.12	0.8
Khair and Sissoo Forest	4	6.4	0.70	2.3	-	-	-	-	11	14.6	0.61	2.7	27	14.0	0.27	3.0
Tamarix scrub	-	-	-	-	4	1.5	0.10	0.6	7	4.1	0.40	2.1	8	2.2	0.10	0.9
Plantation	58	5.4	0.05	0.6	9	4.6	0.07	1.3	64	13.1	0.04	1.3	4	1.7	0.18	0.8
B. Grasslands																
Upland Grasslands	63	16.0	0.04	0.7	11	0.3	0.04	0.1	51	2.2	0.04	0.2	7	0.3	0.10	0.2
Lowland Grasslands	111	14.4	0.04	0.7	23	13.4	0.04	1.3	27	5.8	0.04	0.7	30	5.9	0.05	1.2
C. Wetlands																
Swamps	23	1.0	0.03	0.2	8	0.8	0.01	0.2	2	0.02	0.01	0.02	16	1.0	0.005	0.3
River	20	4.6	0.07	0.5	3	1.4	0.58	1.0	5	1.5	0.05	0.6	10	21.9	0.06	3.4
Sandy Banks	4	0.2	0.17	0.1	5	2.7	0.06	0.9	6	5.7	0.11	1.1	52	5.7	0.07	1.2

Fig 2.8 – Distribution of Forest Patches in Four Constituent Areas of TCA

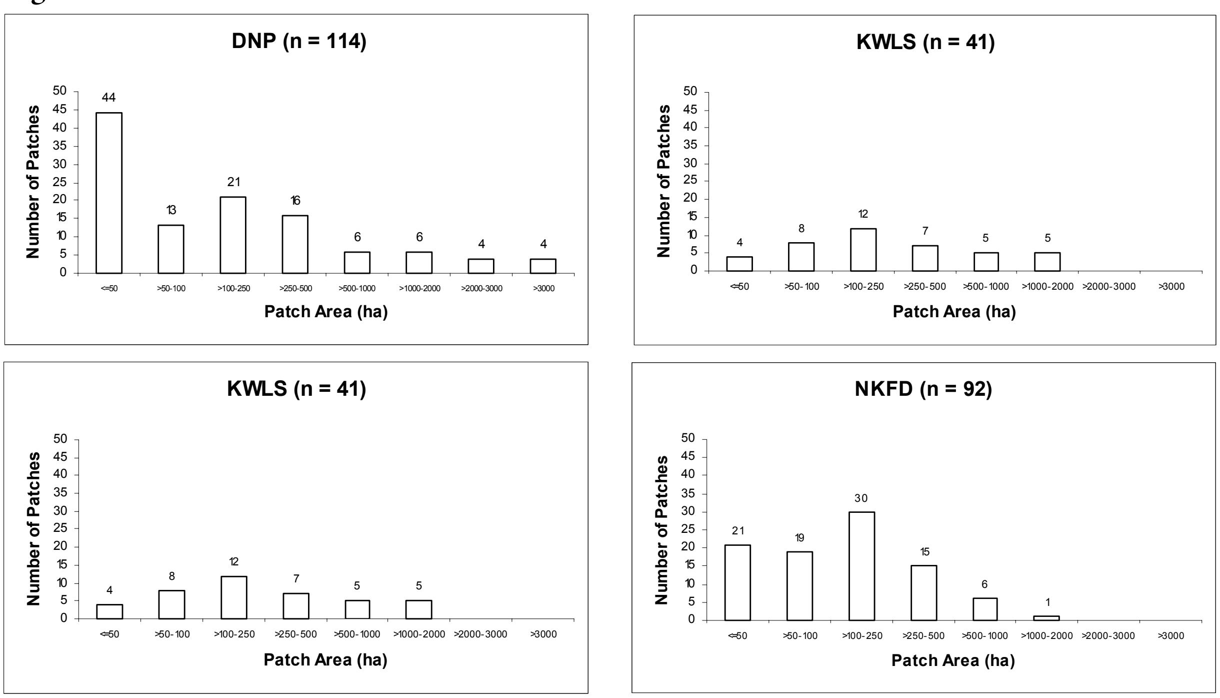


Fig 2.9 – Distribution of Upland and Lowland grassland Patches in Four Constituent Areas of TCA

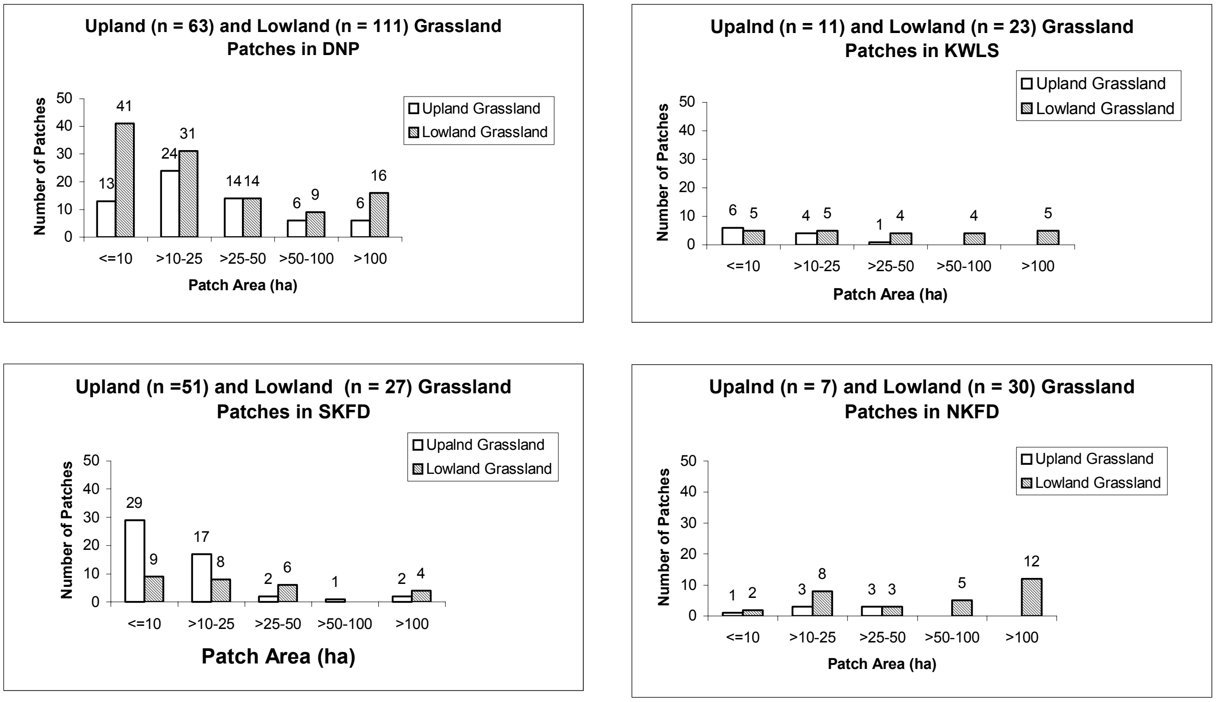
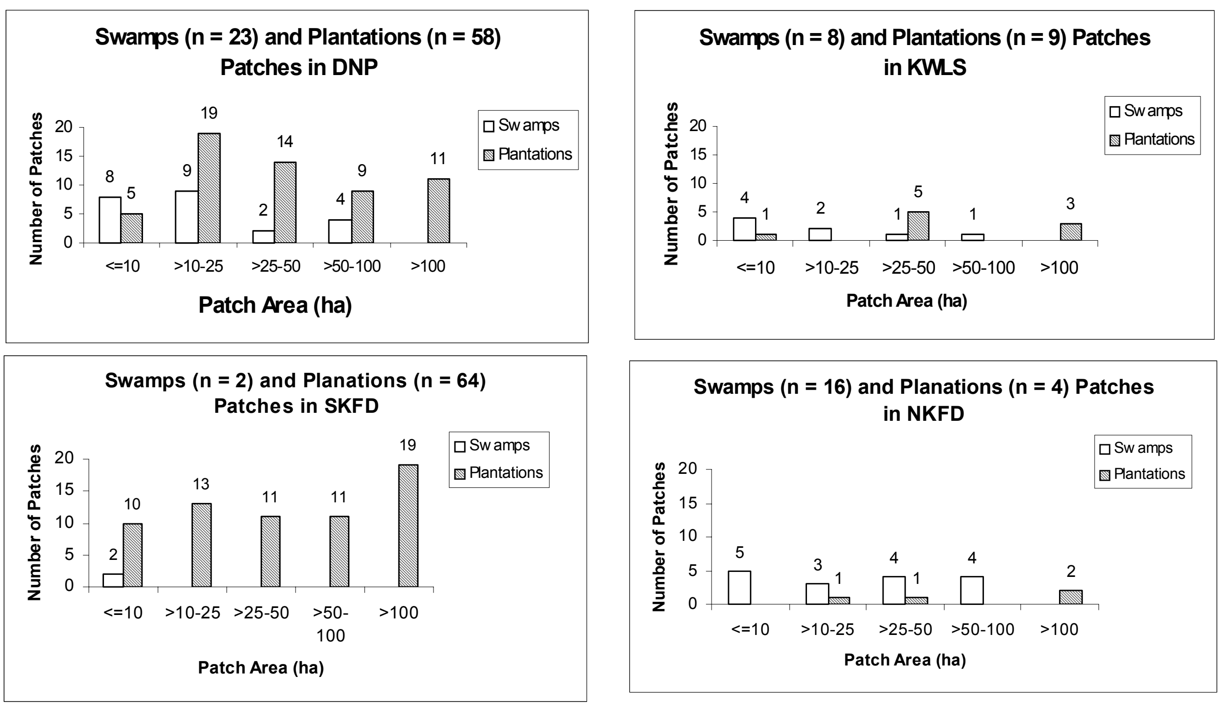


Fig 2.10 – Distribution of Swamps and Plantations Patches in Four Constituent Areas of TCA



corridors between any two LMUs despite severe biotic pressure. Vast surrounding agricultural land or matrix is a source of human disturbance and therefore, has been recognized as an important element of forest management and biodiversity conservation.

- Broadly, the landscape was constituted by 25.8% of forestland (PAs and MFs) either in larger compact blocks or in smaller, isolated fragments, and 74.2% matrix including extensive private agricultural lands, community lands, and scattered government lands. Interspersed grasslands and swamps occupied just 2.8% and 0.5% area of the landscape, respectively. Thus, the landscape represented a complex of forest-grassland-wetland.

- Detailed landscape level assessment using remotely sensed satellite data provided 17 categories of landuse/land cover types. This include nine different forest types, two grassland types, forest plantations and five other land cover categories (Scrub, River, Swamp, Sandy Bank, and Agriculture including habitations).

- The forests occupied 73% of the forestland under the control of U.P. Forest Department. Five different Sal (*Shorea robusta*) forest types together constituted 44.5% of the forestland. The Moist Mixed Deciduous, Tropical Semi-Evergreen, and Tropical Seasonal Swamp forests occupied 9.3%, 0.6%, and 2.5% area of the forestland, respectively. The plantations alone covered 7.7% of the forestland. Interspersed tall or riverine grasslands (Upland and Lowland) covered 12.8% area of the forested tract. The Upland and Lowland grasslands occurred in 1:3 ratio. Rivers and Swamps combined occupied 3.6% area of the forestland. Sandy banks devoid of any vegetation occurred along Sharda and Ghagra rivers covered 4.3% of the forestland. About 6% of the forestland was found actually encorached and under illegal cultivation.

- Sal dominated forests were categorized into five types: dense Sal, moderately closed Sal, open Sal, and *Chandar* Sal forests. Dense Sal forest type occurred only in DNP and occupied 13.4% of the national park area while *Chandar* Sal forests were recorded only in KWLS and SKFD. Later forest type was conspicuous in its absence in DNP. The Tropical Semi-Evergreen forest type occurred only in a very small proportion, being 0.6% of the forestland while it represented just 0.1% area of TCA. This forest type was confined to DNP only among the four constituent areas. Swamps and Rivers together occupied 3.6% area of the forestland.

- Dense Sal, Sal Mixed and Tropical Semi-Evergreen forest types were absent in two managed forets (NKFD and SKFD). The bulk (>90%) of the Khair and Sissoo forests occurred in two MFs. The forest plantation areas were nearly double in its extent in two MFs than two PAs. Further, a comparison of two core areas with two MFs revealed that the two PAs had 17.6% of its area under grasslands while the managed forests had only 7.7% of its area under grasslands. Nearly, three-fourth area of the Upland grasslands occurred in two PAs alone. Likewise, two PAs also possessed about 2/3rd of the Lowland grasslands. The NKFD had the maximum extent of encroachment (~25.7%). Open Sal forest type occupied the maximum extent of the forestland.

- The spatial complexity of the landscape assessed using software FRAGSTATS* Arc at three scales *viz.,* individual patch, vegetation type (Class), and the overall landscape allowed striking observations. The Largest Patch Index (LPI) at the class and landscape levels quantified the percentage of total landscape area comprised by the largest patch. The values of LPI ranged from 3.6% (MFs) to 30.4% (TCA). This was due to the smaller isolated forest fragments in the case of former while larger contiguous blocks of agriculture in the case of TCA. It revealed that a contiguous block of agriculture alone occupied as large as 30% area of the entire landscape. As such, the overall number of patches (NP) ranged from 100 to 1,084 among the constituent areas and entire landscape. However, this variation was possibly a result of variation in the actual extent of the constituent units. TCA had the maximum number of patches, being 1,084 while KWLS had the minimum number of patches (100). The greater number of patches denoted a finer grain or the spatial heterogeneity occurred at a final resolution. DNP had 393 patches while KWLS had only 100 patches. Two PAs had greater number of patches than two managed forests together.

- The NKFD had maximum value of Patch Density (PD), being 0.7 patches per sq km. The PD expressed number of patches on a per unit area basis. This maximum value in the case of NKFD was due to several small isolated forest fragments in this managed forest.

- Nine forest types and *Tamarix* scrub covering 14.2% area of the landscape had altogether 319 patches. The Tropical Semi-Evergreen forest type covered only 10.8 sq km area of TCA which was constituted by just 12 different patches. 10 and 43 patches constituted *Chandar* Sal (28.6 sq km) and Tropical Seasonal Swamp forest (43.2 sq km) types, respectively. 316 patches constituted two type of grasslands. Swamps occurred in TCA in as many as 105 patches.

- The values of Mean Patch Size (MPS) varied from 0.7 sq km (Tropical Seasonal Swamp forests) to 13.0 sq km (dense Sal forest) indicating the lowest value in the case of former due to high habitat fragmentation. Dense Sal forest covered 91.0 sq km in DNP was constituted by just seven patches. The average size of the Swamps in TCA was 0.4 sq km based on its value of MPS. The mean patch size of 12 patches of Tropical Semi-Evergreen forest those confined to DNP was 0.9 sq km only. These 12 patches obtained the highest value of Patch Size Coefficient of Variation (PSCV) also indicated high variability in patch size.

- Dense Sal, Sal Mixed and *Chandar* Sal forest types showed relatively lesser fragmentation while higher values of Patch Density (PD) in the case of Moist Mixed Deciduous, Khair and Sissoo, and Tropical Seasonal Swamp forests seen in conjunction with class area (CA), number of patches (NP) and mean patch size (MPS) reflected that these forest types were highly fragmented. Higher values of patch density in the case of plantations, Upland and Lowland grasslands, and swamps indicated more spatial heterogeneity of these vegetation types (Classes). The values of Landscape Shape Index (LSI) varied from 5.1 to 22.8 for Sal Mixed forest and Lowland grasslands, respectively indicating more complex and irregular shape of patches in the case of former while least in the case of Lowland grasslands.

- Values of the Interspersion and Juxtaposition Index (IJI) for each class and the landscape were also computed. The higher value of IJI in the case of Tropical Seasonal Swamp forests (79.8%), and open Sal forests (78.5%) indicated that these forest types were well interspersed while *Chandar* Sal (IJI – 62.4%), and Khair and Sissoo (IJI – 68.9%) forests were moderately interspersed. Based on the lowest IJI value, being 39.0%, it was concluded that Swamps were poorly interspersed in the landscape. This fact can be due to the large-scale reclamation of swamps for agricultural purposes. Interestingly, Agriculture was moderately interspersed in the landscape based on its IJI value, being 67.8%.

- FRAGSTATS also computed several metrics at the patch level characterizing a class or landscape. Adopting the usual presentation style of distribution of trees in standard girth classes, number of patches were segregated in pre-determined area classes for select forest and non-forest classes. Eight patch area classes for forest patches ranging from <=50 ha to >3,000 ha and five patch classes for grasslands, swamps, and plantations varied from <=10 ha to >100 ha were formed to segregate patches in corresponding class categories. Altogether, 1,084 patches of forest and non-forest classes were delineated in TCA. Highly variable values of maximum and minimum patch size were computed. The patch size in the case of Lowland grassland ranged from just 4 ha to 1,002 ha (or 10.2 sq km). The values of patch size in the case of Sal forest type ranged from as low as 43 ha to as high as 7,031 ha (73.1 sq km). The highest mean patch size, being 13 sq km (or 1,300 ha) was in the case of dense Sal forests. 598 patches or 55.1% patches in TCA were very small in size i.e. <=50 ha while only 27 patches or 2.4% patches recorded in TCA were larger than 2,000 ha in size. The number of patches greatly reduced on increase in patch area (ha), thus, giving a negative curve or distribution of patches in eight classes for forests. In the entire landscape only four large patches with size >3,000 ha were recorded. This included one large patch of the dense Sal, two patches of the moderate canopy Sal and one patch of the open Sal in the entire landscape. Nearly, 1/6th patches of the Lowland grasslands were >100 ha in size, otherwise bulk of the grassland patches were much smaller in size i.e. <25 ha. Likewise, 1/3rd Swamps in TCA were much smaller in size i.e. <10 ha while only six Swamps were larger than 100 ha.

Fig. 2.11 - Distribution of Forest Patches in TCA

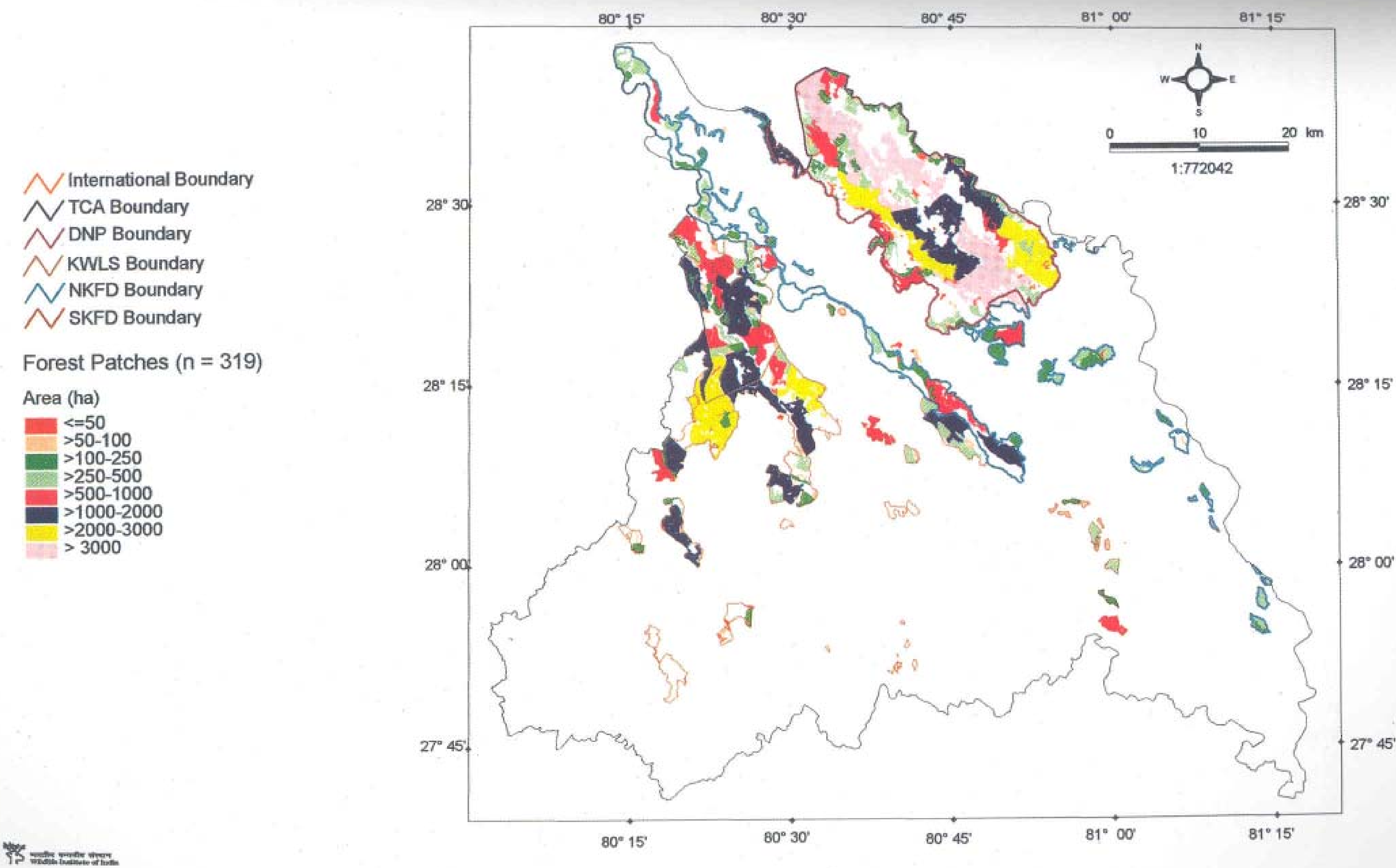


Fig. 2.12 - Distribution of Sal (>60%) Forest Patches in TCA

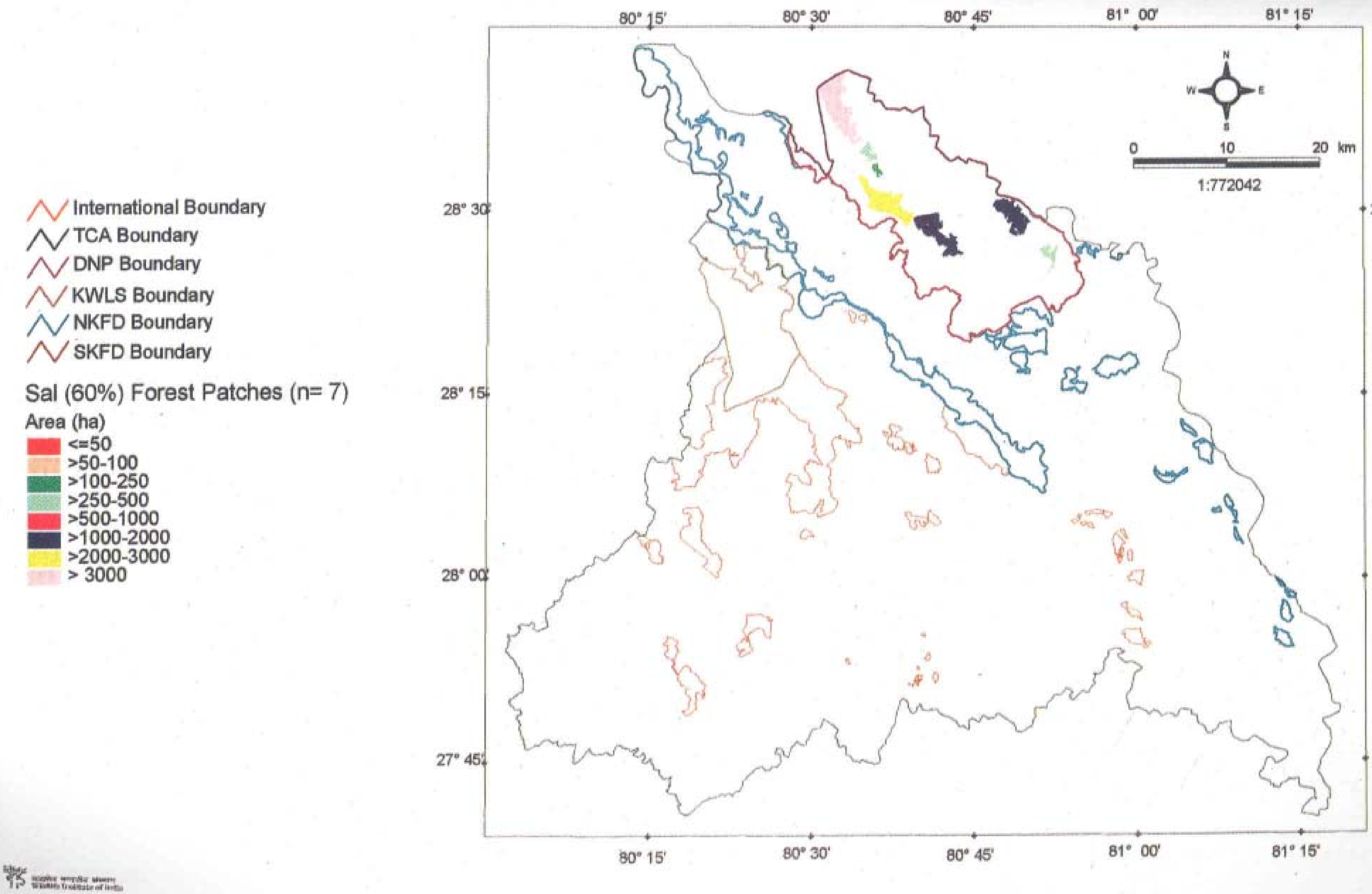


Fig. 2.13 - Distribution of Sal (40-60%) Forest Patches in TCA

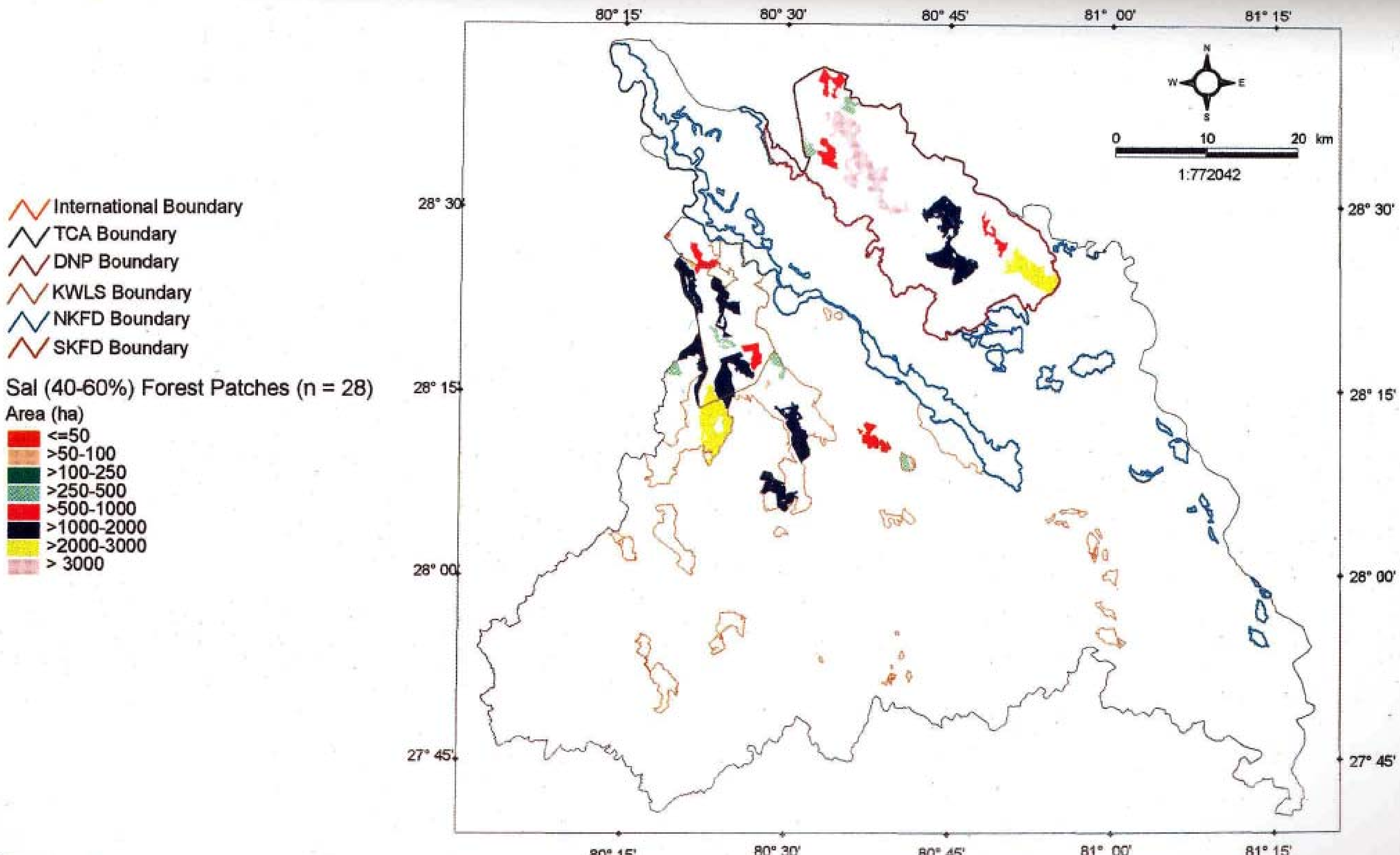


Fig. 2.14 - Distribution of Sal (<40%) Forest Patches in TCA

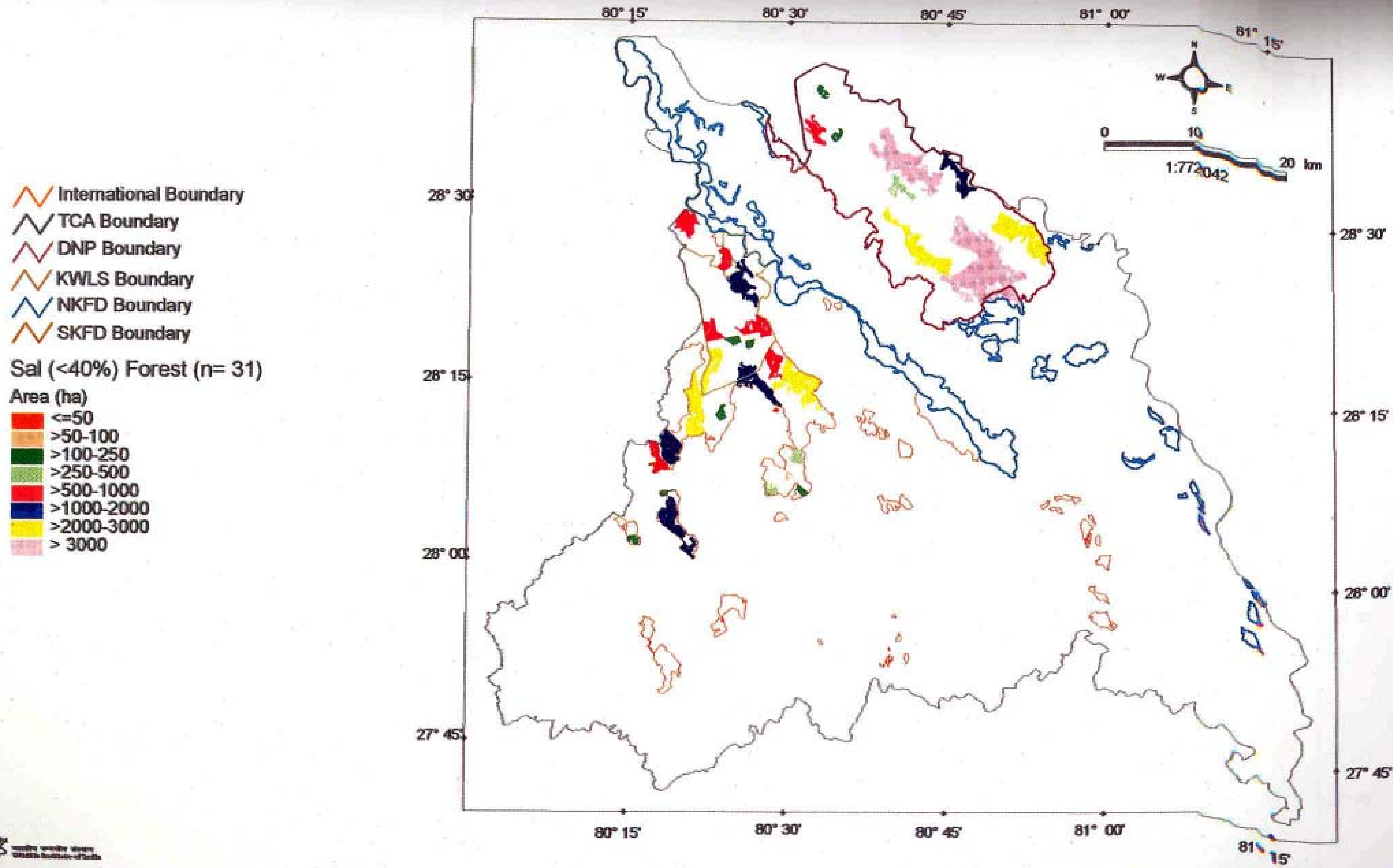


Fig. 2.15 - Distribution of Sal Mixed Forest Patches in TCA

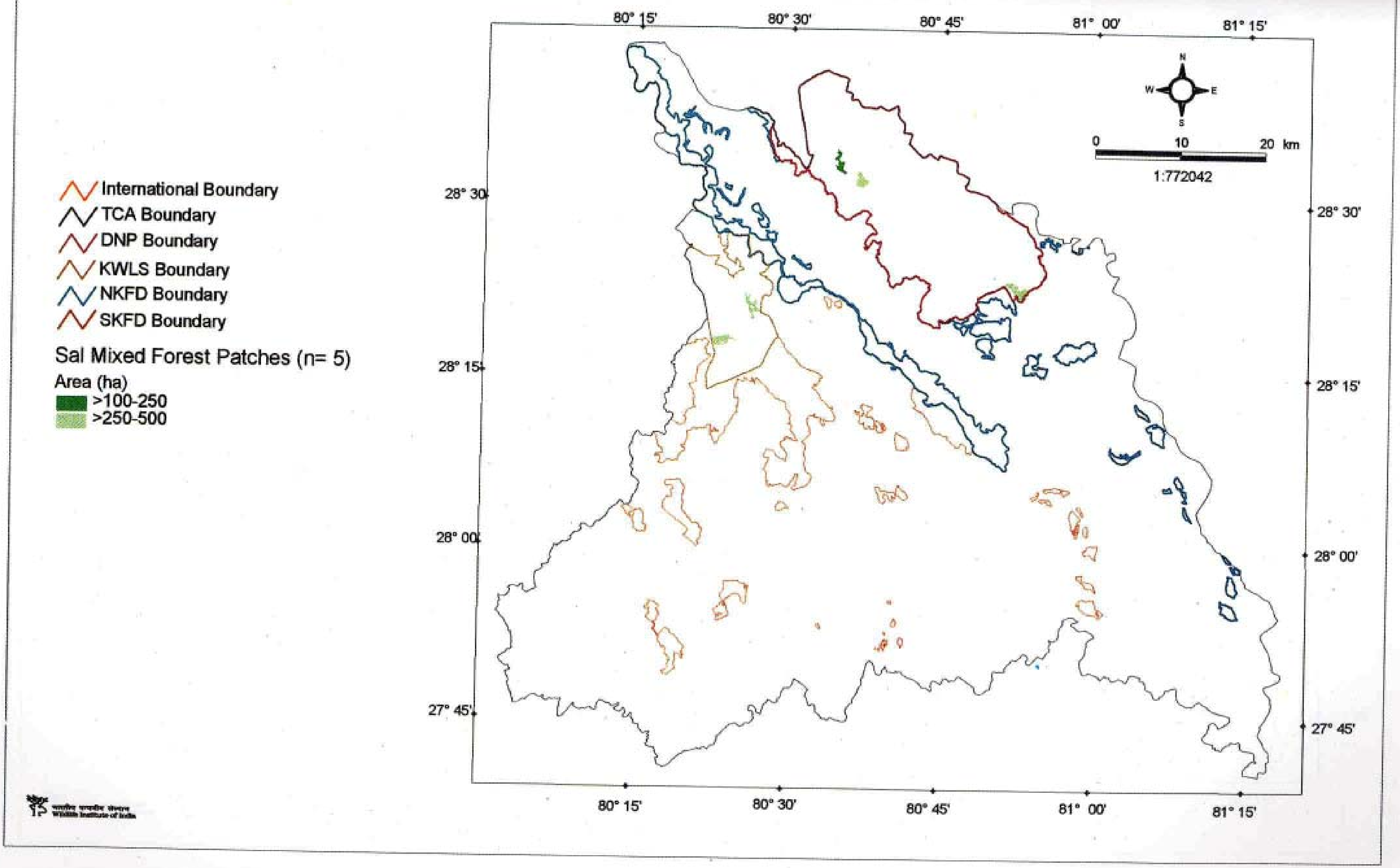


Fig. 2.16 - Distribution of *Chandar* Sal Forest Patches in TCA

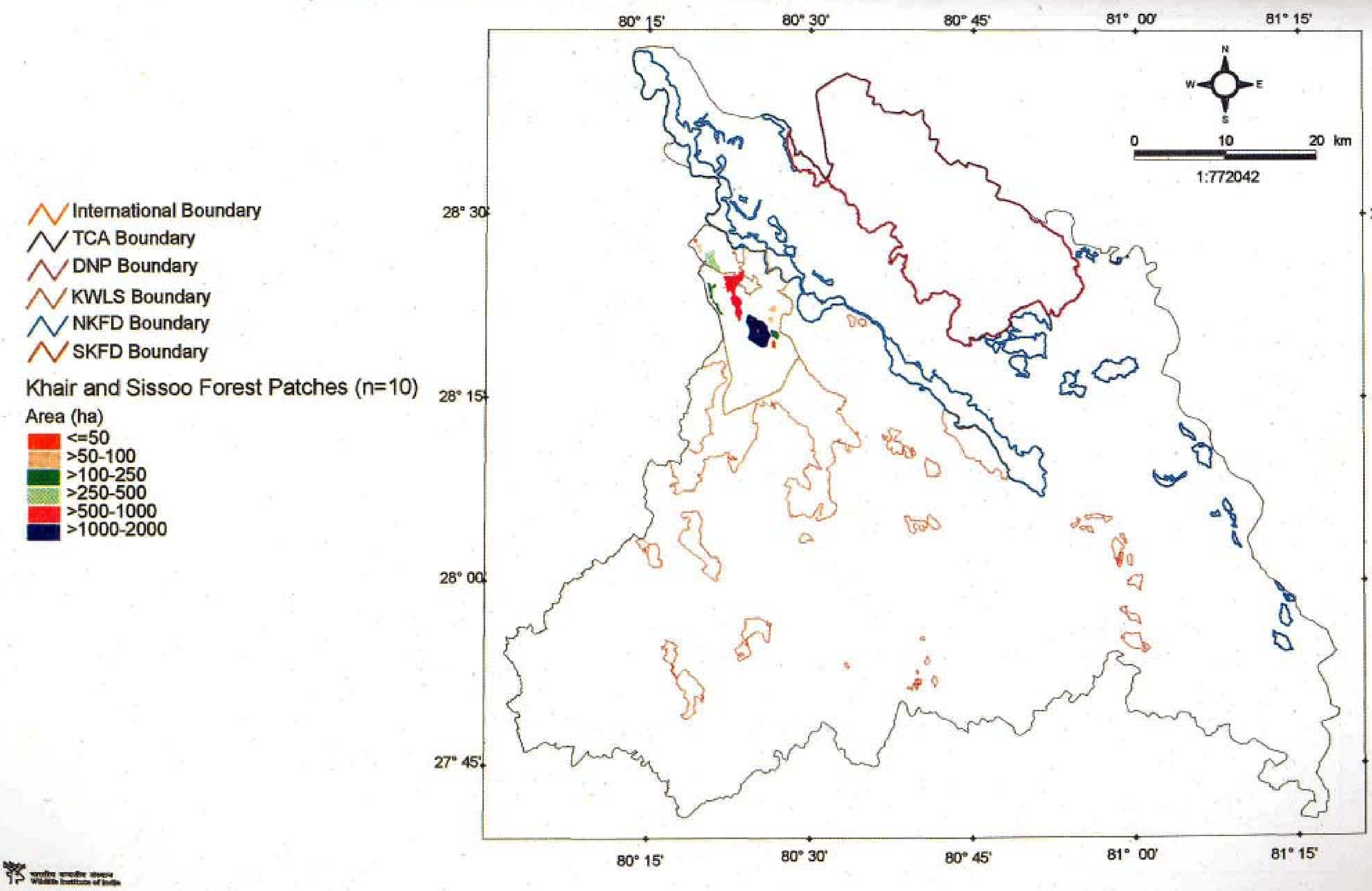


Fig. 2.17 - Distribution of Moist Mixed Deciduous Forest Patches in TCA

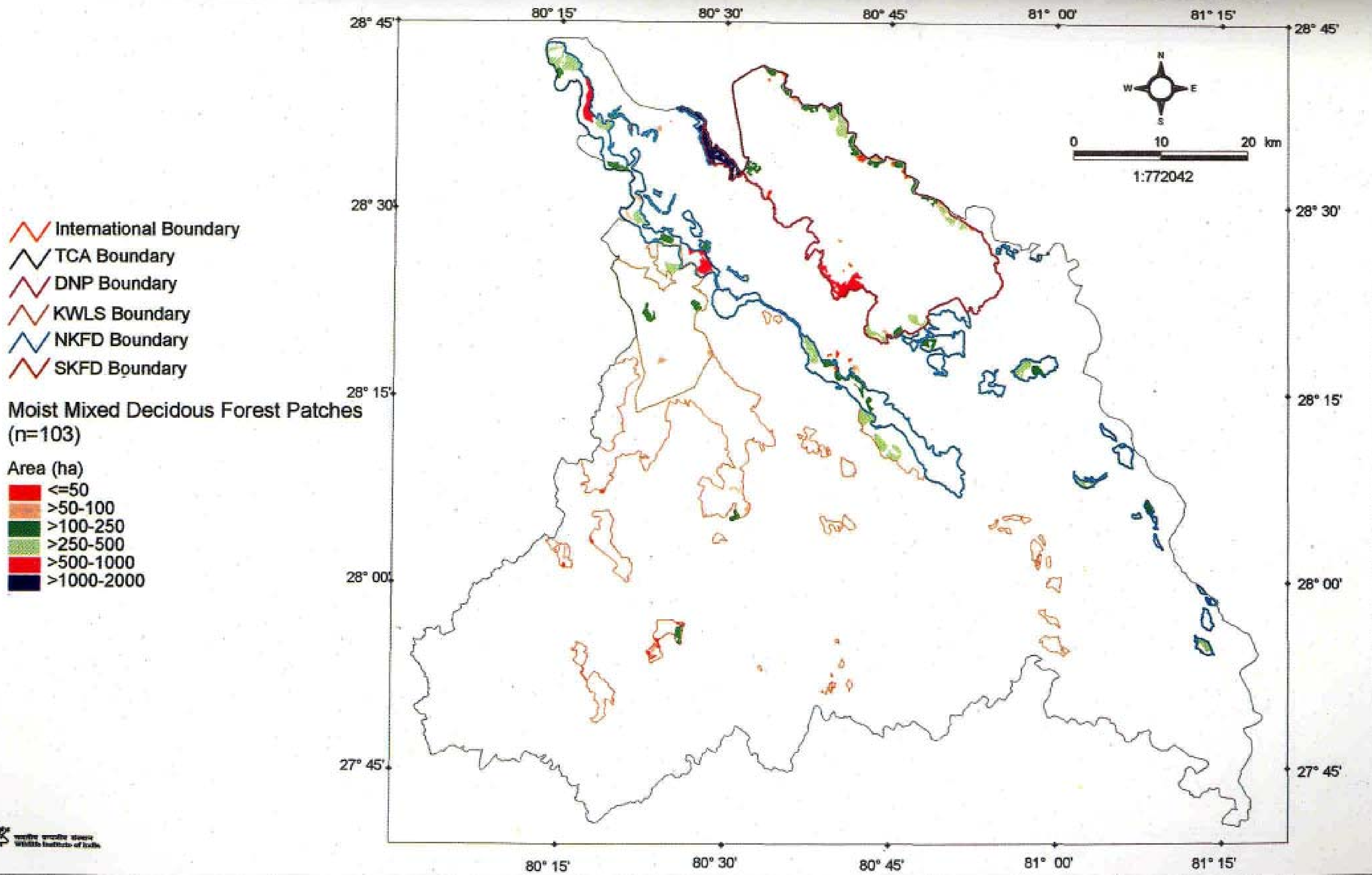


Fig. 2.18 - Distribution of Tropical Semi-Evergreen Forest Patches in TCA

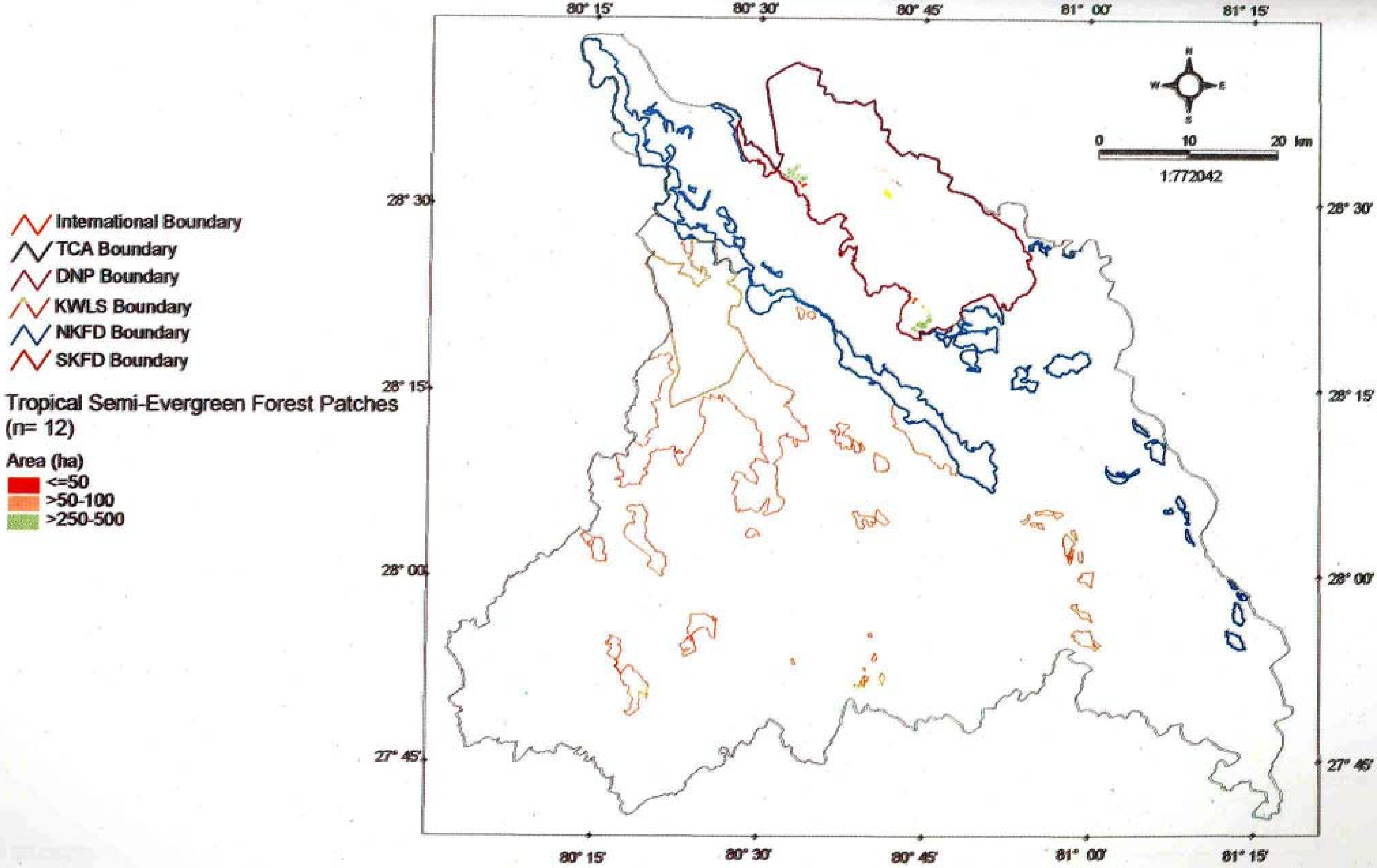


Fig. 2.19 - Distribution of Tropical Seasonal Swamp Forest Patches in TCA

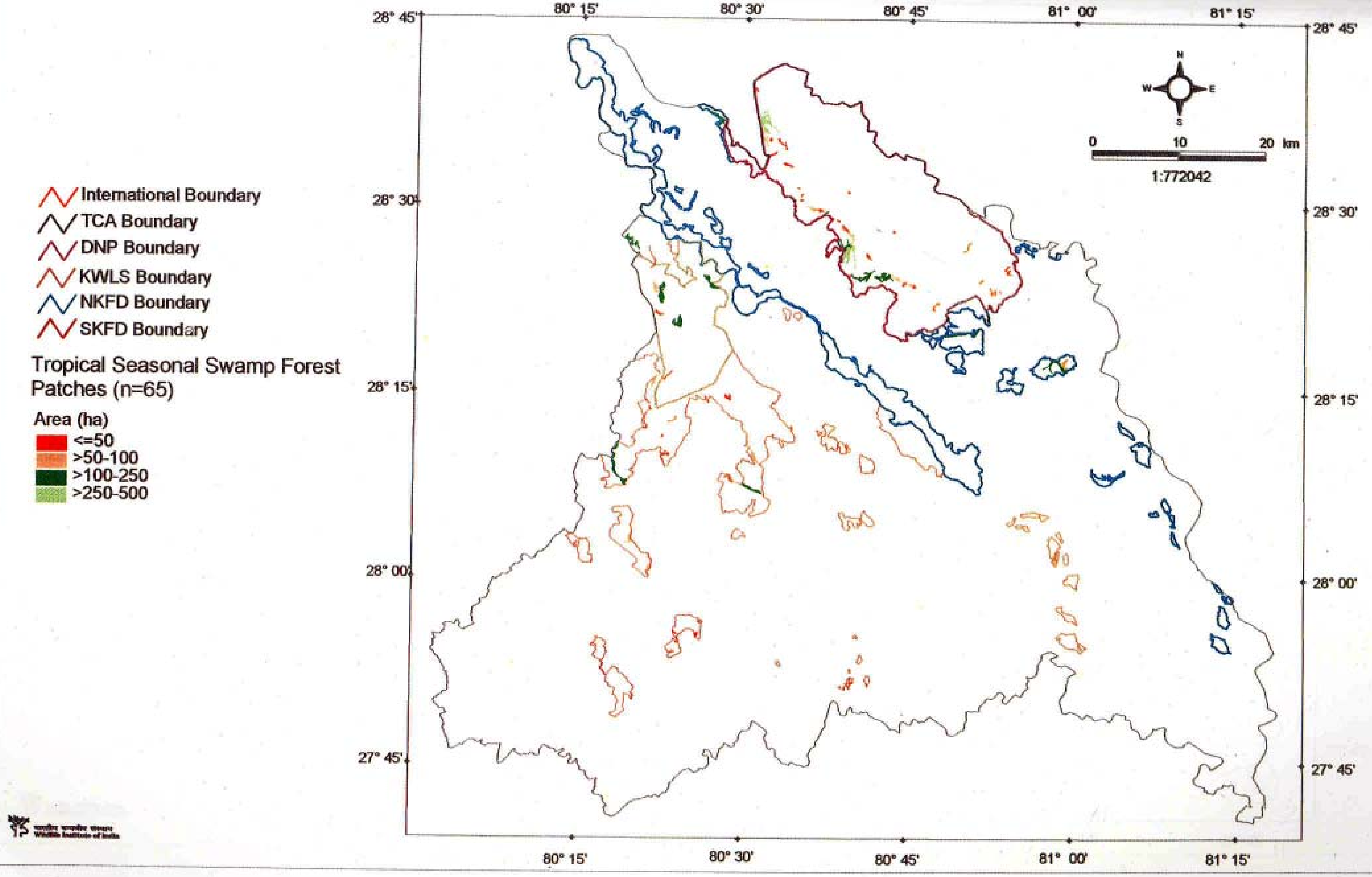


Fig. 2.20 - Distribution of Khair and Sissoo Forest Patches in TCA

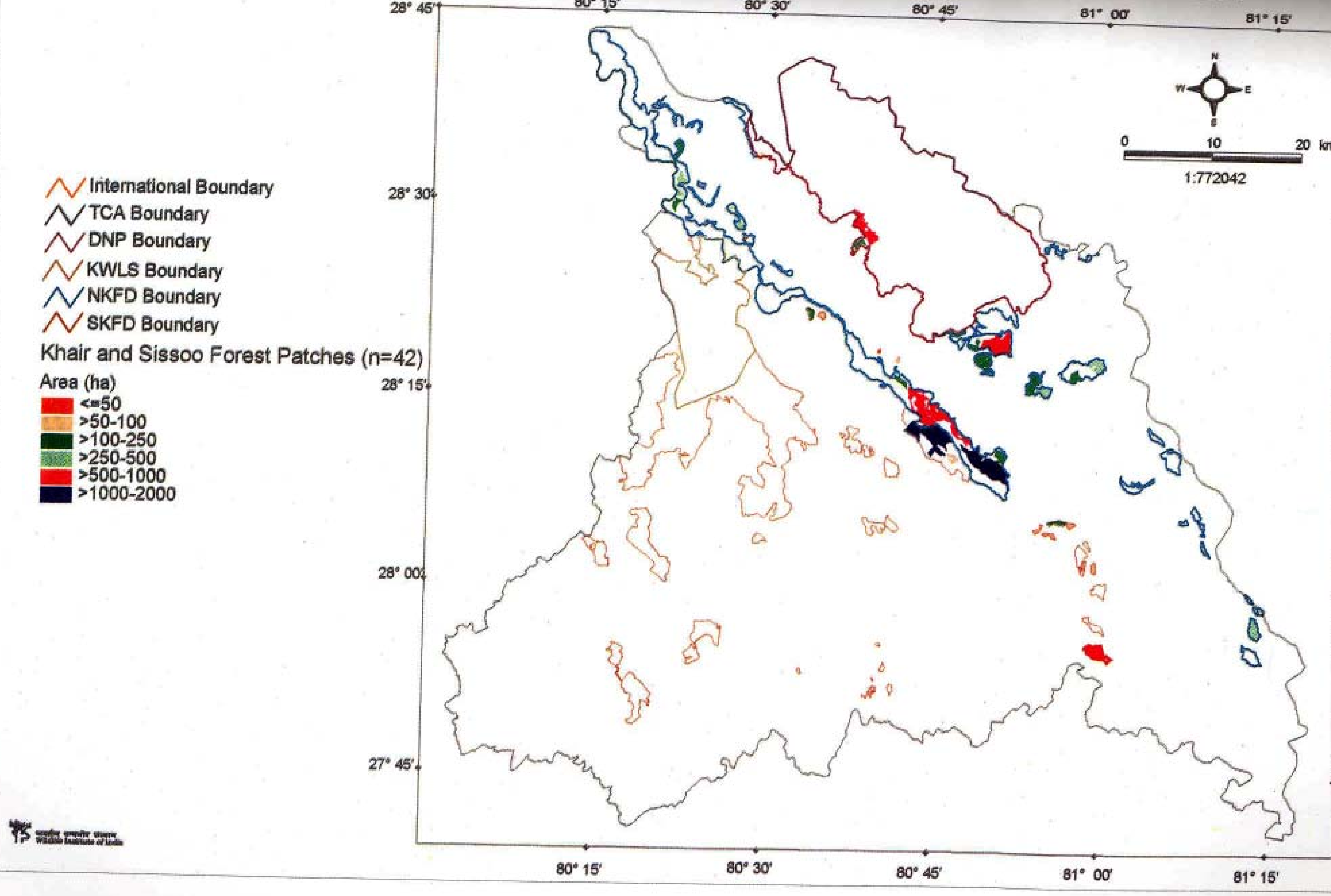


Fig. 2.21- Distribution of Upland and Lowland Grassland Patches in TCA

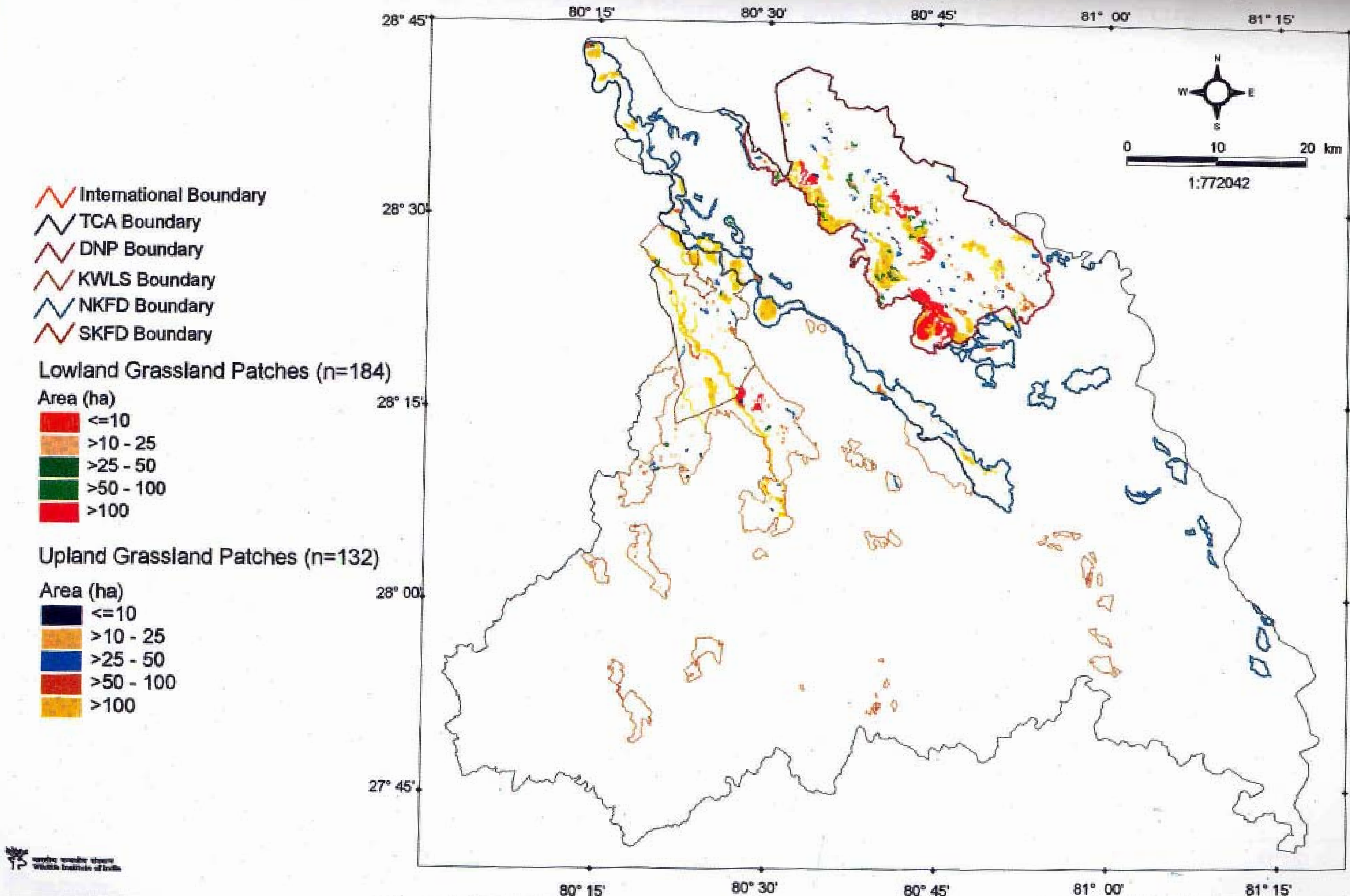
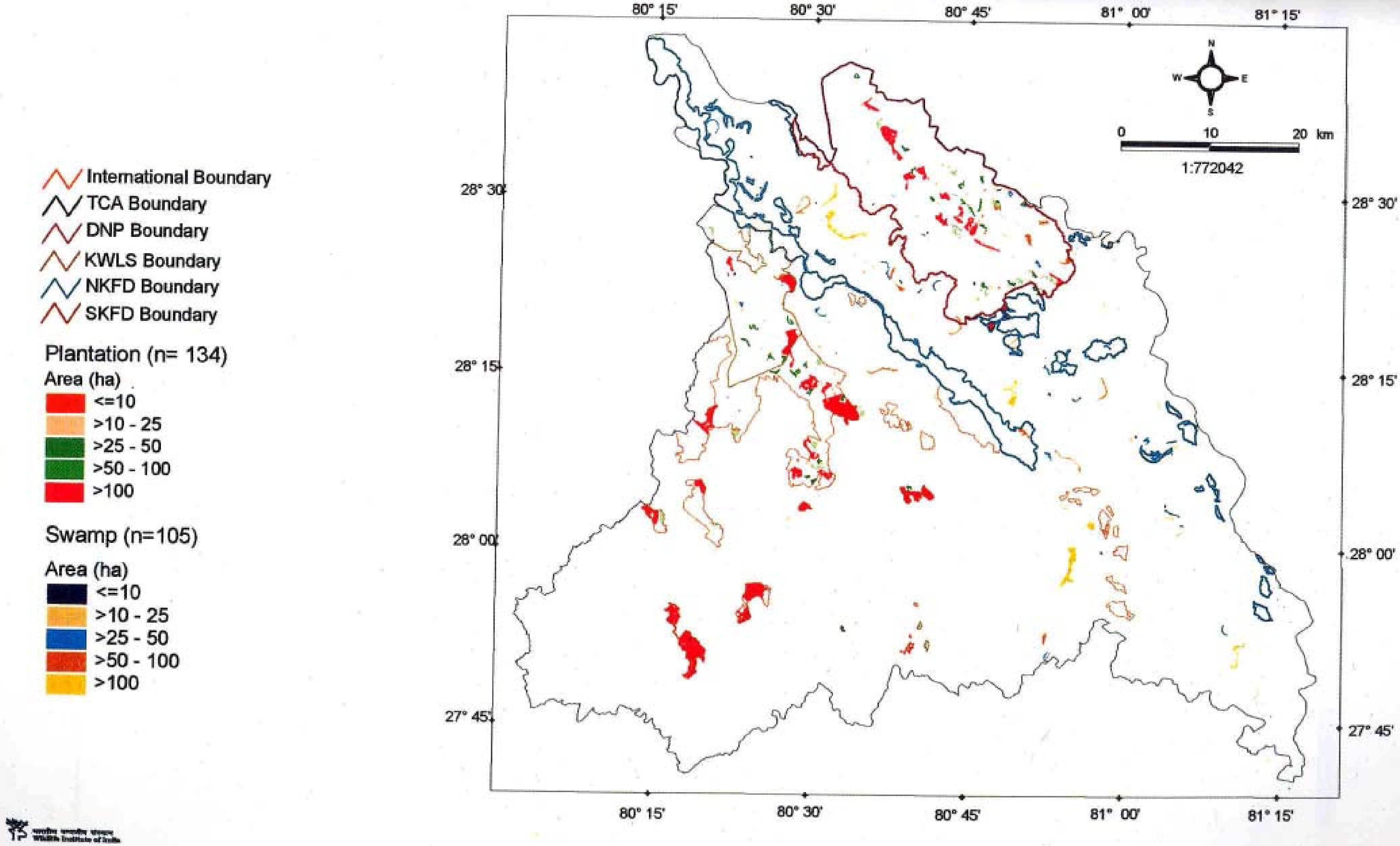


Fig. 2.22 - Distribution of Plantation and Swamp Patches in TCA



Chapter 3

Forest Vegetation – Composition and Diversity

3.1 Forest Vegetation

Forests are dynamic mosaics driven by disturbance and biotic processes. Forests structure, composition, and ecological processes change over a vast range of spatial and temporal scales. Therefore, the condition of vegetation in a stand, landscape, or region is product of the interplay of forces of disturbance and biotic development on a stage set by patterns and dynamics of climate, soil and landforms (Hunter, 1999). Vegetation is universally recognized as a component of major importance in site evaluation and classification; it integrates the effect of many interacting factors, and key species may indicate specific site conditions (Barnes *et al*., 1998). Vegetation is strongly controlled by macro and micro-climate, floristically complex, dynamic and varies in occurrence, abundance, coverage, biomass and vertical layering. These attributes of vegetation are of major significance in animal ecology and wildlife management.

3.2 Methods of Vegetation Assessment

Different methods were employed for the vegetation assessment in TCA so as to: (i) decipher and compare patterns among various vegetation types, (ii) evaluate the effect of two broad forest management options (Protected areas – PAs and managed forests- MFs); and (iii) compare vegetation diversity in four constituent areas. As stated earlier, the Dudwa NP and Kishanpur WLS, two PAs have been protected and managed for wildlife objectives for the over past two decades while in the case of NKFD and SKFD, two MFs, systematic silvicultural management or production forestry has been practiced.

3.2.1 Stratification and Sampling

Samples were distributed on the basis of vegetation types, management unit, and patch size. Thirteen (13) vegetation types (forests, Upland and Lowland grasslands and plantations) identified in the landscape through the vegetation map constituted the primary basis for the detailed vegetation sampling. Each of the vegetation type was adequately sampled in each of the constituent area (DNP, KWLS, NKFD and SKFD) of the landscape. Patches of varying sizes in different vegetation types and constituent areas were delineated and sampled to ensure representative samples of different patch sizes. In the case of sal forests, large, medium and small patches were >20 sq km, 10-20 sq km and <10 sq km area, respectively. In other categories of forests and grasslands, large, medium and small forest patches covered>5 sq km, 1-5 sq km, and <1 sq km area, respectively.

3.2.2 Forest Vegetation

The size of the quadrat for tree assessment in major forest types was determined by species area curves (Mishra, 1968; Mueller-Dombois and Ellenberg, 1974). The species-area curves were flattened at 400 sq m (20m x 20m). Thus, a sample plot size of 20m x 20m = 400 sq m was fixed for tree sampling. Likewise, the sample size i.e. the minimum number of quadrats required to study a particular type of forest or forest patch was also determined. In general, a minimum of 10 quadrats were laid to sample the minimum forest patch (~0.5 sq km). Quadrats were distributed at 200 m intervals within patches along transects of varying length (2-3.5 km) so as to systematically cover the patch. Altogether, 1,748 tree plots (20m x 20m) were sampled in 10 forest types (including plantations) and the Upland grassland (**Table 3.1**). Additionally, 60 plots were laid in the *Tamarix* scrub type for shrubs ((10m x 10m) and ground vegetation (1m x 1m). This vegetation type on river islands was devoid of trees. The allocation of sampled quadrats for each of the constituent area is also provided in **Table 3.1**. In all, 1,052 quadrats were sampled for trees in two PAs and 796 quadrats were laid in the two MFs. The distribution of 1,748 quadrats amongs 103 forest patches is given in **Table 3.2**. Additionally, 159 plots were sampled in the Lowland grassland.

Table 3.1 - Quadrats Sampled for Trees, Shrubs and Ground Vegetation in Different Vegetation types and Four Constituent Areas *viz.,* Dudwa National Park (DNP), Kishanpur Wildlife Sanctuary (KWLS), South Kheri Forest Division (SKFD) and North Kheri Forest Division (NKFD)

Vegetation Types	Constituent Areas				Total
	DNP	KWLS	SKFD	NKFD	Quadrats
Dense Sal Forest	149	-	-	-	149
Moderately Closed Sal Forest	112	51	97	-	260
Open Sal Forest	92	68	111	20	291
Sal Mixed Forest	30	31	-	-	61
Chandar Sal Forest	-	43	15	-	58
Moist Mixed Deciduous Forest	76	33	28	64	201
Tropical Semi-Evergreen Forest	31	-	-	-	-
Tropical Seasonal Swamp Forest	56	31	72	39	198
Khair and Sissoo Forest	36	-	32	92	160
Plantations	85	38	62	20	205
Upland Grasslands	60	30	20	24	134
Total Quadrats Sampled for Tree Assessment	**727**	**325**	**437**	**259**	**1, 748**
Lowland Grasslands	85	30	20	24	159
Tamarix Scrub	--	20	20	20	60
Total Quadrats Sampled for Shrub and Ground Vegetation Assessment	**812**	**375**	**477**	**303**	**1,967**

The four sides (the outermost trees) of the quadrats were marked with green paint and each quadrat was numbered. Quadrat boundaries were demarcated by rope and also by 1.5 m iron pegs at the four corners. Individuals of tree species with >30 cm girth at breast height and >3 m height with a distinct bole were considered trees. In each plot, the species, their individuals and girth at breast height (GBH) in cm of each tree were recorded. A nested plot of 10m x 10m (100 sq m) was marked within the larger plot for shrubs. Woody species with GBH <30 cm, height <3m and those branching from the base of the stem were considered shrubs (Muller-Dombois and Ellenberg, 1974). The species were identified and their number of individuals in each case were recorded. Forest plots were sampled during November, 1997 to February, 2001 prior to the onset of summer and fire season. Existing checklists from forest inventories (trees, shrubs, herbs, sedges, grasses and ferns) along with local names of plants wherever available were the basis of initial identification of plants. Knowledge of field staff on local names was also appropriately used. The specimens of doubtful and unidentified plants were collected, dried and preserved for subsequent identification by the Herbarium Section of the Wildlife Institute of India, Dehra Dun. The Flora of Dudwa National Park (Singh, 1997) and the Flora of Uttar Pradesh (Khanna *et al.,* 1998) were also used for identification and nomenclature. The book on name changes and synonyms by Bennet (1987) was also used to confirm names wherever necessary.

3.2.3 Grasslands

Broadly, two type of grasslands *viz.,* Upland and Lowland grasslands were deciphered and sampled for their composition and diversity. The Upland grasslands had sparsed trees, while Lowland grasslands were devoid of trees, mainly due to their annual flooding and burning. Quadrats 10m x 10m were laid in the Lowland grasslands for the assessment of shrub, herb, sedge and grass diversity. Data collection in grasslands was carried out in the post-rainy season i.e. October-December, 1999 and 2000, when the majority of grasses and other herbs were flowering, aiding identification, and also just before grasses were ready to be burnt in January-February.

In Lowland grasslands that were inaccessible due to surrounding swamps, plots (10m x 10m) were marked and quantified riding an elephant. Cover/abundance for each species was rated on the Domin scale (1-10, or a "+" for solitary plants). This was done as described by Mueller-Dombois and Ellenberg (1974). Unknown species were described, numbered, and collected for later identification.

3.2.4 Vegetation Analyses

Data analysis was performed at the four levels: (i) the entire landscape; (ii) each vegetation type; (iii) each constituent area; and (iv) protected areas (DNP and KWLS) *vs* managed forests (NKFD and SKFD).

Table 3.2 – Selected Forest and Grassland Patches and Sampled Quadrats in Different Vegetation Types for Assessment of Vegetation Diversity

Vegetation Types	Patch Type					
	Large		Medium		Small	
	Area sq km	Quadrats Sampled	Area sq km	Quadrats Sampled	Area sq km	Quadrats Sampled
Dense Sal Forest	30.8	60	13.3	20	3.8	14
	21.1	45			1.4	10
Moderately Closed Sal Forest	43.9	36	19.9	12	5.3	18
	29.9	34	19.8	18	4.0	16
	22.0	28	16.6	20		
			16.4	18		
			12.5	27		
			11.9	15		
			11.8	18		
Open Sal Forest	73.1	54	15.4	17	8.8	12
	25.9	24	13.4	56	7.1	15
			11.2	16	6.6	16
			10.2	18	3.7	26
					3.2	12
					1.7	11
					0.8	14
Sal Mixed Forest					2.9	14
					2.5	16
					3.4	16
					3.1	15
Chandar Sal Forest			10.5	16	9.1	17
					3.5	15
					0.48	10
Moist Mixed Deciduous Forest	15.1	10	2.9	9	0.38	15
	9.4	20	1.5	18	0.40	14
			1.5	24	0.70	12
			1.3	20	0.98	15
			1.2	10	0.07	12
			1.2	12		
Tropical Seasonal Swamp Forest			3.6	27	0.96	21
			2.9	18	0.19	10
			1.1	18	0.39	15
			2.3	16	0.47	18
			1.4	16		
			1.0	21		
			1.0	18		
Tropical Semi-Evergreen Forest			4.8	16	0.31	15
Khair & Sissoo Forest	14.1	20	2.3	10	0.30	15
	9.5	17	1.4	16		
	9.1	29	1.5	16		
	6.4	20	1.3	17		
Plantations	13.6	10	3.5	12	0.97	10
	5.4	20	3.4	10	0.88	12
	5.4	10	1.1	10	0.39	15
			1.5	10	0.47	10
			1.9	10	0.52	10
			2.1	10	0.47	16
			1.1	10	0.19	10
					0.39	10

Contd...

Table 3.3 Contd...

Vegetation Types	Patch Type: Large Area sq km	Large Quadrats Sampled	Medium Area sq km	Medium Quadrats Sampled	Small Area sq km	Small Quadrats Sampled
Upland Grassland	16.0	15	3.6	15	0.24	10
			1.9	10	0.21	10
			2.4	10	0.27	10
					0.06	10
					0.21	10
					0.23	10
					0.16	12
					0.18	12
Lowland Grassland	14.5	20	4.6	10	0.80	10
	12.4	20	5.1	15	0.83	10
	19.2	20	3.9	10	0.48	10
			2.5	10		
			1.6	14		
			1.7	10		
Tamarix Scrub			4.4	10	0.84	10
			1.8	10	0.17	10
					0.40	10
					0.9	10

Corresponding data sets for the above four levels were analyzed for the following:

(a) Presence/absence of species in the landscape, each vegetation type, constituent areas, PAs and MFs.

(b) Total number of represented plant families, genera and species for each of the above categories.

(c) Percentage frequency, abundance, basal area and density as per Mishra (1968). The Importance Value Index (IVI) for each tree species was determined (Curtis, 1950; Mishra, 1968). In case of shrubs, herbs, grasses, sedges and ferns, values of density and abundance were computed.

(d) The girth class distribution of important tree species in standard classes with an interval of 30 cm each was determined.

(e) Diversity indices (Richness, Diversity and Evenness) using software package 'STATECOL" Programme in BASIC were determined.

The vegetation data was analysed for frequency (F), density (D), and abundance (A). The term abundance and density represent the numerical strength of species in the community. Frequency, if considered along with abundance, gives an idea of the distribution pattern of the species while the later represents the number of individuals per unit area. The density and frequency taken together are of prime importance in determining community structure and have a variety of uses far beyond those of other quantitative values (Mishra, 1968). The Importance Value Index (IVI) was computed for each of the tree species by adding the relative values of frequency, density and dominance (basal area) or abundance following Mishra, (1968), Zhang and Cao, (1995). Abundance, density and per cent frequency values for each species were computed using the following formulae:

$$\% \text{ Frequency} = \frac{\text{No. of sample plots in which the species occurred}}{\text{Total no. of studied sample plots}} \times 100$$

$$\text{Abundance} = \frac{\text{Total no. of individuals of a species in all sampled plots}}{\text{No. of sampling plots of occurrence}}$$

$$\text{Density} = \frac{\text{Total no. of individuals of a species in all plots}}{\text{Total no. of studied sample plots}}$$

Diversity Indices: Diversity of communities can be assessed using 'species richness' (measure of total number of species in a sampling area), species abundance model or evenness (how the abundance data are distributed among the species) and indices based on the proportioned abundance of the species. Over the years a number of indices have been proposed for characterizing species richness and evenness. Such indices are termed as richness and evenness indices. For better clarity, these terms/indices and their formulae are explained below:

Species Richness (NO): The number of species in a community or in a sampling area is referred as species richness. Margalef (1958) has given an index for species richness:

Where, S = the total number of species in a community
N = sampling points

$$\text{Margalef Index } \mathbf{R} = \frac{S-1}{\ln(n)}$$

'Higher the value of R means greater species richness'.

Species Evenness or Equitability: Evenness refers to how the species abundances (e.g., the number of individuals, biomass, cover etc.) are distributed among the species. Shannon's Index (H') was used in the present study.

Shannon's Index – H': The Shannon Index (H') has probably been the most widely used index in community ecology. It is based on information theory (Shannon and Weaver, 1949) and is a measure of the average degree of "uncertainty" in predicting to what species an individual chosen at random from a collection of S species and N individuals will belong. This average uncertainty increases as the number of species increases and as the distribution of individuals among the species becomes even.

The equation for the Shannon function, which uses natural logarithms (In), is Where H' is the average uncertainty per

$$H' = \sum_{i=I}^{S*} (p_i \ln p_i)$$

species in a infinite community made up of S* species with known proportional abundances p_1, p_2, p_3..........ps; S* and p_i s are population parameters and, in practice, H' is estimated from a sample as

$$H' = \sum_{i=I}^{S} \left[\left(\frac{n_1}{n}\right)\left(\frac{n_1}{n}\right) \right]$$

Where n_i is the number of individuals belonging to the ith of S species in the sample and n is the total number of individuals in the sample.

"Maximum the value of H' means all S species are represented by the same number of individuals, that is, a perfectly even distribution of abundances".

(f) SPSS (Statistical Package for Social Sciences, Version 8.0) statistical analysis software was used for cluster analysis using tree data collected for the entire landscape. Data on number of individuals for each recorded tree species in sampled quadrats was employed for cluster analysis. Each sample plot in a particular forest type was treated as a separate cluster and combined clusters until one were left. Ward's cluster method and Euclidean distance interval were followed for cluster analysis. Dendrogram was plotted to assess the cohesiveness of the clusters formed.

The grassland classification analysis was carried out using the polythetic divisive clustering technique TWINSPAN (Hill, 1979). Pseudospecies cut levels were set at

2%, 5%, 25%, 50%, and 75% cover, whilst all other options were set to default levels. The groups resulting from the TWINSPAN analysis are summarized in the present study by including only indicator species and strongly preferential species for each group to avoid producing long lists of species (Peet *et al.,* 1997).

(g) The Family Importance Value (FIV) on the basis of corresponding tree species in each family was computed using the values of relative density, relative diversity and relative dominance as per the following formulae (Ganesh *et. al.,* 1996)

FIV = relative density + relative diversity + relative dominance (for all numbers of a given plant family combined)

Relative density = (number of individuals of the species x 100)/total number of individuals in the sample

Relative diversity = (number of species in the family x 100)/total number of species in the sample

Relative dominance= (basal area of the family x100) /total basal area in the sample

3.2 The Results – Forest Vegetation

The forested landscape exhibited rich plant diversity owing to a variety of factors – physiography, topography, climate, biotic interactions, disturbance, past management and succession. The landscape spatial heterogeneity in terms of landuse/land cover types (forest and non-forest categories) in TCA has already been described in the previous Chapter. The present section specifically deals with the vegetation structure and composition in each of the identified vegetation type, constituent area and the overall landscape.

3.3.1 Vegetation Types

Forests in TCA predominantly belong to the Tropical Moist Deciduous type and can be broadly grouped in four categories *viz.,* Moist Sal (*Shorea robusta)* forests, Moist Mixed Deciduous forests, Swamp forests and Savannah (**Plate 2.1**). According to the revised classification of the Forest Types of India given by Champion and Seth (1968), forest plans relevant to TCA have described the four major Groups and several edaphic forest types (Chandra, 1972; De, 2001). The vegetation types mapped in the present study using the satellite data and their probable corresponding forest types those have been earlier described by the previous Forest Plans are presented in **Table 3.3**. The cluster analysis using tree data resulted into a vegetation classification depicted in a dendogram (**Fig. 3.1**). This classification was based on the similarities in tree abundance pattern. The first cluster was formed by grouping moderately closed Sal forests and open Sal forests. This cluster later joined with the dense Sal forests. Thus, all Sal forest types were grouped together. *Chandar* Sal and Sal Mixed forests could not be separated as their corresponding tree species merged with dense Sal forest and moderately closed Sal forest, respectively. Khair and Sissoo forests and the Upland grassland clustered together. The Tropical Seasonal Swamp forests showed affinity with Tropical Semi-Evergreen forests. Plantations were distinctly separated out. Details of different vegetation types mapped are as under:

3.3.1.1 Tropical Semi-Evergreen Forest

This forest type occurred in more or less permanently wet/moist soils consist of fine clay and rich in humus. It prominently occurred along the perennial streams (*nalahs*) and also near swamps (*taals*) in DNP. Prominent tree species *viz., Syzygium cumini, Ficus racemosa* and *Mallotus philippensis* occurred in this forest. Other associated tree species were: *Trewia nudiflora, Schleichera oleosa* and *Syzygium cerasoides. Ardisia solanacea* and *Murraya koenigii were* prominent shrubs. Climbers *Tiliacora acuminata* and cane (*Calamus tenuis*) commonly occurred. Fern (*Lygodium flexuosum*) was conspicuous.

3.3.1.2 Sal Forest

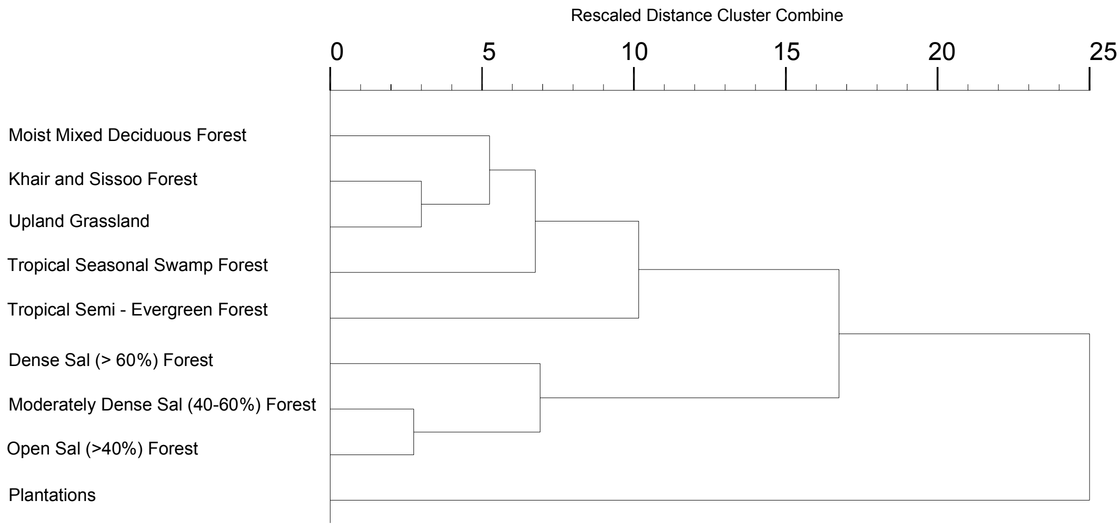
Sal (*Shorea robusta*) occupied a major part of the forestland. Some of the best Sal forests occurred on higher alluvial terraces (*damars*) with loamy soils. Other important associated species found were *Terminalia alata* and *Lagerstromia parviflora*. The middle storey comprised of *Mallotus philippensis* and *Millusa velutina*. Profuse growth of *Syzygium cumini* and *Scheleichera oleosa* along streams occurred. The forest undergrowth was composed of *Ardisia solanacea, Colebrookia oppositifolia, Clerodendron viscosum, Murraya koenigii, Fleminigia macrophylla* and

Plate 3.1 - Different Vegetation Types in TCA

Table 3.3 - Vegetation Types Mapped Using Satellite Data and Corresponding Forest Types As Described in Different Forest Plans

Vegetation Types (Mapped) Using Satellite Data	Corresponding Forest Types (Champion and Seth, 1968) as Described by Chandra (1972) and De (2001) in Previous Forest Plans		
Tropical Semi-Evergreen Forest	Group 2	–	Tropical Semi-Evergreen Forest
	Sub-Group 2B	–	Northern Tropical Semi-Evergreen Forest
	Type	–	2B/E1 (Cane Brakes)
Dense Sal Forest	Group 3	–	Tropical Moist Deciduous Forest
Moderately Closed Sal Forest	Sub-Group 3C	–	North Indian Moist Deciduous Forest
Open Sal Forest	Types	–	3 C/C2b(ii) *Damar* Sal Forest
		–	3C/C2b(ii)/ 3C/C2d(i) *Damar* Sal/Western Light Alluvium Plains Sal
Sal Mixed Forest	Group 3	–	Tropical Moist Deciduous Forest
	Sub-Group 3C	–	North Indian Moist Deciduous Forest
		–	3C/C2b-C2D(i) Moist Bhabhar Sal – Western Light Alluvial Plains Sal
	Group 3	–	Tropical Moist Deciduous Forest
Chandar Sal Forest	Sub-Group 3C	–	North Indian Moist Deciduous Forest
		–	3C/C2d(i) App. *Chandar* Sal Forest
Moist Mixed Deciduous Forest	Group 3	–	Tropical Moist Deciduous Forest
	Sub-Group 3C	–	North Indian Moist Deciduous Forest
		–	3C/C2D(i) Western Light Alluvial Plains Sal and the floristic variant South Kheri Type
		–	3C/C2d(i) / 5B/C1b Western Light Alluvial Plains Sal and Sub-Group 5B – Northern Tropical Deciduous Forest
		–	5B/C1b Dry Plains Sal Forest
Tropical Seasonal Swamp Forest	Group 4	–	Littoral and Swamp Forest
	Sub-Group 4D	–	Tropical Seasonal Swamp Forest
	Type	–	4D/SS2 *Barringtonia* Swamp Forest
		–	4D/353 *Syzygium cumini* Swamp Low Forest
Khair and Sissoo (*Acacia catechu* and *Dalbergia sissoo*) Forest	Group 5	–	Tropical Dry Deciduous Forest
	Sub-Group 5B	–	Northern Tropical Dry Deciduous Forest
	Type	–	5B/IS2 Khair – Sissoo Forest
Tamarix Scrub	Sub Group 5B	–	Northern Tropical Dry Deciduous Forest
	Types	–	5B/IS3 Inundated Babul Forest
		–	5B/DS1 Dry Deciduous Scrub
Plantations	Mainly Teak (*Tectona grandis*) and *Eucalyptus* plantations		
	Group 3	–	Tropical Moist Deciduous Forest
Upland Grassland	Sub-Group 3C	–	North Indian Moist Deciduous Forest
		–	3C/C2/DSI – Moist Sal Savannah
	Group 3	–	Tropical Moist Deciduous Forest
Lowland Grassland	Sub-Group 3C	–	North Indian Moist Deciduous Forest
		–	3C/ISI – Low Alluvial Savannah Woodland

Fig.3.1 – Dendrogram Showing Vegetation Classification Using *Hierarchical Cluster Analysis*



Glycosmis *pentaphylla*. *Phoenix aculis* and *Helicteres isora* also occurred. Woody climber *Tiliacora acuminata* formed a dense carpet on ground in several patches. *Calamus tenuis* could also be seen in moist places along streams. Teak (*Tectona grandis*) has been successfully introduced in several places by clear felling as well as gap planting. Varied species composition was seen in slightly low lying areas or less drained areas. Prominent grass species recorded were *Desmostachya bipinnata*, *Themeda arundinacea*, *Saccharum bengalense*, *Saccharum spontaneum* and *Imperata cylindrica*. Three distinct Sal forest types *viz.,* dense Sal, moderately closed Sal, and open Sal were deciphered based on the corresponding canopy cover classes (>60%, 40-60% and <40%) and their respective colour, texture, and tone in the satellite imageries.

3.3.1.3 Sal Mixed Forest

Basically this forest type occurred only in five patches, that too in two protected areas. These forests confined on the gentle slopes, old river terraces around grasslands in Belghat, Chandpara and Mohrania blocks of DNP. The over-wood was composed of scattered old Sal and *Terminalia alata* trees with majority middle aged trees. Regeneration of Sal was poor. No distinct feature in shrub and herb layer was observed to characterize this forest type from the above Sal forests.

3.3.1.4 *Chandar* Sal Forest

This type of forest occurred in frost affected areas of KWLS and SKFD. Severe frost in most years has kill back all Sal growth under 5 m or so in height. Frosty *Chandars* have either allowed partial or full growth of Sal. The soil is light to very alluvium on a dry sub-soil. Despite severe frost conditions, the Sal saplings have at many places managed to establish and fairly dense pole crop can be seen. The *Chandar* Sal have been recognized as a special type of savannah land, representing a sub-climax on which frost is the chief limiting factor (De, 2001). *Chandars* are mostly covered by tall coarse grasses and *Themeda arundinacea* predominated. The presence of *Eulaliopsis binata* in some patches was conspicuous. Stunted coppice growth is usually mixed up with grasses. Usually a number of shoots springs up from each root stock and from April to about the mid December a good coppice crop of Sal can be seen. In winter the coppice shoots die back and the dry stems get burnt in the deliberate or accidental fires. The root stocks survive the frost and fire and produce new coppice shoots in the next season. *Mallotus philippensis, Bauhinia racemosa, Syzygium cumini* and *Bridelia squamosa* were the main associates with *Chandar* Sal.

3.3.1.5 Moist Mixed Deciduous Forest

The absence of Sal was conspicuous in these forests. The presence of miscellaneous species has made these forests highly diverse. These forests generally occurred on sandy alluvium. Teak (*Tectona grandis*) and *Eucalyptus citriodora* have been successfully introduced. *Mallotus philippensis, Syzygium cumini, Trewia nudiflora, Dalbergia sissoo, Ficus racemosa* and *Acacia catechu* were the main constituents of these forests. *Terminalia alata, Haldina cordifolia, Braussonetia papyrifera, Millusa velutina* and *Streblus asper* also occassionally occurred. *Clerodendrum viscosum, Ardisia solanacea* and *Glycosmis pentaphylla* were the prominent shrubs. Climber *Tiliacora acuminata* was encountered in a good proportion.

3.3.1.6 Tropical Seasonal Swamp Forest

This forest type was found in swampy depressions along streams which remain under water continuously for a long period during the rains or where deep black heavy waterlogged soils occurred. Previous forest plans relevant to TCA have described two sub-types *viz., Barringtonia* swamp forests and *Syzygium cumini* dominated forests. In the present study, both these types have been grouped together and designated as the Tropical Seasonal Swamp forest. Soil aeration is usually poor and the soils are rich in humus. *Syzygium cumini* was the main constituent tree species in such forests. *Barringtonia acutangula* dominated patches occurred along the Ull and Katna rivers in SKFD. *Trewia nudiflora, Terminalia alata, Lagerstromea parviflora* and *Ficus racemosa* were the prominent co-associates. *Clerodendrum viscosum, Glycosmis pentaphylla* and *Murraya koenigii* were the prominent shrubs. *Corchorus aestuans, Dioscorea belophylla* and *Ageratum conyzoides* were the important herbs in this type of forest. *Syzygium cumini* formed a dense crop with long clean boles.

3.3.1.7 Khair and Sissoo Forest

The Khair (*Acacia catechu*) and Sissoo (*Dalbergia sissoo*) type of forest occurred on new sandy alluvium along streams and rivers (Suheli, Mohana, Ghagra and Sharda). These forests were mixed with heavy growth of grasses. Regeneration of both species was scarce, as these forests are prone to fire. Flooding and prolonged water logging of these forests result into poor and stunted growth of Khair and Sissoo. *Bombax ceiba, Haldina cordifolia* and *Catunaregam spinosa* were co-associates. *Clerodendrum viscosum, Triumfetta pilosa, Glycosmis pentaphylla and Ziziphus mauritiana* were important shrubs in such forest. *Lantana camara* and *Calotropis procera* also occurred in these forests. *Cassia tora, Commelina attenuata* and *Dioscorea belophylla* were prominent herbs.

3.3.1.8 Plantations

Extensive plantations of *Acacia catechu, Dalbergia sissoo, Bombax ceiba, Ailanthus excelsa, Tectona grandis* and *Eucalyptus citriodora* have been raised as gap planting as well as after clear felling. During recent decades, large scale mechanised plantations of teak (*Tectona grandis*) and *Eucalyptus* were raised. *Eucalyptus* plantations were successful in grasslands or 'grassy blanks'.

3.3.1.9 Upland grassland

This type was characterized by the occurrence of 'grassy blanks' or 'phantas' inside the moist sal forests. These grasslands occurred on well-drained soils. These grasslands occupied large areas and were scattered. Possible three explantations for the occurrence of such vast 'phantas' have been documented (De, 2001). Accordingly, such areas were either probably old camping sites for passing caravans or such areas are frost prone pockets where tree growth is retarded. The most probable explanation appears to be that these are old river beds of pre-historic lakes or swamps, which have silted up and are devoid of tree growth. This explanation is supported by the fact that the 'phantas' are elongated in shape and are in the general direction of the drainage. Further, tubewell borings in such areas have exposed not only gravel and pebbles but also bones of marine life. Some Upland grasslands have scattered tree growth of species such as *Bombax ceiba, Syzygium cerasoides, Dalbergia sissoo, Randia uliginosa, Haldina cordifolia* and *Acacia catechu*. The undergrowth consists of *Helecteres isora* and dense grass. The dominant grasses vary from place to place depending upon the soil type, drainage and management conditions. *Arundo donax, Phragmites karka* and *Sclerostachya fusca* were thus found in swampy locations while *Themeda arundinacea* occurred in fairly well drained soils and *Imperata cylindrica, Desmostachya bipinnata, Cymbopogon jwarancusa, Saccharum spontaneum* and *S. bengalense* were found over clayey soil.

3.3.1.10 Lowland grassland

This type of grasslands occurred in low lying areas/ depressions which were water logged or marshy in nature. Such areas had alluvial soils, mostly sandy with clayey patches. Depressions mark the old river channels. Frost was common especially in the low-lying areas. These areas got annually burnt. The prominent species occurring in the higher area were *Bombax ceiba, Haldina cordifolia, Butea monosperma, Dalbergia sissoo, Albizia lebbeck, Scheleichera oleosa* and *Syzygium cumini*. In the low-lying areas, prominent species were *Bombax ceiba, Ficus racemosa* and *Syzygium cumini*. Prominent grasses were *Saccharum spontaneum, Arundo donax, Phragmites karka, Themeda arundinacea, Sclerostachya fusca* and *Saccharum narenga*. These grasslands have interspersed swamps.

3.3.1.11 *Tamarix* Scrub

This type occurred on the river islands of Sharda and Ghagra rivers. These islands were of fresh alluvium and devoid of trees. Shrub *Tamarix dioica* dominated these islands. At places, *Ziziphus mauritiana* was also seen. *Saccharum spontaneum* was the dominant grass species.

3.3.2 Species Composition

Plant species diversity in the overall landscape, its four constituent areas and different vegetation types is described below one by one.

3.3.2.1 Landscape

Intensive vegetation sampling in above described forest and grassland types of TCA revealed a floral diversity of 259 plant species belonging to 199 genera and 76 families (**Table 3.4**). This included 96 tree, 38 shrub, 89 herb, 25 grass, 6 sedge and 5 fern species (**Table 3.5**). Out of recorded 259 species, 215 were Dicotyledons and 44 were Monocotyledons. The ratio of families belonging to Monocotyledons to Dicotyledons was 1:4.84, of genera 1:4.85, and of species 1:4.88. Despite intensive systematic sampling, the present study recorded a much lower plant diversity than earlier described 821 species of Angiosperms belonging to 489 genera and 120 families in Dudwa National Park and adjacent areas of Kheri District based on the botanical exploration (Singh, 1997). In this case, the ratio of families belonging to

Table 3.4 - Representation of Plant Families, Genera and Species in TCA and Four Constituent Areas

Area	Families	Genera	Species
Terai Conservation Area (TCA) – Present Study	76	199	259
Dicotyledons	63	165	215
Monocotyledons	13	34	44
Dudwa National Park (DNP)	73	192	249
Kishanpur Wildlife Sanctuary (KWLS)	69	159	181
North Kheri Forest Division (NKFD)	60	122	143
South Kheri Forest Division (SKFD)	65	128	154
Kheri District (Singh, 1997)	120	489	821

Monocotyledons to Dicotyledons was 1:4.76, of genera 1:3.75, and of species 1:3.41. The lower plant diversity recorded in the present study can be mainly attributed to the exclusion of aquatic and cultivated plants, poor representation of several highly localized, seasonal and rare herbs and other short lived annual grasses.

Except for the members of the families Poaceae and Cyperaceae, the Monocotyledons were rather poorly represented. Ten dominant families based on higher representation of genera and species were: Poaceae, Fabaceae, Moraceae, Euphorbiaceae, Asteraceae, Rubiaceae. The most dominant family i.e. Poaceae was represented by 21 genera and 25 species. The Fabaceae was the second most dominant family with 17 genera and 21 species (**Table 3.6**).

3.3.2.2 Constituent Areas

Among the four constituent areas, DNP harboured the maximum plant diversity in terms of represented families, genera and species i.e. 73, 192 and 249, respectively (**Table 3.4**). The least diverse was the NKFD. This was obvious due to the absence of five forest types (Tropical Semi Evergreen, dense Sal, moderately closed Sal, Sal Mixed and *Chandar* Sal forests) in NKFD.

Table 3.5 - Representation (Presence and Absence) of Trees, Shrubs, Herbs, Grasses, Sedges and Ferns in Four Constituent Areas of TCA

Sl. No.	Species	Family	DNP n = 727	KWLS n = 325	NKFD n= 259	SKFD n = 437	Total Quadrats (n = 1, 748) and Presence in Constituent Areas*
A	**Trees**						
1	*Albizia procera*	Mimosaceae	*				1
2	*Alstonia scholaris*	Apocynaceae	*				1
3	*Antidesma acidum*	Euphorbiaceae		*			1
4	*Careya arborea*	Lecythidaceae		*			1
5	*Casearia graveolens*	Flacourtiaceae	*				1
6	*Catunaregam uliginosa*	Rubiaceae	*				1
7	*Ficus semicordata*	Moraceae	*				1
8	*Ficus oligodon*	Moraceae	*				1
9	*Ficus palmata*	Moraceae	*				1
10	*Gardenia turgida*	Rubiaceae	*				1
11	*Gmelina arborea*	Verbenaceae	*				1
12	*Grewia sapida*	Tiliaceae	*				1
13	*Lagerstoemia speciosa*	Lythraceae	*				1
14	*Lepisanthes rubiginosa*	Sapindaceae	*				1
15	*Miliusa tomentosa*	Annonaceae	*				1
16	*Emblica officinalis*	Euphorbiaceae	*				1
17	*Premna latifolia*	Verbenaceae		*			1
18	*Randia tetrasperma*	Rubiaceae	*				1
19	*Terminalia chebula*	Combretaceae	*				1
20	*Albizia lebbeck*	Mimosaceae		*	*		2
21	*Artocarpus lakoocha*	Moraceae	*	*			2
22	*Azidarachta indica*	Meliaceae			*	*	2
23	*Barringtonia acutangula*	Lecythidaceae			*	*	2
24	*Bauhinia variegata*	Caesalpiniaceae	*		*		2
25	*Braussonetia papyrifera*	Moraceae	*		*		2
26	*Celtis tetrandra*	Urticaceae	*		*		2
27	*Cordia dichotoma*	Boraginaceae	*			*	2
28	*Dillenia pentagyna*	Dillieniaceae			*	*	2
29	*Garuga pinnata*	Burseraceae	*	*			2
30	*Kydia calycina*	Malvaceae		*		*	2
31	*Mangifera indica*	Anarcardiaceae	*			*	2
32	*Melia azedarach*	Meliaceae	*	*			2
33	*Pithecellobium dulce*	Mimosaceae	*			*	2
34	*Pterocarpus marsupium*	Fabaceae	*	*			2
35	*Pterospermum acerifolium*	Sterculiaceae		*		*	2
36	*Sapindus mukorossi*	Sapindaceae	*	*			2
37	*Acacia nilotica*	Mimosaceae	*	*	*		3
38	*Cassine glaca*	Celastraceae	*		*	*	3
39	*Citrus medica*	Rutaceae	*		*	*	3
40	*Drypetes roxburghii*	Euphorbiaceae	*		*	*	3

Contd...

Table 3.5 Contd...

Sl. No.	Species	Family	DNP n = 727	KWLS n = 325	NKFD n= 259	SKFD n = 437	Total Quadrats (n = 1, 748) and Presence in Constituent Areas*
41	*Ficus benghalensis*	Moraceae	*		*	*	3
42	*Ficus rumphii*	Moraceae	*		*	*	3
43	*Ficus virens*	Moraceae	*	*	*		3
44	*Grewia disperma*	Tiliaceae	*	*		*	3
45	*Grewia elastica*	Tiliaceae	*	*	*		3
46	*Moringa oleifera*	Moringaceae	*		*	*	3
47	*Morus alba*	Moraceae	*	*	*		3
48	*Pongamia pinnata*	Fabaceae	*	*	*		3
49	*Psidium gujava*	Myrtaceae	*		*	*	3
50	*Sterculia villosa*	Sterculiaceae		*	*	*	3
51	*Syzygium cerasoides*	Myrtaceae	*	*		*	3
52	*Terminalia arjuna*	Combretaceae	*		*	*	3
53	*Toona ciliata*	Meliaceae	*	*		*	3
54	*Acacia catechu*	Mimosaceae	*	*	*	*	4
55	*Acacia concinna*	Mimosaceae	*	*	*	*	4
56	*Aegle marmelos*	Rutaceae	*	*	*	*	4
57	*Albizia chinensis*	Mimosaceae	*	*	*	*	4
58	*Bauhinia racemosa*	Caesalpiniaceae	*	*	*	*	4
59	*Bombax ceiba*	Bombacaceae	*	*	*	*	4
60	*Bridelia squamosa*	Euphorbiaceae	*	*	*	*	4
61	*Butea monosperma*	Fabaceae	*	*	*	*	4
62	*Casearia elliptica*	Flacourtiaceae	*	*	*	*	4
63	*Casearia tomentosa*	Flacourtiaceae	*	*	*	*	4
64	*Cassia fistula*	Caesalpiniaceae	*	*	*	*	4
65	*Catunaregam spinosa*	Rubiaceae	*	*	*	*	4
66	*Dalbergia sissoo*	Fabaceae	*	*	*	*	4
67	*Diospyros melanoxylon*	Ebenaceae	*	*	*	*	4
68	*Ehretia laevis*	Boraginaceae	*	*	*	*	4
69	*Eucalyptus citriodora*	Myrtaceae	*	*	*	*	4
70	*Ficus hispida*	Moraceae	*	*	*	*	4
71	*Ficus racemosa*	Moraceae	*	*	*	*	4
72	*Ficus religiosa*	Moraceae	*	*	*	*	4
73	*Flacourtia indica*	Flacourtiaceae	*	*	*	*	4
74	*Haldina cordifolia*	Rubiaceae	*	*	*	*	4
75	*Holarrhena pubescens*	Apocynaceae	*	*	*	*	4
76	*Holoptelea integrifolia*	Ulmaceae	*	*	*	*	4
77	*Hymendictyon orixense*	Rubiaceae	*	*	*	*	4
78	*Lagerstroemia parvifolia*	Lythraceae	*	*	*	*	4
79	*Lannea coromandelica*	Anacardiaceae	*	*	*	*	4
80	*Litsea glutinosa*	Lauraceae	*	*	*	*	4
81	*Madhuca longifolia*	Sapotaceae	*	*	*	*	4

Contd...

Table 3.5 Contd...

Sl. No.	Species	Family	DNP n = 727	KWLS n = 325	NKFD n= 259	SKFD n = 437	Total Quadrats (n = 1, 748) and Presence in Constituent Areas*
82	*Mallotus philippensis*	Euphorbiaceae	*	*	*	*	4
83	*Miliusa velutina*	Annonaceae	*	*	*	*	4
84	*Mitragyna parvifolia*	Rubiaceae	*	*	*	*	4
85	*Ougeinia oojeinensis*	Fabaceae	*	*	*	*	4
86	*Schleichera oleosa*	Sapindaceae	*	*	*	*	4
87	*Semecarpus anacardium*	Anarcardiaceae	*	*	*	*	4
88	*Shorea robusta*	Dipterocarpaceae	*	*	*	*	4
89	*Spondias pinnata*	Anarcardiaceae	*	*	*	*	4
90	*Streblus asper*	Moraceae	*	*	*	*	4
91	*Syzygium cumini*	Myrtaceae	*	*	*	*	4
92	*Tectona grandis*	Verbenaceae	*	*	*	*	4
93	*Terminalia alata*	Combretaceae	*	*	*	*	4
94	*Terminalia bellirica*	Combretaceae	*	*	*	*	4
95	*Trewia nudiflora*	Euphorbiaceae	*	*	*	*	4
96	*Ziziphus xylopyra*	Rhamnaceae	*	*	*	*	4
	Total Tree Species		**86**	**63**	**64**	**63**	
B	**Shrubs**						
1	*Clerodendrum indicum*	Verbenaceae	*				1
2	*Flemingia chappar*	Fabaceae	*				1
3	*Desmodium gangeticum*	Fabaceae	*				1
4	*Desmodium motorium*	Fabaceae	*				1
5	*Desmodium pulchellum*	Fabaceae	*				1
6	*Desmodium triflorum*	Fabaceae	*				1
7	*Callicarpa macrophylla*	Verbenaceae	*	*	*		2
8	*Calotropis procera*	Asclepiadaceae	*		*	*	2
9	*Sesbania bispinosa*	Fabaceae	*			*	2
10	*Sesbania sesban*	Fabaceae	*		*		2
11	*Calotropis gigantea*	Asclepiadaceae	*	*			2
12	*Erthyrina resupinata*	Fabaceae	*	*			2
13	*Ventilago denticulata*	Rhamnaceae	*	*			2
14	*Asparagus adscendens*	Liliaceae	*	*		*	3
15	*Cassia occidentalis*	Ceasalpiniaceae	*		*	*	3
16	*Clerodendrum serratum*	Verbenaceae	*		*	*	3
17	*Leea asiatica*	Leeaceae	*		*	*	3
18	*Securinega virosa*	Euphorbiaceae	*		*	*	3
19	*Thespesia lampas*	Malvaceae	*	*		*	3
20	*Triumfetta pilosa*	Tiliaceae	*		*	*	3
21	*Calamus tenuis*	Arecaceae	*		*	*	3
22	*Ichnocarpus frutescens*	Apocynaceae	*	*		*	3
23	*Ardisia solanacea*	Myrsinaceae	*	*	*	*	4

Contd...

Table 3.5 Contd...

Sl. No.	Species	Family	DNP n=812	KWLS n=375	NKFD n=303	SKFD n=477	Total Quadrats (n = 1, 967) and Presence in Constituent Areas*
24	*Carissa opaca*	Apocynaceae	*	*	*	*	4
25	*Glycosmis pentaphylla*	Rutaceae	*	*	*	*	4
26	*Clerodendrum viscosum*	Verbenaceae	*	*	*	*	4
27	*Colebrookea oppositifolia*	Lamiaceae	*	*	*	*	4
28	*Flemingia macrophylla*	Fabaceae	*	*	*	*	4
29	*Grewia hirsuta*	Tiliaceae	*	*	*	*	4
30	*Grewia sapida*	Tiliaceae	*	*	*	*	4
31	*Helicteres isora*	Sterculiaceae	*	*	*	*	4
32	*Lantana camara*	Verbenaceae	*	*	*	*	4
33	*Murraya koenigii*	Rutaceae	*	*	*	*	4
34	*Phoenix acaulis*	Arecaceae	*	*	*	*	4
35	*Ziziphus mauritiana*	Rhamnaceae	*	*	*	*	4
36	*Tamarix dioica*	Tamaricaceae	*	*	*	*	4
37	*Tiliacora acuminata*	Menispermaceae	*	*	*	*	4
38	*Securinega leucopyrus*	Euphorbiaceae	*	*	*	*	4
	Total Shrub Species		**38**	**23**	**25**	**27**	
C	**Herbs**						
1	*Abelmoschus crinitus*	Malvaceae	*				1
2	*Anisomeles indica*	Lamiaceae	*				1
3	*Arnebia hispidissima*	Boraginaceae	*				1
4	*Cayratia trifolia*	Vitaceae	*				1
5	*Cleome gynandra*	Cleomaceae	*				1
6	*Curcuma angustifolia*	Zingiberaceae	*				1
7	*Diclitptera roxburghiana*	Acanthaceae	*				1
8	*Erigeron sublyratus*	Asteraceae	*				1
9	*Evolvulus alsinoides*	Convolvulaceae	*				1
10	*Gnaphalium luteo-album*	Asteraceae	*				1
11	*Hemigraphis hirta*	Acanthaceae	*				1
12	*Lactuca dolichophylla*	Asteraceae	*				1
13	*Launaea acaulis*	Asteraceae	*				1
14	*Malvastrum coromandelianum*	Malvaceae	*				1
15	*Martynia annua*	Martyniaceae	*				1
16	*Melilotus alba*	Fabaceae	*				1
17	*Oldenlandia corymbosa*	Rubiaceae	*				1
18	*Polygonum barbatum*	Polygonaceae	*				1
19	*Rauvolfia serpentina*	Apocynaceae	*				1
20	*Saussurea heteromalla*	Asteraceae	*				1
21	*Sida rhombifolia*	Malvaceae	*				1
22	*Withania somnifera*	Solanaceae	*				1
23	*Aeschynomene indica*	Fabaceae	*	*			2
24	*Atylosia scarabaeoides*	Fabaceae	*	*			2

Contd...

Table 3.5 Contd...

Sl. No.	Species	Family	DNP n=812	KWLS n=375	NKFD n=303	SKFD n=477	Total Quadrats (n = 1, 967) and Presence in constituent Areas*
25	*Blumea hieracifolia*	Asteraceae	*	*			2
26	*Borreria articularis*	Rubiaceae	*		*		2
27	*Borreria pusilla*	Rubiaceae	*	*			2
32	*Eulophia dabia*	Orchidaceae	*	*			2
33	*Euphorbia hirta*	Euphorbiaceae	*	*			2
34	*Euphorbia hypericifolia*	Euphorbiaceae	*	*			2
35	*Heliotropium strigosum*	Boraginaceae	*	*			2
36	*Heliotropium zeylanicum*	Boraginaceae	*	*			2
37	*Hygrophila auriculata*	Acanthaceae	*		*		2
38	*Leea alata*	Leeaceae	*	*			2
39	*Lysimachia candida*	Primulaceae	*	*			2
40	*Naravelia zeylanica*	Ranunculaceae	*		*		2
41	*Pentanema indicum*	Asteraceae	*	*			2
42	*Polygala arvensis*	Polygalaceae	*	*			2
43	*Polygala crotalarioides*	Polygalaceae	*	*			2
44	*Polygonum plebeium*	Polygonaceae	*	*			2
45	*Rhynchosia minima*	Fabaceae	*	*			2
46	*Sphaeranthus indicus*	Asteraceae	*	*			2
47	*Swertia angustifolia*	Gentianaceae	*	*			2
48	*Vicia hirsuta*	Fabaceae	*	*			2
49	*Arisaema tortuosum*	Araceae	*	*	*		3
50	*Biophytum sensitivum*	Oxalidaceae	*	*	*		3
51	*Blumea lacera*	Asteraceae	*	*	*		3
52	*Cissampelos pariera*	Menispermaceae	*	*	*		3
53	*Crotalaria albida*	Fabaceae	*	*	*		3
54	*Curculigo orchioides*	Amaryllidaceae	*	*		*	3
55	*Dioscorea belophylla*	Dioscoreaceae	*	*	*		3
56	*Exacum tetragonum*	Gentianaceae	*	*	*		3
57	*Gloriosa superba*	Liliaceae	*	*	*		3
58	*Parthenium hysterophorus*	Asteraceae	*		*	*	3
59	*Trichodesma sedgwickianum*	Boraginaceae	*	*		*	3
60	*Typha elephantina*	Typhaceae	*	*	*		3
61	*Uraria picta*	Fabaceae	*	*	*		3
62	*Ageratum conyzoides*	Asteraceae	*	*	*	*	4
63	*Alternanthera sessilis*	Amaranthaceae	*	*	*	*	4
64	*Amaranthus spinosus*	Amaranthaceae	*	*	*	*	4
65	*Amaranthus viridis*	Amaranthaceae	*	*	*	*	4
66	*Argemone mexicana*	Papaveraceae	*	*	*	*	4
67	*Blumea mollis*	Asteraceae	*	*	*	*	4
68	*Cannabis sativa*	Cannabaceae	*	*	*	*	4
69	*Cassia tora*	Caesalpiniaceae	*	*	*	*	4

Contd...

Table 3.5 Contd...

Sl. No.	Species	Family	DNP n=812	KWLS n=375	NKFD n=303	SKFD n=477	Total Quadrats (n = 1, 967) and Presence in constituent Areas*
70	*Chenopodium album*	Chenopodiaceae	*	*	*	*	4
71	*Coccinia grandis*	Cucurbitaceae	*	*	*	*	4
72	*Corchorus aestuans*	Tiliaceae	*	*	*	*	4
73	*Curcuma amada*	Zingiberaceae	*	*	*	*	4
74	*Dioscorea hispida*	Dioscoreaceae	*	*	*	*	4
75	*Eclipta prostrata*	Asteraceae	*	*	*	*	4
76	*Evolvulus nummularius*	Convolvulaceae	*	*	*	*	4
77	*Ipomoea pes-tigridis*	Covolvulaceae	*	*	*	*	4
78	*Leucas cephalotes*	Lamiaceae	*	*	*	*	4
79	*Leucus mollissima*	Lamiaceae	*	*	*	*	4
80	*Mimosa pudica*	Mimosaceae	*	*	*	*	4
81	*Olax nana*	Olacaceae	*	*	*	*	4
82	*Oxalis corniculata*	Oxalidaceae	*	*	*	*	4
83	*Piper longum*	Piperaceae	*	*	*	*	4
84	*Polygonum hydropiper*	Polygonaceae	*	*	*	*	4
85	*Rungia pectinata*	Acanthaceae	*	*	*	*	4
86	*Selinm monnieri*	Apiaceae	*	*	*	*	4
87	*Solanum nigrum*	Solanaceae	*	*	*	*	4
88	*Solanum surattense*	Solanaceae	*	*	*	*	4
89	*Sonchus asper*	Asteraceae	*	*	*	*	4
	Total Herb Species		**89**	**63**	**42**	**31**	
D	**Grasses**						
1	*Arundo donax*	Poaceae	*				1
2	*Cymbopogon osmastonii*	Poaceae	*				1
3	*Oryza rufipogon*	Poaceae	*				1
4	*Arthraxon prionodes*	Poaceae	*				1
5	*Apluda mutica*	Poaceae	*	*			2
6	*Cymbopogon flexuosus*	Poaceae	*	*			2
7	*Cymbopogon jwarancusa*	Poaceae	*	*			2
8	*Dendrocalamus strictus*	Poaceae	*	*			2
9	*Sclerostachya fusca*	Poaceae	*	*			2
10	*Seteria verticillata*	Poaceae	*	*			2
11	*Paspalum paspalodes*	Poaceae	*	*			2
12	*Bothriochloa bladhii*	Poaceae	*	*	*	*	4
13	*Cynodon dactylon*	Poaceae	*	*	*	*	4
14	*Desmostachya bipinnata*	Poaceae	*	*	*	*	4
15	*Eulaliopsis binata*	Poaceae	*	*	*	*	4
16	*Heteropogon contortus*	Poaceae	*	*	*	*	4
17	*Imperata cylindrica*	Poaceae	*	*	*	*	4
18	*Phragmites karka*	Poaceae	*	*	*	*	4

Contd...

Table 3.5 Contd...

Sl. No.	Species	Family	DNP n=812	KWLS n=375	NKFD n=303	SKFD n=477	Total Quadrats (n = 1, 967) and Presence in Constituent Areas*
19	*Saccharum bengalense*	Poaceae	*	*	*	*	4
20	*Saccharum narenga*	Poaceae	*	*	*	*	4
21	*Saccharum spontaneum*	Poaceae	*	*	*	*	4
22	*Sorghum halepense*	Poaceae	*	*	*	*	4
23	*Themeda arundinacea*	Poaceae	*	*	*	*	4
24	*Vetiveria zizanioides*	Poaceae	*	*	*	*	4
25	*Hemarthria compressa*	Poaceae	*	*	*	*	4
	Total Grass Species		**25**	**21**	**14**	**14**	
E	**Sedges**						
1	*Scleria levis*	Cyperaceae	*	*			2
2	*Carex fedia*	Cyperaceae	*	*	*	*	4
3	*Cyperus iria*	Cyperaceae	*	*	*	*	4
4	*Cyperus kyllingia*	Cyperaceae	*	*	*	*	4
5	*Cyperus niveus*	Cyperaceae	*	*	*	*	4
6	*Fimbristylis dichotoma*	Cyperaceae	*	*	*	*	4
	Total Sedge Species		**6**	**6**	**5**	**5**	
F	**Ferns**						
1	*Diplazium esculentum*	Athyriaceae	*	*			2
2	*Adiantum lunulatum*	Adiantaceae	*	*	*		3
3	*Lygodium flexuosum*	Lygodiaceae	*	*	*	*	3
4	*Pteris vittata*	Pteridaceae	*	*	*	*	4
5	*Ceratopteris thalicteroides*	Parkeriaceae	*	*	*	*	4
	Total Fern Species		**5**	**5**	**4**	**3**	

Table 3.6 - Ten Dominant Families in TCA

Family	Genera	Species
Poaceae	21	25
Fabaceae	17	21
Moraceae	5	13
Euphorbiaceae	10	11
Asteraceae	5	11
Rubiaceae	4	8
Mimosaceae	4	8
Verbenaceae	6	8
Boraginaceae	7	7
Tiliaceae	3	7

The **Table 3.5** presents representation of habit-wise (tree, shrub, herb, grass, sedge and fern) plant diversity in four constituent areas of TCA. The number of tree species among the four constituent areas ranged from 63 (KWLS and SKFD) to 86 (DNP). Ten tree species *viz., Antidesma acidum, Careya arborea, Premna latifolia, Albizia lebbeck, Azadirachta indica, Barringtonia acutangula, Dillenia pentagyna, Kydia calycina, Pterospermum acerifolium* and *Sterculia villosa* could not be recorded through vegetation sampling (n=727) undertaken in DNP. Otherwise, these ten tree species were seen in the park area. Likewise, some of the tree species could not be recorded in KWLS, NKFD and SKFD through the vegetation sampling while they might have occurred in low number in those constituent areas. As in the case of trees, the maximum number of shrub species, being 38 was recorded in DNP while the minimum number of shrubs, being 23 was recorded in KWLS. Shrubs *viz., Clerodendrum indicum, Flemingia chappar* and four species of genus *Desmodium* (*D. gangeticum, D. pulchellum, D. triflorum* and *D. motorium*) were recorded only in DNP. These six species remained absent in sample plots laid in three other constituent areas. Sixteen shrub species (42.1%) were common to all the four constituent areas. Woody climbers *viz., Tiliacora acuminata* and *Calamus tenuis* were grouped with shrubs. The former often made a dense mat like profuse growth and was common throughout TCA.

The number of herb species varied from 31 to 89 in SKFD and DNP, respectively. Absence of almost 50% herb species in two managed forests (NKFD and SKFD) can be attributed due to high biotic disturbance i.e. grazing and fire. It seems that higher relative protection and consequent better soil conditions in the case of two PAs might have favoured enhanced herb diversity. Twenty-one herb species (31.4%) were common to all the constituent areas of the landscape.

Singh (1997) has described 77 grass species representing 54 genera in Kheri District. However, only 25 grass species belonging to 21 genera were recorded through intensive sampling in different forest and grassland types. Single species of bamboo i.e. *Dendrocalamus strictus* was recorded in two PAs only. Fourteen (14) grass species i.e. 56% of total grass species recorded in the present study were common to all the constituent areas of the landscape.

Only six species of sedges were recorded. *Scleria levis* occurred only in two PAs. Rest five sedge species recorded were common to all the constituent areas of the landscape.

Five species of ferns were recorded in TCA through intensive sampling. *Diplazium esculantum* was recorded in two PAs only. *Adiantum lunulatum* was absent in SKFD. Three fern species *viz., Lygodium flexuosum, Pteris vittata* and *Ceratopteris thalicteroides* were common to all the four constituent areas and they were widely distributed.

3.3.2.3 Vegetation Types

The variation in species composition among different vegetation types is summarized in **Table 3.7.** Tree, shrub, herb, and grass diversity in the landscape, constituent areas and each vegetation type is described below in detail.

3.3.3 Forest Diversity - Trees

The number of tree species among different vegetation types varied from 11 to 71. The lowest number of tree species was recorded in the case of Upland grassland while the highest number of tree species was obtained in the case of Moist Mixed Deciduous forest. Thus, the Moist Mixed Deciduous forest was highly diverse in terms of tree species, followed by Tropical Seasonal Swamp forest and open Sal forest with 65 and 59 tree species, respectively. Surprisingly, the Tropical Semi-Evergreen forest had only 25 tree species. This lowest value of tree species amongst all the forest types can be attributed to the fact that the present extent of Tropical Semi-Evergreen forests in DNP is just 10.8 sq km or covering only 0.6% of the forestland (see **Table 2.2**). This small extent was also distributed into 12 scattered patches, mostly occurring in peripheral areas of DNP (see **Table 2.13**). These forest patches experience maximum biotic disturbance due to their proximity to villages.

A gradual increase in tree species from 33 to 56 was observed while moving from dense Sal (>60%) forest to open Sal forest. This increase can be attributed to the fact that probably the opened canopy has favoured several miscellaneous species. The Sal Mixed forest had lower number of tree species, being 32, less than even the dense Sal forest. This lower number of tree species in Sal Mixed forest, on the contrary to expected

Table 3.7- Variation in Plant Species Composition Among Different Vegetation Types in

Vegetation Types	Number of Species						
	Trees	Shrubs	Herbs	Grasses	Sedges	Ferns	Total
Dense Sal Forest	33	15	08	01	1	5	63
Moderately Closed Sal Forest	56	19	11	02	1	5	94
Open Sal Forest	59	22	17	02	1	5	106
Sal Mixed Forest	32	10	06	02	1	5	56
Chandar Sal Forest	29	11	07	05	2	4	58
Tropical Semi-Evergreen Forest	25	08	07	02	2	5	49
Tropical Seasonal Swamp Forest	65	21	15	02	2	5	110
Moist Mixed Deciduous Forest	71	19	18	02	2	5	117
Khair and Sissoo Forest	36	17	16	06	2	4	81
Tamarix Scrub	-	02	04	02	3	5	16
Plantations	51	20	12	03	2	3	91
Upland Grassland	11	10	60	15	5	2	103
Lowland Grassland	-	13	80	17	6	5	121

higher number of species can be accounted to the fact that this forest type also occurred in small extent i.e. 17.4 sq km and that too distributed in just 5 patches. Probably poor soil conditions, past working and resultant poor regeneration of Sal and other species were the causative factors. Again, *Chandar* Sal forests had the second lowest number of tree species, being 29 among different forest types. The severe frost conditions and frequent burning of dense grass growth in such areas have prohibited regeneration and growth of frost and fire sensitive species. The Khair and Sissoo forests harboured a diversity of 36 tree species. The typical proximity of such forests, one side to river bank while other side to a village results into their seasonal flooding, frequent fire and livestock grazing. Such site conditions thus, allowed regeneration and growth of only flood, fire and grazing resistant tree species only.

Fourteen tree species or nearly 15% of the recorded tree species were just confined to any one forest type (**Table 3.8**). Thus, Albizia *procera, Bauhinia variegata, Gardenia turgida, Miliusa tomentosa* and *Pithecellobium dulce* occurred only in the Moist Mixed Deciduous forest. *Gmelina arborea, Grewia sapida* and *Lagerstromea speciosa* were recorded in Khair and Sissoo forest only. Four tree species *viz., Emblica officinalis, Lepisanthes rubiginosa, Caesaria graveolens* and *Ficus oligodon* were recorded in moderately dense Sal forest only.

Sal (*Shorea robusta*) was conspicuous in its absence in the Moist Mixed Deciduous, Tropical Semi-Evergreen, Tropical Seasonal Swamp, Khair and Sissoo forests. On the contrary, *Bombax ceiba* occurred in these forest types and the Upland grassland wherein Sal was completely absent.

Five tree species *viz., Syzygium cumini, Mallotus philippensis, Lagerstromea parviflora, Cassia fistula* and *Bridelia squamosa* were common to all the forest types. *Haldina cordifolia* was absent in *Chandar* Sal forest only while *Bauhinia racemosa* was absent in Tropical Semi-Evergreen forest only. *Syzygium cerasoides* occurred in almost all forest types, except in dense Sal forests. *Miliusa velutina* and *Casearia elliptica* were also common to majority of forest types, except these species were absent in Khair and Sissoo forest.

3.3.3.1 Importance Value Index (IVI)

The Importance Value Indices (IVI) for each tree species were computed separately for the overall landscape (TCA), constituents areas and each vegetation type. Noticeable observations made in each category are highlighted in the following paragraphs:

Table 3.8 - Tree Species in Different Vegetation Types in Terai Conservation Area (n=1,748)

Sl. No.	Species	Vegetation Types										
		Sal >60% Forest N=149	Sal 40-60% Forest N=238	Sal <40% Forest N=333	Sal Mixed Forest N=61	*Chandar* Sal Forest N=58	Tropical Moist Mixed Deciduous Forest N=234	Tropical Seasonal Swamp Forest N=178	Tropical Semi-Evergreen Forest N=31	Khair and Sissoo Forest N= 127	Plantations N=205	Upland Grassland N=134	Total
1	*Albizia procera*						*						1
2	*Bauhinia variegata*						*						1
3	*Casearia graveolens*		*										1
4	*Ficus oligodon*		*										1
5	*Ficus palmata*							*					1
6	*Gardenia turgida*						*						1
7	*Gmelina arborea*									*			1
8	*Grewia sapida*									*			1
9	*Lagerstoemia speciosa*									*			1
10	*Lepisanthes rubiginosa*			*									1
11	*Miliusa tomentosa*						*						1
12	*Phyllanthus emblica*			*									1
13	*Pithecellobium dulce*						*						1
14	*Terminalia chebula*										*		1
15	*Antidesma acidum*		*	*									2
16	*Artocarpus lakoocha*		*					*					2
17	*Azadirachta indica*						*			*			2
18	*Barringtonia acutangula*							*			*		2
19	*Careya arborea*		*	*									2
20	*Catunaregam uliginosa*									*		*	2
21	*Cordia dichotoma*				*			*					2
22	*Ficus semicoradata*							*			*		2
23	*Holoptelea integrifolia*						*	*					2
24	*Morus alba*			*			*						2
25	*Premna latifolia*			*				*					2
26	*Psidium gujava*						*			*			2
27	*Pterocarpus marsuplum*			*	*								2
28	*Randia tetrasperma*									*		*	2
29	*Sapidus mukorossi*						*				*		2
30	*Terminalia arjuna*						*	*					3

Contd...

Table 3.8 Contd...

Sl. No.	Species	Vegetation Types: Sal >60% Forest N=149	Sal 40-60% Forest N=238	Sal <40% Forest N=333	Sal Mixed Forest N=61	*Chandar* Sal Forest N=58	Tropical Moist Mixed Deciduous Forest N=234	Tropical Seasonal Swamp Forest N=178	Tropical Semi-Evergreen Forest N=31	Khair and Sissoo Forest N= 127	Plantations N=205	Upland Grassland N=134	Total
31	*Dillenia pentagyna*			*		*		*					3
32	*Eucalyptus citriodora*			*			*				*		3
33	*Ficus virens*					*		*			*		3
34	*Moringa oleifera*			*		*	*						3
35	*Pongamia pinnata*						*	*			*		4
36	*Toona ciliata*		*	*			*						4
37	*Albizia lebbeck*					*	*	*			*		4
38	*Alstonia scholaris*		*	*	*		*						4
39	*Braussonetia papyrifera*		*				*	*		*			4
40	*Cassine glauca*						*	*		*	*		4
41	*Garuga pinnata*	*	*	*				*					4
42	*Grewia dispema*		*	*	*			*					4
43	*Mangifera indica*	*	*				*	*					5
44	*Acacia catechu*			*			*		*	*		*	5
45	*Acacia nilotica*		*		*	*	*	*					5
46	*Flacourtia indica*	*		*	*		*	*					5
47	*Madhuca indica*		*	*			*	*			*		5
48	*Melia azedarach*	*	*	*		*	*						5
49	*Ougeinia oojeinensis*	*	*	*				*			*		5
50	*Pterospermum acerifolium*		*		*	*	*	*					5
51	*Shorea robusta*	*	*	*	*	*							5
52	*Spondias pinnata*	*		*			*	*			*		5
53	*Sterculia villosa*		*	*	*		*				*		5
54	*Tectona grandis*		*	*	*		*				*	*	6
55	*Ziziphus xylopyra*		*	*			*	*		*			5
56	*Acacia concinna*	*			*		*	*	*		*		6
57	*Butea monosperma*			*			*	*		*	*	*	6
58	*Diospyros melanoxylon*		*	*			*	*		*	*		6
59	*Drypetes roxburghii*		*	*			*	*	*		*		6

Contd...

Table 3.8 Contd...

Sl. No.	Species	Sal >60% Forest N=149	Sal 40-60% Forest N=238	Sal <40% Forest N=333	Sal Mixed Forest N=61	*Chandar* Sal Forest N=58	Tropical Moist Mixed Deciduous Forest N=234	Tropical Seasonal Swamp Forest N=178	Tropical Semi-Evergreen Forest N=31	Khair and Sissoo Forest N= 127	Plantations N=205	Upland Grassland N=134	Total
		Vegetation Types											
60	*Ficus benghalensis*	*	*	*			*	*			*		6
61	*Ficus hispida*		*	*			*	*	*	*			6
62	*Ficus rumphii*		*	*	*		*	*			*		6
63	*Hymendictyon orixense*		*	*	*	*	*	*					6
64	*Terminalia bellirica*		*	*	*	*	*	*					6
65	*Albizia chinensis*	*	*	*		*	*	*				*	7
66	*Bombax ceiba*	*					*	*	*	*	*	*	7
67	*Catunaregam spinosa*	*	*		*		*	*		*	*		7
68	*Citrus medica*		*		*		*	*		*	*	*	7
69	*Dalbergia sissoo*			*			*	*	*	*	*	*	7
70	*Ficus religiosa*		*	*			*	*		*	*	*	7
71	*Grewia elastica*												7
72	*Kydia calycina*	*	*	*		*	*	*			*		7
73	*Litsea glutinosa*	*		*			*	*	*	*	*		7
74	*Semicarpus anacardium*		*	*	*		*	*			*	*	7
75	*Streblus asper*	*		*			*	*	*	*	*		7
76	*Trewia nudiflora*	*	*	*			*	*	*	*	*		8
77	*Aegle marmelos*	*		*			*	*	*	*	*	*	8
78	*Casearia tomentosa*	*	*	*		*	*	*		*	*		8
79	*Celtis tetrandra*	*	*	*	*		*	*	*		*		8
80	*Ehretia laevis*	*	*	*	*		*	*	*		*		8
81	*Ficus racemosa*	*	*	*			*	*	*	*	*		8
82	*Lannea coromandelica*		*	*		*	*	*	*	*	*		8
83	*Mitragyna parvifolia*	*	*	*	*		*	*		*	*		8

Contd...

Table 3.8 Contd...

Sl. No.	Species	Sal >60% Forest N=149	Sal 40-60% Forest N=238	Sal <40% Forest N=333	Sal Mixed Forest N=61	*Chandar* Sal Forest N=58	Tropical Moist Mixed Deciduous Forest N=234	Tropical Seasonal Swamp Forest N=178	Tropical Semi-Evergreen Forest N=31	Khair and Sissoo Forest N= 127	Plantations N=205	Upland Grassland N=134	Total
		Vegetation Types											
84	*Schleichera oleosa*	*	*	*		*	*	*	*		*		8
85	*Terminalia alata*	*	*	*	*	*	*	*			*		8
86	*Casearia elliptica*	*	*	*	*	*	*	*	*		*		9
87	*Holarrhena pubescens*		*	*	*	*	*	*	*	*	*		9
88	*Miliusa velutina*	*	*	*	*	*	*	*	*		*		9
89	*Syzygium cerasoides*		*	*	*	*	*	*	*	*	*		9
90	*Bauhinia racemosa*	*	*	*	*	*	*	*		*	*	*	10
91	*Bridelia squamosa*	*	*	*	*	*	*	*	*	*	*	*	10
92	*Cassia fistula*	*	*	*	*	*	*	*	*	*	*		10
93	*Haldina cordifolia*	*	*	*	*		*	*	*	*	*	*	10
94	*Lagerstroemia parvifolia*	*	*	*	*	*	*	*	*	*	*		10
95	*Mallotus philippensis*	*	*	*	*	*	*	*	*	*	*		10
96	*Syzygium cumini*	*	*	*	*	*	*	*	*	*	*		10
	Total Species	**33**	**56**	**59**	**32**	**29**	**71**	**65**	**25**	**36**	**51**	**11**	

3.3.3.1.1 IVI – Landscape

The **Table 3.9** presents values of percentage frequency of occurrence, density, basal area and IVI for 96 tree species recorded in TCA. The data revealed that altogether 31,467 trees (>30 cm girth) representing 96 species were enumerated in 1,748 sampled quadrats (20m x 20m).

Mallotus philippensis recorded the highest value of percentage frequency of occurrence. This species occurred in 54.7% sampled plots. This was followed by Sal (*Shorea robusta*) and *Syzygium cumini* with frequency values, being 45.1% and 39.8%, repectively. *Tectona grandis,* an exotic to *Terai* occurred in as many as 16.3% sampled plots illustrating that this species has been widely planted throughout the landscape either in forest gaps or after clear-felling of native forests. As many as 47 tree species have just occurred in 17 sampled plots or less (i.e. 1.0% frequency of occurrence) out of sampled 1,748 plots. Further, out of 96 recorded tree species, only 10 species obtained values >10% frequency of occurrence.

The overall value of tree density computed for TCA was 450.04 trees/ha. The highest value of tree density, being 115.55 trees/ha was obtained in the case of Sal. This was followed by *Mallotus philippensis,* being 71.35 trees/ha. Interestingly, two planted exotic species *viz., Tectona grandis* and *Eucalyptus citriodora* together contributed 16.4% of total enumerated trees in TCA. *Syzygium cumini, Miliusa velutina, Dalbergia sissoo, Acacia catechu, Trewia nudiflora, Terminalia alata, Ficus racemosa, Lagerstromea parviflora* and *Barringtonia acutangula* were other prominent species those contributed to tree density. Only 13 tree species or 13.5% of recorded tree species obtained higher density values than 6.0 trees/ha.

Sal alone occupied 41.8% of total basal area covered by 96 tree species in TCA. Sal, thus registered the highest value of basal area, being 15.64 sq m/ha. This was followed by *Syzygium cumini* (3.70 sq m/ha) and *Tectona grandis* (2.73 sq m/ha), respectively. Six native tree species *viz., Shorea robusta, Mallotus philippensis, Syzygium cumini, Terminalia alata, Ficus racemosa* and *Miliusa velutina* together contributed for the 68.5% of the total basal area. The values of IVI for 96 tree species recorded in TCA ranged from 0.02 to 79.16. The highest value of IVI, being 79.16 was obtained in the case of Sal (*Shorea robusta*) indicating it as the most dominant tree species in the landscape. Prominent co-associates based on IVI values were *Mallotus philippensis, Syzygium cumini, Miliusa velutina, Dalbergia sissoo, Terminalia alata* and *Acacia catechu*. Other important species were: *Ficus racemosa, Trewia nudiflora* and *Lagerstromea parviflora*. Planted tree species *viz., Tectona grandis* and *Eucalyptus citriodora* also obtained relatively higher values of IVI, being 24.82 and 5.67, respectively. Seventy-nine tree species i.e. 82.3% recorded tree species registered IVI less than 3.0. First seventeen tree species in the list based on their higher IVI values can be considered prominent species in terms of their occurrence, density and basal area. Nevertheless, rest majority species were also of greater significance in terms of their contribution to the overall tree diversity and providing various values to dependent wild animals and local people despite they obtained lower values of IVI.

3.3.3.1.2 IVI – Constituent Areas

Only distinctive Importance Values (IVI) of select tree species those either characterized a particular constituent area or facilitated distinction among constituent areas were pooled and presented in **Table 3.10**. Interestingly, about one fourth of the total recorded tree species were found mainly responsible those either directly influenced the structure and composition of a specific area or their current level of distribution and abundance reflected overall site conditions and management.

Based on highest values of IVI, the Sal (*Shorea robusta*) was the most prominent tree species in the case of DNP and KWLS. Two important co-associates in both the cases were *Mallotus philippensis* and *Syzygium cumini*. In addition to this, other characterizing tree species in the case of DNP were *Terminalia alata, Ficus racemosa* and *Trewia nudiflora* while *Milliusa velutina, Lagerstromea parviflora, Bauhinia racemosa* and *Ehretia laevis* were noticeable in their contribution in the case of KWLS. Disproportionately higher IVI values of a few select species in DNP and KWLS amply indicated that those species characterized forests in these two constituent areas.

It is evident from the **Table 3.10** that *Acacia catechu* along with the co-associates *viz., Dalbergia sissoo, Syzygium cumini* and *Ficus racemosa* characterized the forests in NKFD. Other important tree species in this forest division were *Mallotus philippensis, Trewia nudiflora, Bombax ceiba* and *Haldina cordifolia*. Sal in NKFD could stand only at the fifth rank based on its IVI while in other managed forest i.e. SKFD, the Sal was again the most prominent species based on its

Table 3.9 - Importance Value Index (IVI) for Tree Species in Terai Conservation Area (n= 1, 748)

Species	Plots	% Fr	Individuals	Tree/ ha	BA	Ba/ ha	RF	RD	RD	IVI
Shorea robusta	789	45.1	8079	115.55	1093.8	15.64	11.69	25.67	41.80	79.16
Mallotus philippensis	957	54.7	4989	71.35	140.3	2.01	14.18	15.85	5.36	35.39
Syzygium cumini	695	39.8	3380	48.34	258.9	3.70	10.29	10.74	9.89	30.93
Tectona grandis	285	16.3	4182	59.81	191.2	2.73	4.22	13.29	7.31	24.82
Miliusa velutina	416	23.8	1165	16.66	30.8	0.44	6.16	3.70	1.18	11.04
Dalbergia sissoo	145	8.3	1314	18.79	92.2	1.32	2.15	4.18	3.52	9.85
Terminalia alata	229	13.1	570	8.15	107.2	1.53	3.39	1.81	4.10	9.30
Acacia catechu	200	11.4	1139	16.29	56.0	0.80	2.96	3.62	2.14	8.72
Ficus racemosa	185	10.6	425	6.08	100.9	1.44	2.74	1.35	3.85	7.95
Trewia nudiflora	181	10.4	686	9.81	46.9	0.67	2.68	2.18	1.79	6.65
Lagerstroemia parvifolia	248	14.2	436	6.24	27.2	0.39	3.67	1.39	1.04	6.10
Eucalyptus citriodora	57	3.3	990	14.16	43.8	0.63	0.84	3.15	1.68	5.67
Schleichera oleosa	130	7.4	176	2.52	25.8	0.37	1.93	0.56	0.99	3.47
Bombax ceiba	88	5.0	173	2.47	34.7	0.50	1.30	0.55	1.32	3.18
Casearia elliptica	152	8.7	199	2.85	6.6	0.09	2.25	0.63	0.25	3.14
Haldina cordifolia	104	5.9	227	3.25	20.9	0.30	1.54	0.72	0.80	3.06
Barringtonia acutangula	46	2.6	429	6.14	26.3	0.38	0.68	1.36	1.00	3.05
Ficus benghalensis	46	2.6	50	0.72	55.2	0.79	0.68	0.16	2.11	2.95
Bridelia squamosa	132	7.6	172	2.46	10.9	0.16	1.96	0.55	0.42	2.92
Ehretia laevis	112	6.4	189	2.70	16.4	0.23	1.66	0.60	0.63	2.89
Bauhinia racemosa	129	7.4	187	2.67	5.5	0.08	1.91	0.59	0.21	2.72
Mitragyna parvifolia	75	4.3	109	1.56	20.3	0.29	1.11	0.35	0.78	2.23
Streblus asper	84	4.8	174	2.49	7.2	0.10	1.24	0.55	0.28	2.07
Lannea coromandelica	79	4.5	97	1.39	14.7	0.21	1.17	0.31	0.56	2.04
Holarrhena pubescens	90	5.1	148	2.12	4.8	0.07	1.33	0.47	0.18	1.99
Aegle marmelos	70	4.0	131	1.87	7.5	0.11	1.04	0.42	0.29	1.74
Diospyros melanoxylon	63	3.6	119	1.70	7.8	0.11	0.93	0.38	0.30	1.61
Drypetes roxburghii	60	3.4	113	1.62	7.8	0.11	0.89	0.36	0.30	1.55
Ficus rumphii	27	1.5	29	0.41	24.7	0.35	0.40	0.09	0.94	1.43
Ficus religiosa	29	1.7	29	0.41	20.4	0.29	0.43	0.09	0.78	1.30
Cassia fistula	54	3.1	98	1.40	3.6	0.05	0.80	0.31	0.14	1.25
Celtis tetrandra	55	3.1	86	1.23	2.1	0.03	0.81	0.27	0.08	1.17
Madhuca indica	38	2.2	65	0.93	7.1	0.10	0.56	0.21	0.27	1.04
Kydia calycina	25	1.4	69	0.99	6.2	0.09	0.37	0.22	0.24	0.83
Braussonetia papyrifera	27	1.5	63	0.90	5.0	0.07	0.40	0.20	0.19	0.79
Sterculia villosa	33	1.9	48	0.69	3.0	0.04	0.49	0.15	0.11	0.76
Ficus hispida	28	1.6	52	0.74	4.3	0.06	0.41	0.17	0.17	0.75
Litsea glutinosa	33	1.9	46	0.66	2.1	0.03	0.49	0.15	0.08	0.71

Contd...

Table 3.9 Contd...

Species	Plots	% Fr	Indivi-duals	Tree/ ha	BA	Ba/ ha	RF	RD	RD	IVI
Terminalia bellirica	27	1.5	30	0.43	5.4	0.08	0.40	0.10	0.21	0.70
Syzygium cerasoides	25	1.4	35	0.50	4.9	0.07	0.37	0.11	0.19	0.67
Butea monosperma	25	1.4	30	0.43	5.1	0.07	0.37	0.10	0.20	0.66
Catunaregam spinosa	31	1.8	45	0.64	1.1	0.02	0.46	0.14	0.04	0.65
Semicarpus anacardium	29	1.7	37	0.53	2.1	0.03	0.43	0.12	0.08	0.63
Citrus medica	19	1.1	44	0.63	5.1	0.07	0.28	0.14	0.20	0.62
Pongamia pinnata	17	1.0	51	0.73	5.2	0.07	0.25	0.16	0.20	0.61
Casearia tomentosa	29	1.7	37	0.53	1.4	0.02	0.43	0.12	0.05	0.60
Acacia concinna	27	1.5	43	0.61	1.0	0.01	0.40	0.14	0.04	0.58
Grewia elastica	24	1.4	33	0.47	1.1	0.02	0.36	0.10	0.04	0.50
Albizia chinensis	20	1.1	29	0.41	2.9	0.04	0.30	0.09	0.11	0.50
Toona ciliata	13	0.7	16	0.23	6.4	0.09	0.19	0.05	0.24	0.49
Ougeinia oojeinensis	20	1.1	25	0.36	2.4	0.03	0.30	0.08	0.09	0.47
Melia azedarach	17	1.0	24	0.34	3.3	0.05	0.25	0.08	0.13	0.45
Albizia lebbeck	11	0.6	12	0.17	5.6	0.08	0.16	0.04	0.21	0.41
Pterospermum acerifolium	15	0.9	27	0.39	1.1	0.02	0.22	0.09	0.04	0.35
Acacia nilotica	16	0.9	21	0.30	0.7	0.01	0.24	0.07	0.03	0.33
Terminalia arjuna	9	0.5	44	0.63	1.4	0.02	0.13	0.14	0.05	0.33
Flacourtia indica	14	0.8	20	0.29	1.2	0.02	0.21	0.06	0.05	0.32
Hymendictyon orixense	13	0.7	16	0.23	1.6	0.02	0.19	0.05	0.06	0.30
Ziziphus xylopyra	12	0.7	21	0.30	0.6	0.01	0.18	0.07	0.02	0.27
Dillenia pentagyna	8	0.5	9	0.13	3.1	0.04	0.12	0.03	0.12	0.27
Spondias pinnata	12	0.7	12	0.17	1.0	0.01	0.18	0.04	0.04	0.26
Holoptelea integrifolia	10	0.6	15	0.21	0.3	0.00	0.15	0.05	0.01	0.21
Moringa oleifera	6	0.3	8	0.11	2.2	0.03	0.09	0.03	0.08	0.20
Bauhinia variegata	7	0.4	12	0.17	0.4	0.01	0.10	0.04	0.02	0.16
Ficus cunia	3	0.2	22	0.31	1.0	0.01	0.04	0.07	0.04	0.15
Grewia dispema	6	0.3	8	0.11	0.9	0.01	0.09	0.03	0.03	0.15
Alstonia scholaris	7	0.4	9	0.13	0.2	0.00	0.10	0.03	0.01	0.14
Morus alba	4	0.2	4	0.06	1.4	0.02	0.06	0.01	0.05	0.13
Antidesma acidum	6	0.3	7	0.10	0.1	0.00	0.09	0.02	0.00	0.12
Garuga pinnata	5	0.3	5	0.07	0.5	0.01	0.07	0.02	0.02	0.11
Psidium gujava	5	0.3	6	0.09	0.1	0.00	0.07	0.02	0.00	0.10
Ficus virens	3	0.2	4	0.06	0.9	0.01	0.04	0.01	0.03	0.09
Mangifera indica	4	0.2	5	0.07	0.4	0.01	0.06	0.02	0.02	0.09
Premna latifolia	4	0.2	5	0.07	0.3	0.00	0.06	0.02	0.01	0.09
Catunaregam uliginosa	4	0.2	5	0.07	0.1	0.00	0.06	0.02	0.01	0.08
Carissa opaca	4	0.2	4	0.06	0.1	0.00	0.06	0.01	0.00	0.08

Contd...

Table 3.9 Contd...

Species	Plots	% Fr	Indivi-duals	Tree/ ha	BA	Ba/ ha	RF	RD	RD	IVI
Pithecellobium dulce	4	0.2	4	0.06	0.1	0.00	0.06	0.01	0.00	0.07
Careya arborea	3	0.2	4	0.06	0.3	0.00	0.04	0.01	0.01	0.07
Artocarpus lakoocha	3	0.2	3	0.04	0.2	0.00	0.04	0.01	0.01	0.06
Casearia graveolens	3	0.2	4	0.06	0.1	0.00	0.04	0.01	0.00	0.06
Lagerstoemia speciosa	3	0.2	4	0.06	0.1	0.00	0.04	0.01	0.00	0.06
Lepisanthes rubiginosa	2	0.1	3	0.04	0.5	0.01	0.03	0.01	0.02	0.06
Grewia sapida	3	0.2	3	0.04	0.1	0.00	0.04	0.01	0.00	0.06
Azidarachta indica	3	0.2	3	0.04	0.0	0.00	0.04	0.01	0.00	0.06
Cordia dichotoma	2	0.1	2	0.03	0.5	0.01	0.03	0.01	0.02	0.05
Albizia procera	2	0.1	3	0.04	0.4	0.01	0.03	0.01	0.01	0.05
Emblica officinalis	2	0.1	3	0.04	0.3	0.00	0.03	0.01	0.01	0.05
Ficus palmata	1	0.1	2	0.03	0.6	0.01	0.01	0.01	0.02	0.04
Ficus oligodon	2	0.1	3	0.04	0.1	0.00	0.03	0.01	0.00	0.04
Pterocarpus marsupium	2	0.1	2	0.03	0.2	0.00	0.03	0.01	0.01	0.04
Sapidus mukorossi	2	0.1	2	0.03	0.1	0.00	0.03	0.01	0.00	0.04
Randia tetrasperma	2	0.1	2	0.03	0.1	0.00	0.03	0.01	0.00	0.04
Gmelina arborea	2	0.1	2	0.03	0.0	0.00	0.03	0.01	0.00	0.04
Miliusa tomentosa	1	0.1	3	0.04	0.1	0.00	0.01	0.01	0.00	0.03
Gardenia turgida	1	0.1	1	0.01	0.1	0.00	0.01	0.00	0.00	0.02
Terminalia chebula	1	0.1	1	0.01	0.0	0.00	0.01	0.00	0.00	0.02
	6751		**31467**	**450.04**	**2616.7**	**37.42**	**100.0**	**100.0**	**100.0**	**300.0**

IVI value. Like DNP and KWLS, two co-dominant species of Sal in SKFD were *Mallotus philippensis* and *Syzygium cumini*. Other important tree species those were quite distinctive in forests of SKFD were *Barringtonia acutangula, Dalbergia sissoo, Milliusa velutina, Terminalia alata* and *Ficus benghalensis*.

Further, a comparison of IVI values of select 23 tree species in the case of two PAs (DNP and KWLS) with two MFs (NKFD and SKFD) allowed several noteworthy observations. Accordingly, *Shorea robusta, Mallotus philippensis, Syzygium cumini* and *Ehretia laevis* registered much higher values of IVI in the case of two PAs than their corresponding values in two MFs. On the contrary, tree species *viz., Acacia catechu, Dalbergia sissoo, Terminalia alata, Barringtonia acutangula* and *Haldina cordifolia* obtained much higher IVI values in two MFs than their corresponding values in two PAs. This clearly indicates striking distinction in structure and composition of tree species in two PAs and two MFs.

Comparison of IVI values for select tree species across various constituent areas in the landscape also allowed several interesting observations. The IVI values in the case of *Acacia catechu* varied from 0.30 (KWLS) to 40.86 (NKFD), illustrating that *Acacia catechu* was a characterizing tree species in the case of NKFD. This was obvious due to the occurrence of greater chunk of Khair and Sissoo forests in NKFD. *Shorea robusta* was common to all the four constituent areas with IVI values ranging from 20.44 (NKFD) to 96.65 (KWLS). The Kishanpur Sanctuary obtained the highest value, being 96.65, which was greater than the value for the overall landscape (79.16).

Table 3.10 - Importance Value Index (IVI) of Select Tree Species in Four Constituent Areas, PAs, MFs and the Overall Landscape

Species	DNP N=727	KWLS N=325	NKFD N=259	SKFD N=437	PAs N=1052	MFs N=796	TCA N=1748
Acacia catechu	4.71	0.30	40.86	5.33	3.40	17.24	8.72
Bauhinia racemosa	1.34	6.79	1.30	2.80	3.03	2.26	2.23
Barringtonia acutangula	_	_	0.98	11.51	-	8.05	3.05
Bombax ceiba	3.08	-	8.38	1.82	2.70	3.97	3.18
Bridelia squamosa	1.18	5.31	4.52	3.31	2.42	3.71	2.92
Dalbergia sissoo	5.24	3.32	35.81	10.01	4.65	18.46	9.85
Dryptes roxburghii	1.53	-	6.54	0.16	1.06	2.34	1.55
Ehretia laevis	3.23	6.50	1.60	0.47	4.19	0.85	2.89
Eucalyptus citriodora	9.05	3.22	0.13	4.16	7.37	2.80	5.67
Ficus benghalensis	1.54	-	0.35	8.77	1.09	6.20	2.95
Ficus racemosa	9.25	3.70	23.01	0.90	7.69	8.22	7.95
Haldina cordifolia	3.18	0.33	10.66	0.92	2.32	4.23	3.06
Lagerstroemia parviflora	0.60	7.96	2.48	5.94	6.98	4.74	6.10
Mallotus philippensis	40.09	36.82	21.73	34.14	38.98	29.85	35.39
Milliusa velutina	8.81	17.35	2.49	19.70	11.43	10.43	11.04
Shorea robusta	88.57	96.65	20.44	78.03	90.82	59.24	79.16
Syzygium cumini	41.93	19.13	25.38	24.26	35.02	29.61	30.93
Syzygium cerasoides	0.82	1.46	-	0.17	1.02	0.11	0.67
Tectona grandis	17.93	41.11	15.57	29.65	24.69	24.88	24.82
Terminalia alata	10.71	4.01	0.56	14.81	8.83	10.04	9.30
Terminalia arjuna	0.05	-	1.62	0.34	8.04	0.70	0.33
Trewia nudiflora	8.21	3.99	15.25	1.70	6.89	6.29	6.65
Ziziphus xylopyra	0.10	0.22	0.90	0.24	0.14	0.47	0.27

Three tree species *viz., Bauhinia racemosa, Bridelia squamosa* and *Lagerstroemia parviflora* obtained the maximum IVI values, being 6.79, 5.31 and 7.96, respectively in the case of KWLS. These three species thus, characterized forests of KWLS owing to the greater proportion therein of *Chandar* Sal and Sal Mixed forests. Likewise, based on the maximum values obtained, four tree species *viz., Barringtonia acutangula, Ficus benghalensis, Milliusa velutina* and *Terminalia alata* characterized forests of SKFD. The values obtained were 11.51, 8.77, 19.70 and 14.81, respectively. Prominence of these four characteristic species in the forests of SKFD can be attributed to the fact that SKFD harboured greater extent of Tropical Seasonal Swamp, moderately closed Sal and open Sal forests and these species were chief constituents of such forests. The IVI values in the case of *Ziziphus xylopyra* ranged from 0.10 (DNP) to 0.90 (NKFD). The species being one of the important constituents of Moist Mixed Deciduous forests and their greater occurrence in NKFD resulted in its maximum value.

Two extensively planted exotic tree species *viz., Tectona grandis* and *Eucalyptus citriodora* were widely distributed in all the four constituent areas. The IVI values in the case of *Tectona grandis* ranged from 15.57 (NKFD) to 41.11 (KWLS). The maximum value in the case of KWLS amongst the four constituent areas was obvious due to greater extent of plantations in the sanctuary area. On the contrary, the maximum IVI value, being 9.05 of *Eucalyptus citriodora* was registered in DNP. The national park had several plantation pockets of this species particularly in 'grassy blanks' or 'phantas'.

Table 3.11- Important Value Indices (IVI) of Tree species Across Different Vegetation Types in Terai Conservation Area

Sl. No.	Species	Vegetation Types											Total
		Sal >60% n=149	Sal 40-60% n=260	Sal <40% n=291	Sal Mixed n=61	*Chandar* Sal n=58	Mixed Forest n=201	SS Forest n=198	SE Forest n=31	K&S Forest n=160	Plantation n=205	Grassland n=134	
1	*Albizia procera*						0.40						1
2	*Bauhinia variegata*						1.13						1
3	*Casearia graveolens*		0.35										1
4	*Ficus oligodon*		0.24										1
5	*Ficus palmata*							0.38					1
6	*Gardenia turgida*						0.15						1
7	*Gmelina arborea*									0.62			1
8	*Grewia sapida*									0.93			1
9	*Lagerstroemia speciosa*									0.98			1
10	*Lepisanthes rubiginosa*		0.33										1
11	*Miliusa tomentosa*						0.20						1
12	*Emblica officinalis*		0.29										1
13	*Pithecellobium dulce*						0.51						1
14	*Terminalia chebula*										0.21		1
15	*Antidesma acidum*		0.32	0.29									2
16	*Artocarpus lakoocha*		0.23					0.17					2
17	*Azidarachta indica*						0.25			0.30			2
18	*Barringtonia acutangula*							26.22			0.39		2
19	*Careya arborea*		0.23	0.13									2
20	*Catunaregam uliginosa*									0.70		8.84	2
21	*Cordia dichotoma*				0.45			0.31					2
22	*Ficus semicordata*							0.21			1.18		2
23	*Holoptelea integrifolia*			0.12			1.19	0.29					3
24	*Morus alba*			0.12			0.79						2
25	*Premna latifolia*			0.29				0.25					2
26	*Psidium gujava*						0.25			0.96			2
27	*Pterocarpus marsupium*			0.11	1.70								2

Contd....

Table 3.11 Contd....

Sl. No	Species	Vegetation Types Sal >60% n=149	Sal 40-60% n=260	Sal <40% n=291	Sal Mixed n=61	*Chandar* Sal n=58	Mixed Forest n=201	SS Forest n=198	SE Forest n=31	K&S Forest n=160	Plantation n=205	Grassland n=134	Total
28	*Randia tetrasperma*									0.32		4.35	2
29	*Sapidus mukorossi*						0.13				0.24		2
30	*Terminalia arjuna*						1.51	1.08					2
31	*Dillenia pentagyna*			0.09		0.71		1.98					3
32	*Eucalyptus citriodora*			0.09			1.67				47.78		3
33	*Ficus virens*					0.67		0.14			0.57		3
34	*Moringa oleifera*			0.46		1.42	0.37						3
35	*Pongamia pinnata*						0.96	4.05			0.21		3
36	*Toona ciliata*		0.45	1.59			0.42						3
37	*Albizia lebbeck*					2.51	1.19	1.23			0.54		4
38	*Alstonia scholaris*		0.45	0.11	0.50		0.13						4
39	*Braussonetia papyrifera*		0.24				4.95	0.18		1.46			4
40	*Cassine glauca*						0.15	0.14		0.30	0.21		4
41	*Garuga pinnata*	0.23	0.26	0.09				0.23					4
42	*Grewia disperma*		0.11	0.11	0.45			0.75					4
43	*Mangifera indica*	0.24	0.11				0.14	0.28					4
44	*Acacia catechu*			0.31			11.19		1.38	110.14		37.88	5
45	*Acacia nilotica*		0.35		0.07	0.58	1.33	0.16					5
46	*Flacourtia indica*	0.87		0.18	1.43		0.63	0.48					5
47	*Madhuca longifolia*		0.87	1.73			3.41	0.17			0.70		5
48	*Melia azedarach*	0.93	1.50	0.03		0.58	0.13						5
49	*Ougeinia oojeinensis*	0.99	1.06	0.62				0.16			0.49		5
50	*Pterospermum acerifolium*		0.78		1.70	1.33	0.51	0.21					5
51	*Shorea robusta*	166.03	140.44	105.95	141.06	196.34							5
52	*Spondias pinnata*	0.48		0.29			0.13	0.79			0.43		5
53	*Sterculia villosa*		0.57	1.59	0.72		0.48				2.36		5
54	*Tectona grandis*			19.59	15.90		22.98				153.20	12.94	5

Contd....

Table 3.11 Contd....

Sl. No	Species	Vegetation Types											
		Sal >60% n=149	Sal 40-60% n=260	Sal <40% n=291	Sal Mixed n=61	*Chandar* Sal n=58	Mixed Forest n=201	SS Forest n=198	SE Forest n=31	K&S Forest n=160	Plantation n=205	Grassland n=134	Total
55	*Ziziphus xylopyra*		0.11	0.09			0.44	0.65		1.46			5
56	*Acacia concinna*	0.46			1.43		2.98	0.15	1.03		0.25		6
57	*Butea monosperma*			0.42			1.03	1.90		1.18	0.77	18.86	6
58	*Diospyros melanoxylon*		1.93	3.27			2.11	0.94		0.41	1.90		6
59	*Drypetes roxburghii*		0.49	0.09			6.01	4.09	1.20		1.42		6
60	*Ficus benghalensis*	0.64	1.09	6.34			2.34	1.12			9.37		6
61	*Ficus hispida*		0.19	0.22			2.24	1.71	5.79	0.68			6
62	*Ficus rumphii*		0.73	3.74	0.45		1.93	1.12			0.92		6
63	*Hymendictyon orixense*		0.23	0.10	0.46	1.02	0.70	0.76					6
64	*Terminalia bellirica*		0.63	1.63	0.45	2.15	0.25	0.83					6
65	*Albizia chinensis*	0.24	0.24	3.74		0.04	0.14	0.48			0.40		7
66	*Bombax ceiba*						3.89	3.77	1.87	27.91	0.50	130.11	7
67	*Catunaregam spinosa*	0.97	0.13		0.55		0.99	8.77		3.30	0.87		7
68	*Citrus medica*		0.27		2.09		0.59	2.72		0.65	0.22	4.35	7
69	*Dalbergia sissoo*			1.42			25.59	0.15	6.84	99.53	0.47	18.71	7
70	*Ficus religiosa*		0.57	1.76			3.84	1.79		1.82	0.44	4.96	7
71	*Grewia elastica*		0.24	0.18		0.60	0.61	1.94	2.13	0.61			7
72	*Kydia calycina*		1.33	0.18	1.07	1.84	0.28	0.82			2.92		7
73	*Litsea glutinosa*	0.23	0.68	1.00		1.27	1.33	0.88			0.45		7
74	*Semecarpus anacardium*	0.93	1.36	0.67		1.89	0.17	0.37			0.47		7
75	*Streblus asper*	0.23		0.46			4.04	8.59	3.54	2.13	1.41		7
76	*Trewia nudiflora*	0.23		0.13			28.34	18.34	25.68	6.19	0.23		7
77	*Aegle marmelos*	0.49	0.84	1.67			3.08	4.80	1.04	0.93	1.34		8
78	*Casearia tomentosa*	0.92	0.23	0.49		1.86	0.73	1.25		0.69	0.21		8
79	*Celtis tetrandra*	1.02	1.00	0.60	0.09		3.14	1.43	4.68		0.44		8
80	*Ehretia laevis*	8.41	1.67	1.50	11.38		2.05	4.61	3.34		1.29		8
81	*Ficus racemosa*	0.74	1.11	7.42			32.38	9.42	36.00	5.99	0.21		8
82	*Lannea coromandelica*		1.75	2.92		1.44	2.73	3.96	3.80	1.20	0.69		8

Contd....

Table 3.11 Contd....

Sl. No	Species	Vegetation Types											
		Sal >60% n=149	**Sal 40-60% n=260**	**Sal <40% n=291**	**Sal Mixed n=61**	***Chandar* Sal n=58**	**Mixed Forest n=201**	**SS Forest n=198**	**SE Forest n=31**	**K&S Forest n=160**	**Plantation n=205**	**Grassland n=134**	**Total**
83	*Mitragyna parvifolia*	0.80	1.28	2.09	0.51		2.78	7.69		0.71	1.57		8
84	*Schleichera oleosa*	0.48	4.15	5.26		0.58	1.63	8.00	17.41		0.97		8
85	*Terminalia alata*	11.45	16.38	15.26	0.42	0.59	5.85	6.90			1.70		8
86	*Casearia elliptica*	1.86	4.13	4.13	2.30	3.73	2.54	3.13	1.11		4.11		9
87	*Holarrhena pubescens*		0.64	3.07	0.95	7.47	2.69	1.59	6.20	0.62	2.57		9
88	*Miliusa velutina*	6.95	15.97	22.7	11.07	6.15	4.64	6.35	1.03		10.76		9
89	*Syzygium cerasoides*		0.77	0.20	1.34	1.42	0.17	0.15	16.57	0.39	0.22		9
90	*Bauhinia racemosa*	1.66	3.37	1.71	5.63	13.60	1.96	2.44		0.96	1.64	49.15	10
91	*Bridelia squamosa*	0.96	2.52	4.65	1.50	10.90	1.56	3.76	1.06	0.67	2.96		10
92	*Cassia fistula*	2.53	0.56	0.84	0.45	0.59	1.41	2.56	3.13	0.60	1.07		10
93	*Haldina cordifolia*	0.47	0.55	1.13	0.53		5.41	5.84	2.17	15.66	1.74	9.67	10
94	*Lagerstroemia parvifolia*	3.97	10.78	8.68	12.82	2.81	1.50	3.62	1.06	0.95	7.76		10
95	*Mallotus philippensis*	60.50	45.32	39.07	44.66	24.85	40.39	32.66	28.98	0.99	19.77		10
96	*Syzygium cumini*	22.59	26.77	19.38	29.30	10.48	35.51	96.16	122.94	7.05	7.20		10
	Total Species	**33**	**56**	**59**	**32**	**29**	**71**	**65**	**25**	**36**	**51**	**11**	

3.3.3.1.3 IVI – Vegetation Types

A comparison of Importance Value Indices of 96 recorded tree species across different vegetation types is presented in **Table 3.11**. Noticeable observations made are discussed below.

Shorea robusta occurred only in five forest types *viz., dense* Sal, moderately closed Sal, open Sal, Sal Mixed and *Chandar* Sal and it was the chief constituent species of these forests. The IVI values of Sal ranged from 105.95 to 196.34 among the five forest types. There was a clear-cut decline of IVI value while moving from closed canopy to open canopy Sal. Thus, dense Sal registered higher IVI value, being 166.03 while open Sal obtained a much lower value i.e.105.95. Otherwise, among five forest types of Sal, the maximum value of IVI (196.34) was obtained in the case of *Chandar* Sal forests. This highest value can be attributed to the fact that *Chandar* Sal forests had the lowest tree diversity of 29 tree species only and Sal was the predominant tree species among them.

As in the case of overall landscape, *Mallotus philippensis* and *Syzygium cumini* remained the second and third prominent species in atleast five forest types dominated by Sal. The maximum IVI value of *Mallotus philippensis*, being 60.50 was computed in the case of dense Sal forests. The IVI values of *Syzygium cumini* varied from 7.05 to 122.94, the minimum in the case of Khair and Sissoo forest while the maximum in Tropical Semi-Evergreen forest.

Ficus benghalensis was an important species in the case of open Sal forests while *Ficus racemosa* was one of the prominent species of Tropical Semi-Evergreen and Moist Mixed Deciduous forests based on their higher corresponding IVI values. *Terminalia alata* was one of the important co-associates of dense Sal, moderately closed Sal and open Sal forests. However, its lowest IVI value, being 0.42 in the case of Sal Mixed forest indicated that this species is being substituted *by Ehretia laevis* and *Milliusa velutina*. *Ehretia laevis* obtained the maximum IVI value, being 11.38 in the case of Sal Mixed forest. The IVI values of *Milliusa velutina* ranged from 1.03 to 22.7 among the different vegetation types. The former being in the case of Tropical Semi-Evergreen forest while the later in the case of open Sal forest.

Bauhinia racemosa, Bridelia squamosa, Holarrhena pubescens, Terminalia bellirica, Albizia lebbeck, Kydia calycina, Semecarpus anacardium, Casearia tomentosa obtained the maximum IVI values in the case of *Chandar* Sal. It indicates that either open savannah like conditions in *Chandar* Sal forests or frost and frequent fires in such forests have favoured relative occurrence of these species. On the contrary, *Lagerstroemia parviflora* and *Terminalia alata* found less favourable conditions in *Chandar* Sal forests than other forest types dominated by Sal.

Based on the higher IVI values of *Catunaregam spinosa, Bauhinia recemosa, Acacia catechu, Dalbergia sissoo, Haldina cordifolia, Catunaregam uliginosa, Randia tetrasperma, Citrus medica, Ziziphus xylopyra* and *Ficus religiosa* it can be inferred that these were characteristic tree species of Upland grasslands.

3.3.3.1.4 Family Importance Value (FIV) Indices

The Family Importance Values (FIV) for TCA based on tree species were computed and are presented in **Table 3.12**. Accordingly, the Dipterocarpaceae was he most important family with the highest FIV, being 68.52. This family included just one tree species i.e. *Shorea robusta*.

The second important family was Euphorbiaceae with six tree species *viz., Mallotus philippensis, Trewia nudiflora, Bridelia squamosa, Dryptes roxburghii, Emblica officinalis,* and *Antidesma acidum.* Contribution by the first three species was mainly responsible in bringing this family at the second rank in its importance. The family Myrtaceae with FIV, being 29.94 ranked third in the importance. As such this family included four species. However, *Syzygium cumini* and *Eucalyptus citriodora* were the prominent species in bringing this family at the third number. In spite the family Moraceae had the highest number of tree species i.e. 13, remained fourth in order based on FIV. Nine species of genus *Ficus* and *Braussonetia papyrifera* significantly contributed to get the higher FIV for the family Moraceae. The family Verbenaceae with three species *viz., Tectona grandis, Premna latifolia* and *Gmelina arborea* got the fifth rank based on the family importance value. Extensive plantations of *Tectona grandis* was the obvious reason for higher value in this case.

Table 3.12 - Family Importance Value (FIV) Indices of Tree Species in Terai Conservation Area (n = 1,7,48)

Family	No. of Species	No. of Individuals	Basal Area (sq m)	Relative Diversity	Relative Density	Relative Dominance	Family Importance Value
Dipterocarpaceae	1	8079	1093.8	1.04	25.67	41.80	68.52
Euphorbiaceae	6	5970	206.4	6.25	18.97	7.89	33.11
Myrtaceae	4	4411	307.6	4.17	14.02	11.76	29.94
Moraceae	13	863	221.9	13.54	2.74	8.48	24.76
Verbenaceae	3	4189	191.6	3.13	13.31	7.32	23.76
Mimosaceae	7	1251	`66.7	7.29	3.98	2.55	13.81
Fabaceae	5	1422	105.1	5.21	4.52	4.02	13.74
Combretaceae	4	645	114.0	4.17	2.05	4.36	10.57
Rubiaceae	7	405	44.2	7.29	1.29	1.69	10.27
Annonaceae	2	1168	30.8	2.08	3.71	1.18	6.97
Flacourtiaceae	4	260	9.3	4.17	0.83	0.36	5.35
Anacardiaceae	4	151	18.3	4.17	0.48	0.70	5.35
Sapindaceae	3	181	26.4	3.13	0.58	1.01	4.71
Lythraceae	2	440	27.3	2.08	1.40	1.04	4.53
Lecythidaceae	2	433	26.6	2.08	1.38	1.02	4.48
Caesalpiniaceae	3	286	8.5	3.13	0.94	0.36	4.43
Meliaceae	3	43	9.7	3.13	0.14	0.37	3.63
Boraginaceae	2	191	16.9	2.08	0.61	0.65	3.34
Tiliaceae	3	41	2.0	3.13	0.13	0.08	3.33
Rutaceae	2	175	12.7	2.08	0.56	0.48	3.12
Bombacaceae	1	173	34.7	1.04	0.55	1.32	2.92
Apocynaceae	2	157	5.0	2.08	0.50	0.19	2.77
Sterculiaceae	2	75	4.0	2.08	0.24	0.15	2.48
Ebenaceae	1	119	7.8	1.04	0.38	0.30	1.72
Sapotaceae	1	65	7.1	1.04	0.21	0.27	1.52
Malvaceae	1	69	6.2	1.04	0.22	0.24	1.50
Urticaceae	1	86	2.1	1.04	0.27	0.08	1.39
Lauraceae	1	46	2.1	1.04	0.15	0.08	1.27
Dillieniaceae	1	9	3.1	1.04	0.03	0.12	1.19
Moringaceae	1	8	2.2	1.04	0.03	0.08	1.15
Rhamnaceae	1	21	0.6	1.04	0.07	0.02	1.13
Ulmaceae	1	15	0.3	1.04	0.05	0.01	1.10
Burseraceae	1	5	0.5	1.04	0.02	0.02	1.08
Celestraceae	1	4	0.1	1.04	0.01	0.00	1.06
Total	**96**	**31467**	**2616.7**	**100.00**	**100.00**	**100.00**	**300.00**

Despite the family Mimosaceae had second largest number of tree species i.e. 7, it stood at the sixth rank based on the family importance value. This family included three species each of genera *Acacia* and *Albizia* in addition to *Pithecellobium dulce*. The family Combretaceae with four species of just one genus i.e. *Terminalia* stood at eighth number. Among them, *T. alata* and *T. arjuna* were two important species contributed to the higher FIV.

The order of first ten families based on descending family importance values was: Dipterocarpaceae→ *Euphorbiaceae* → *Myrtaceae* → *Moraceae* → *Verbenaceae*→ *Mimosaceae*→ *Fabaceae* → *Combretaceae* → *Rubiaceae* → *Annonaceae*. These 10 families included 52 species out of 96 tree species recorded in TCA and together they contributed for more than three fourth diversity, density and dominance. Nevertheless, the remaining 24 families with 44 species were of also greater significance in terms of diversity and other wildlife values. Indeed majority tree species i.e. 83, had only less than 250 trees each out of total 31,467 trees enumerated in the overall TCA (**Table 3.12**). It indicates that such species were either highly localized or were in low abundance. It is also possible that naturally several of these species occur in low number only. However, they are of utmost ecological importance and calls for a priority attention and monitoring.

3.3.4 Shrub Diversity

Composition of shrub species, their percentage frequency of occurrence, density and abundance assessed in TCA, constituent areas and each forest type are described here. This diversity description excludes shrub diversity in grasslands of TCA.

3.3.4.1 Landscape

Earlier in **Table 3.5**, a diversity of 38 shrub species in TCA just on the basis of presence/absence noted in 1,967 quadrats laid in different forest as well as grassland types was listed. However, shrub quantification carried out in different forest types, *Tamarix* Scrub and plantation areas through 1,674 sample revealed a diversity of only 29 shrub species (**Table 3.13**). Nine shrub species *viz., Flemingia chappar, Desmodium gangeticum, D. motorium, D. pulchellum, D. triflorium, Calotropis gigantea, Ventilago denticulata, Ichnocarpus frutescens* and *Securinega leucopyrus* were absent in 1,674 sampled plots.

Clerodendrum viscosum was the most widely distributed shrub species in different forests of TCA as it occurred in as many as 56.9% sampled plots. This was followed by *Flemingia macrophylla* and *Tiliacora acuminata*, with values of percentage frequency of occurrence, being 32.5 and 32.0, respectively. *Ardisia solanacea* and *Murraya koenigii* occurred in almost one fourth of the plots sampled. Other common species were *Glycosmis pentaphylla and Helicteres isora with* values of 19.1% and 18.6%, respectively. As many as 18 shrub species obtained lower values of frequency of occurrence i.e. <5%.

The values of shrub density for 29 species ranged from 0.5 shrubs/ha to 5,713.0 shrubs/ha. The highest value was obtained in the case of *Clerodendrum viscosum*. More than one third (34.2%) of the shrubs enumerated were of *Clerodendrum viscosum*. Four shrub species *viz., Tiliacora acuminata, Ardisia solanacea, Glycosmis pentaphylla* and *Murraya koenigii* together contributed nearly half of the total shrubs enumerated. Unfortunately, these four species and *C.viscosum* provide hardly any browse value to wild herbivores. Instead preferred shrub species *viz., Helicteres isora, Grewia hirsuta, G. sapida, Carissa opaca* and *Ziziphus mauritiana* occurred in much lower densities. The overall shrub density computed for different forests in TCA was 16,698.9 shrubs/ha.

Lantana camara, an exotic woody shrub occurred in 5.7% sampled plots with density, being 393.1 shrubs/ha.

The abundance values of different shrub species in forests of TCA varied from 4.5 to 100.7. The lowest value was in the case of *Sesbania bispinosa* while the highest abundance value was of *Clerodendrum serratum*. *C.viscosum* was the second most abundant species. On the contrary, the third species of *Clerodendrum* i.e. *C. indicum* registered second lowest of abundance, being 5.0. Other co-dominant shrubs species based on the higher abundance values were *Ardisia solanacea, Tiliacora acuminata, Glycosmis pentaphylla, Tamarix dioica, Lantana camara* and *Calamus tenuis*.

3.3.4.1 Constituents Areas

Forest shrub diversity was also assessed in different constituent areas. Only characterizing or distinctive observations are highlighted below.

Table 3.13 – Shrub Diversity in Different Forests of Terai Conservation Area (n = 1,674)

Sl. No.	Species	Plots of Occurrence	Percentage Frequency	No. of Shrubs	Density Shrubs/ha	Abundance
1	*Clerodendrum viscosum*	953	56.9	95636	5713.0	100.4
2	*Tiliacora acuminata*	536	32.0	47929	2863.1	89.4
3	*Ardisia solanacea*	428	25.6	42209	2521.4	98.6
4	*Glycosmis pentaphylla*	320	19.1	27621	1650.0	86.3
5	*Murraya koenigii*	410	24.5	16176	966.3	39.5
6	*Flemingia macrophylla*	544	32.5	11310	675.6	20.8
7	*Lantana camara*	96	5.7	6581	393.1	68.6
8	*Clerodendrum serratum*	65	3.9	6543	390.9	100.7
9	*Helicteres isora*	311	18.6	6341	378.8	20.4
10	*Tamarix dioica*	60	3.6	3729	222.8	62.2
11	*Colebrookea oppositifolia*	114	6.8	3311	197.8	29.0
12	*Securinega virosa*	60	3.6	2086	124.6	34.8
13	*Ziziphus mauritiana*	133	7.9	1737	103.8	13.1
14	*Callicarpa macrophylla*	119	7.1	1491	89.1	12.5
15	*Calamus tenuis*	24	1.4	1390	83.0	57.9
16	*Triumfetta pilosa*	56	3.3	1172	70.0	20.9
17	*Grewia hirsuta*	61	3.6	874	52.2	14.3
18	*Grewia sapida*	82	4.9	786	47.0	9.6
19	*Carrisa opaca*	46	2.7	678	40.5	14.7
20	*Erythrina resupinata*	29	1.7	563	33.6	19.4
21	*Phoenix aculis*	71	4.2	461	27.5	6.5
22	*Thespesia lampas*	23	1.4	417	24.9	18.1
23	*Asparagus adscendens*	79	4.7	258	15.4	3.3
24	*Leea asiatica*	11	0.7	85	5.1	7.7
25	*Sesbania sesban*	2	0.1	76	4.5	38.0
26	*Calotropis procera*	6	0.4	39	2.3	6.5
27	*Clerodendrum indicum*	2	0.1	21	1.3	10.5
28	*Cassia occidentalis*	2	0.1	10	0.6	5.0
29	*Sesbania bispinosa*	2	0.1	9	0.5	4.5
	Total			**279539**	**16698.9**	

The overall number of shrub species recorded in different forests of DNP, KWLS, SKFD and NKFD were 28, 19, 26 and 23, respectively (**Table 3.14**). The evergreen woody climber *Tiliacora acuminata* commonly climbing Sal trees and also spreading on the ground was the most abundant species in the case of DNP. It occurred in as many as 57.0% sampled plots laid in the national park area with highest density, being 6,293.4 shrubs/ha and also highest abundance value (120.4). *Ardisia solanacea* was the second most abundant species in DNP with abundance value, being 103.7. *Clerodendrum viscosum* ranked third on the basis of its density and abundance values, being 4848.7 shrubs/ha and 82.9, respectively. Other important shrub species in the case of DNP were *Glycosmis pentaphylla, Murraya koenigii* and *Colebrookea oppositifolia* based on their corresponding density values. *Lantana camara* occurred just in 1.2% sampled plots (n=667) with values of density and abundance being 10.3 shrubs/ha and 8.6, respectively. Thus, it can be inferred that the distribution and influence of *Lantana camara* in DNP was not so alarming as of other undesirable species *viz., Tiliacora acuminata, Clerodendrum viscosum, Ardisia solanacea* and *Murraya koenigii,* those have proliferated.

Clerodendrum viscosum was the most dominant species in two managed forests (NKFD and SKFD) in terms of percentage frequency of occurrence, density and abundance values. *Flemingia macrophylla* was the second densest shrub in the case of SKFD while *Glycosmis pentaphylla* occupied second place in NKFD based on its density value. *Clerodendrum serratum* was yet another prominent shrub species in both the managed forest divisions. Unlike DNP, *Lantana camara* was conspicuous in NKFD based on its

Table 3.14- Percentage Frequency of Occurrence, Density and Abundance of Select Shrub Species in Forests of Four Constituent Areas

Item/Species	DNP n=667	KWLS n=315	NKFD n=255	SKFD n=437
Number of Shrub Species	28	19	22	26
Overall Shrub Density	21532.8	13968.9	21570.2	9250.6
A. **Percentage Frequency of Occurrence**				
Clerodendrum viscosum	58.5	67.3	45.9	53.5
Flemingia macrophylla	26.7	42.2	15.3	44.4
Ardisia solanacea	48.4	18.4	2.7	9.2
Glycosmis pentaphylla	25.3	8.3	34.1	8.9
Tiliacora acuminata	57.0	11.4	28.6	10.8
Lantana camara	1.2	1.0	31.0	1.4
Clerodendrum serratum	1.2	-	15.7	3.9
Colebrookea oppositifolia	13.6	1.9	6.3	0.2
B. Density – Shrubs/ha				
Clerodendrum viscosum	4848.7	7727.0	6524.3	5118.8
Flemingia macrophylla	399.0	891.7	578.4	1008.5
Ardisia solanacea	5020.8	1140.6	203.5	578.9
Glycosmis pentaphylla	1642.3	534.6	5369.4	314.4
Tiliacora acuminata	6859.5	121.6	842.0	234.1
Lantana camara	10.3	6.7	2497.3	28.1
Clerodendrum serratum	12.6	-	1898.4	370.3
Colebrookea oppositifolia	438.7	55.9	85.1	0.7
C. Abundance				
Clerodendrum viscosum	82.9	114.8	142.2	95.6
Flemingia macrophylla	14.9	21.1	37.8	22.7
Ardisia solanacea	103.7	120.3	74.1	63.3
Glycosmis pentaphylla	64.8	64.8	157.4	35.2
Tiliacora acuminata	120.4	10.6	29.4	21.8
Lantana camara	8.6	7.0	80.6	20.5
Clerodendrum serratum	10.5	-	121.0	95.2
Colebrookea oppositifolia	32.2	29.3	13.6	3.0

abundance. It occurred in 30.5% sampled plots (n=255) in NKFD with much higher density value, being 2,497.3 shrubs/ha. In contrast, *Lantana camara* occurred in only 1.1% plots (n=437) sampled in SKFD. Noticeably, the values of percentage frequency of occurrence of *Tiliacora acuminata* greatly reduced in KWLS (10.6%), NKFD (28.6%) and SKFD (10.8%) against a value of 57.0% in DNP. Similarly, the density values of *Tiliacora acuminata* also declined from as high as 6,859.5 shrubs/ha (DNP) to 842.0 shrubs/ha, 234.1 shrubs/ha, and 121.6 shrubs/ha in NKFD, SKFD, and KWLS, respectively. This indicates that probably relatively open forest canopy and other habitat factors have not favoured *Tiliacora acuminata* in KWLS, SKFD and NKFD (**Table 3.14**).

Interestingly, the overall shrub density was highest in NKFD, being 21.570.2 shrubs/ha. This was followed by 21,532.8 shrubs/ha in DNP and less than half i.e. 9,017.8 shrubs/ha in SKFD. One of the possible reasons for this low shrub density in SKFD can be attributed on the account of greater disturbance by livestock grazing, fire and even forest working.

3.3.4.3 Forest Types

A comparison of shrub layer composition amongst different forest types in TCA also allowed noteworthy observations. Accordingly, the number of shrub species ranged from 8 to 22. The Tropical Semi-Evergreen Forest had the lowest number of shrub species while open Sal forest had the highest number of shrub species. The number of shrub species increased while moving from dense Sal to open Sal forests. The former had just 15 shrubs species while open Sal forests had 22 species.

Clerodendrum viscosum was the densest shrub in five forest types *viz.,* moderately closed Sal, open Sal, *Chandar* Sal, Moist Mixed Deciduous, Khair and Sissoo and also in plantation areas with its highest corresponding density values. Likewise, *Tiliacora acuminata* was the densest shrub in dense Sal, Sal Mixed and Tropical Semi-Evergreen forests. *Ardisia solanacea* with its highest value of density showed specific affinity with Tropical Seasonal Swamp forest.

Noticeably, *Chandar* Sal forests were the only exception in the entire landscape wherein *Tiliacora acuminata* was absent. Otherwise, it commonly occurred in all other forest types. Likewise, *Lantana camara* was almost absent in dense Sal, moderately closed dense Sal, Sal Mixed, *Chandar* Sal and Tropical Semi-Evergreen forests. In contrast, *Lantana camara* prominently occurred in Khair and Sissoo forests and sporadically in Moist Mixed Deciduous and Tropical Seasonal Swamp forests. *Helicteres isora* widely occurred in majority of forest types, except in Tropical Semi-Evergreen, and Khair and Sissoo forests wherein it was conspicuously absent. *Helicteres isora* was common in *Chandar* Sal forests wherein it was one of the prominent shrubs. The density of *Helicteres isora* increased considerably from dense Sal to open Sal forests. *Ziziphus mauritiana* widely occurred in Khair and Sissoo and Tropical Seasonal Swamp forests while only few individuals were recorded in moderately Sal and open Sal forests. The species was conspicuously absent in dense Sal, Sal Mixed, *Chandar* Sal and Tropical Semi-Evergreen forests. *Flemingia macrophylla* occurred widely and profusely in all forest types.

3.3.5 Herb Diversity

As in the case of shrubs, a diversity of 89 herb species was earlier listed in different forests and grasslands of TCA (**Table 3.5**). However, herb layer assessment carried out in different forests only allowed several noteworthy observations. These observations for the landscape, four constituent areas and each forest type are described one by one.

3.3.5.1 Landscape

In all, 27 herb species were recorded in 1,674 plots sampled in different forest types of TCA (**Table 3.15**). It is apprehended that this low herb diversity could be for the fact that majority of herbs were short lived and seasonal in nature. They prominently occured in the rainy season. It is possible that due to delayed sampling in later months, a large number of herb species could not be captured despite extensive sampling. Nevertheless, some important findings have emerged. *Dioscorea belophylla* was the most prominent herb species based on its highest value of frequency of occurrence being 13.3%. This was followed by *Sonchus asper, Dioscorea hispida* and *Ageratum conyzoides* with 11.8%, 9.3% and 9.2% of frequency of occurrence, respectively.

Swertia angustifolia occurred in 7.0% sampled plots while *Cassia tora* was recorded in just 5.8% plots. Two species each of genera *Sonchus, Dioscorea* and *Leucas* were recorded. Sixteen species out of 27 recorded herbs species had much limited distribution i.e. having values <2.5% frequency of occurrence.

Cassia tora was the densest herb. This was followed by *Ageratum conyzoides*. Both had little or no value to wildlife instead they were more as weeds. *Cassia tora* was the most dominant species based on its highest abundance value. *Corchorus aestuans* was the second most abundant herb. *Curcuma amada, Ageratum conyzoides* and *Typha elephantina* were other prominent herbs based on their higher values of abundance.

3.3.5.2 Constituents Areas

A comparison of herb diversity among the four constituent areas was also made (**Table 3.16**). In general, it was inferred that the two managed forests had relatively higher values of frequency of occurrence for the herbaceous flora than the two protected areas. Likewise, the density values of different herb species were much higher in the case of MFs than PAs indicating that herbs were widely distributed and abundant in MFs than PAs.

3.3.5.3 Forest Types

The number of herb species in different forest types ranged from 7 to 18. The lowest number of species

Table 3.15 – Herbs in Different Forests of Terai Conservation Area (n=1,674)

Sl. No.	Species	Plots of Occurrence	% Frequency	Herbs (No.)	Density (herbs/ha)	Abundance
1	*Cassia tora*	94	5.6	14697	87795.7	156.4
2	*Ageratum conyzoides*	148	8.8	8751	52276.0	59.1
3	*Sonchus asper*	191	11.4	7249	43303.5	38.0
4	*Dioscorea belophylla*	215	12.8	5795	34617.7	27.0
5	*Corchorus aestuans*	44	2.6	4974	29713.3	113.0
6	*Discrorea hispida*	150	9.0	3313	19790.9	22.1
7	*Swertia angustifolia*	113	6.8	3286	19629.6	29.1
8	*Curcuma amada*	27	1.6	2465	14725.2	91.3
9	*Commelina attenuata*	50	3.0	1893	11308.2	37.9
10	*Piper longum*	42	2.5	1212	7240.1	28.9
11	*Typha elephantina*	9	0.5	479	2861.4	53.2
12	*Solanum nigrum*	14	0.8	249	1487.5	17.8
13	*Chenopodium album*	26	1.6	221	1320.2	8.5
14	*Croton bonplandianus*	10	0.6	197	1176.8	19.7
15	*Oxalis corniculata*	14	0.8	249	1075.3	17.8
16	*Amaranthus viridis*	10	0.6	176	1051.4	17.6
17	*Solanum suranttense*	12	0.7	148	884.1	12.3
18	*Leucas cephalotes*	10	0.6	147	878.1	14.7
19	*Amaranthus spinosus*	6	0.4	145	866.2	24.2
20	*Polygonum hydropiper*	5	0.3	135	806.5	27.0
21	*Cannabis sativa*	4	0.2	103	615.3	25.8
22	*Ipomoea pes-tigridis*	4	0.2	41	244.9	10.3
23	*Leucus mollissima*	5	0.3	35	209.1	7.0
24	*Coccina grandis*	3	0.2	14	83.6	4.7
25	*Blumea mollis*	1	0.1	10	59.7	10.0
26	*Eclipta prostrata*	1	0.1	6	35.8	6.0
27	*Rungia pectinata*	2	0.1	6	35.8	3.0
	Total			55927	334092.0	

Table 3.16 – Percentage Frequency of Occurrence, Density and Abundance of Prominent Forest Herb Species in Four Constituent Areas

Item/Species	DNP n=667	KWLS n=315	NKFD n=255	SKFD n=437
Number of Herb Species	25	17	17	17
Overall Herb Density	177901.0	134571.3	956117.6	371846.5
A. Percentage Frequency of Occurrence				
Cassia tora	4.5	-	15.3	-
Ageratum conyzoides	10.6	3.8	12.2	8.0
Sonchus asper	10.5	7.6	10.2	-
Dioscorea belophylla	8.4	11.1	12.5	21.1
Swertia angustifolia	3.4	8.3	8.2	10.1
Curcuma amada	3.6	-	1.2	-
B. Density – Herbs/ha				
Cassia tora	12353,8	-	461098.0	-
Ageratum conyzoides	46656.7	6095.2	121725.5	53615.6
Sonchus asper	26956.5	27682.5	60705.9	-
Dioscorea belophylla	18725.6	29764.9	27490.2	66407.3
Swertia angustifolia	6776.6	28761.9	33921.6	24324.9
Curcuma amada	29340.3	-	19921.6	-
C. Abundance				
Cassia tora	27.5	-	301.5	84.6
Ageratum conyzoides	43.8	16.0	100.1	66.9
Sonchus asper	25.7	36.3	59.5	-
Dioscorea belophylla	22.3	26.9	21.9	-
Swertia angustifolia	19.7	34.8	41.2	31.5
Curcuma amada	81.5	-	169.2	-

recorded were in Tropical Semi-Evergreen forest while the highest number of herb species was in open Sal and Moist Mixed Deciduous forests. *Ageratum conyzoides* obtained the highest density values in dense Sal and Moist Mixed Deciduous forests. *Curcuma amada, Dioscorea hispida, Dioscorea belophylla, Desmodium triflorum* and *Sonchus asper* were the prominent herbs species in moderately dense Sal, open Sal, *Chandar* Sal, Tropical Seasonal Swamp, and Moist Mixed Deciduous forests whilst *Cassia tora* charaterized Khair and Sissoo forests due to its highest value of density.

3.3.6 Diversity Indices

Values of Margalef Index (R) for species richness and Shannon's Index (H') for diversity and evenness computed for trees, shrubs and herbs in TCA and constituent areas are presented in **Table 3.17**. A comparison between two PAs and MFs is also presented. The analysis excludes shrubs and herb diversity in Lowland grasslands.

The values of tree species richness based on the Margalef Index ranged from 6.9 (SKFD) to 9.3 (PAs). The DNP with the highest R-value, being 8.9 revealed the greatest species richness among the four constituent areas, followed by other PA i.e. KWLS. Two managed forest divisions (NKFD and SKFD) as well as two MFs combined had lower values of R than two PAs. Lower values of tree species richness in two MFs were obvious owing to the inadequate representation of the complete array of forest/ vegetation types in them. In contrast, two MFs were more even in terms of distribution of species abundance.

The SKFD was richest in the shrub diversity based on the highest R-value amongst the four constituent areas, being 2.36 while KWLS was the poorest in shrub richness. Two PAs were richer in shrub diversity than two MFs. The KWLS was least even in terms of distribution of shrub species abundance. As in the case of trees, two MFs combined were more even in shrub species abundance than PAs.

The DNP was the richest in herb diversity amongst the four constituent areas based on the highest R-value, being 2.55. This was followed by KWLS. The NKFD and SKFD were relatively poorer in herb diversity. Thus, PAs were richer in herb diversity than MFs as well as more even in the distribution of species abundance.

Table 3.17 - Diversity Indices for Trees, Shrubs, and Herbs in Terai Conservation Area

Diversity Indices	Constituent Areas						
	DNP	KWLS	NKFD	SKFD	PAs	MFs	TCA
Trees							
Margalef Index (R) for Species Richness	8.9	7.1	7.6	6.9	9.3	7.5	9.2
Shannon's Index (H') for Diversity	2.4	2.3	2.8	2.5	2.4	2.8	2.7
Shrubs							
Margalef Index (R) for Species Richness	2.3	1.7	2.0	2.4	2.3	2.3	2.2
Shannon's Index (H') for Diversity	1.8	1.6	2.0	1.8	1.9	2.1	2.1
Herbs							
Margalef Index (R) for Species Richness	2.6	1.9	1.6	1.7	2.7	2.0	2.4
Shannon's Index (H') for Diversity	2.2	1.9	1.6	2.2	2.3	2.1	2.7

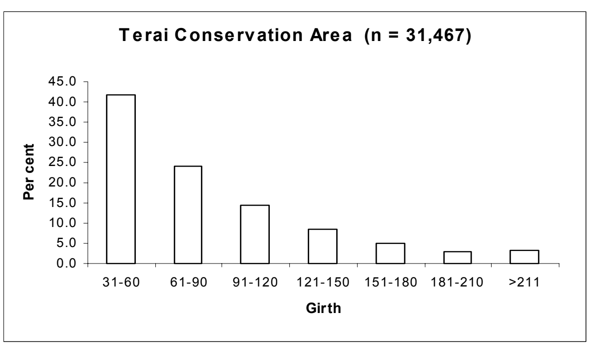
3.3.7 Tree Regeneration

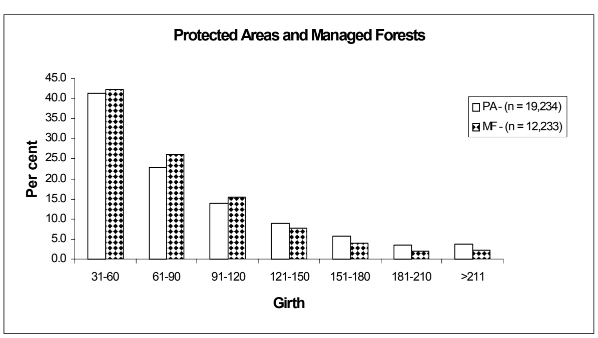
Data on girth size for 31,467 trees enumerated in TCA through extensive sampling in the four constituent areas allowed an understanding of the girth class distribution in standard classes of 30 cm interval. Data analysis revealed near normal girth class distribution for trees in TCA, PAs and MFs indicating occurrence of young, middle-aged, and matured trees (**Fig. 3.2**). However, similar analysis on select tree species of management and conservation concern (e.g. timber, Non -Timber Forest Produces, and fruit bearing species) allowed interesting inferences about the regeneration and recruitment status on one hand while able to forecast the future on the other hand.

3.3.7.1 Timber Species

Sal (*Shorea robusta*), *Terminalia alata*, *Dalbergia sissoo*, and *Haldina co*rdifolia were the prominent timber species of TCA. *Tectona grandis* and *Eucalyptus citriodora*, two introduced species to TCA are also in great demand as the former is one of the best and most expensive timber species while the later is being used by the Paper and Pulp industry as well as small timber and firewood by local people. *Terminalia bellirica*, *Syzygium cumini*, *Albizia* sp., etc. are also being used as small timber species.

Fig.3.2 – Girth Class Distribution of Trees in Terai Conservation Area, Protected Areas (PAs) and Managed Forests



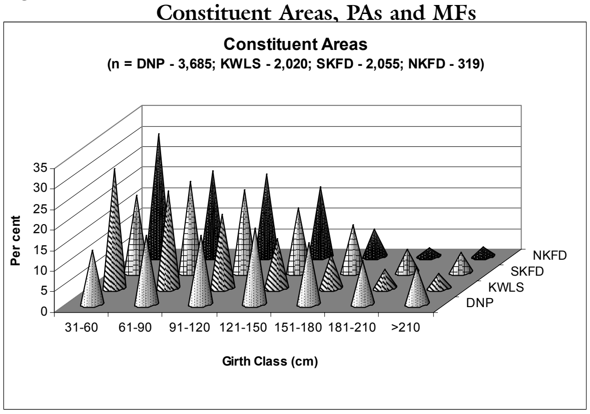


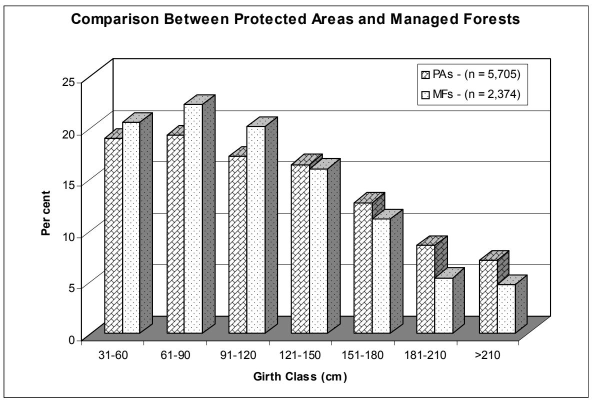
Sal (*Shorea robusta*) being the most prominent species in TCA in terms of its wide spread occurrence, density, abundance, timber value, and long management history yielded near normal girth class distribution in PAs as well as MFs (**Fig. 3.3**). However, a close scrutiny revealed that DNP area lacked young trees (between 31 and 90 cm girth) while middle-aged, and matured and larger trees existed in adequate proportion. The inadequate representation of young sal trees in DNP indicated poor regeneration and/or establishment in at least past 2-3 decades. It can be postulated that the dense Sal situation or current management practices in DNP were probably not conducive to the regeneration and establishment of Sal. In contrast, three other constituent areas (KWLS, NKFD and SKFD) proportionately showed higher representation of young trees. Interestingly, small and scattered forest patches of NKFD those are adjacent to DNP had proportionately the highest percentage of young Sal trees. Almost 70% enumerated Sal trees in NKFD were in the first three girth classes i.e. upto 120 cm. Apparently, forest fragments of NKFD experience much more biotic pressure due to their proximity to villages and thus, are greatly disturbed in comparison to Sal forests in DNP. The KWLS and two MFs were conspicuous in poor representation of girth classes >150 cm. The percentage values of Sal trees above 210 cm girth in the four constituent areas ranged from 2.5% (NKFD) to 9.0% (DNP). The greater representation of trees in the higher girth classes in DNP amply indicates that the active protection in past 3 decades and simultaneous discontinuation of forest working has allowed middle age trees to further grow on one hand while regeneration and establishment have been badly affected.

In contrast to the native Sal, exotic teak (*Tectona grandis*) which was extensively planted throughout the TCA in 1960s and 1970s exhibited majority (~95%) of young and middle age trees in all the constituent areas. Higher girth classes were almost absent or poorly represented (**Fig 3.3**).

One of the co-associates of Sal i.e. *Terminalia alata* depicted relatively low population of young trees in DNP and SKFD. This situation can be argued on the basis of two potential reasons. Firstly, the dense Sal with closed canopy, thick litter, and abundance of shrubs might be inhibiting adequate regeneration and establishment in the case of DNP despite ample protection from biotic disturbance. Secondly, in

Fig. 3.3 – Girth Class Distribution of *Shorea robusta* in Four Constituent Areas, PAs and MFs





SKFD the annual ground fires and other biotic pressure might be resulting into poor regeneration and establishment. In contrast, the KWLS possessed proportionate percentage of young trees. Otherwise, the DNP as well as SKFD harboured relatively a greater proportion of middle aged and matured trees of *Terminalia alata* (**Fig. 3.4).**

Dalbergia sissoo, yet an another important timber species showed adequate regeneration and establishment. In DNP, more than 60% trees recorded were young while only a small number of trees were middle aged and adult. The greater proportion of young trees could be due to the extensive plantation of this species in 1970s. In contrast to DNP, KWLS and two managed forests lacked desired regeneration and establishment of *D. sissoo* (**Fig. 3.5**).

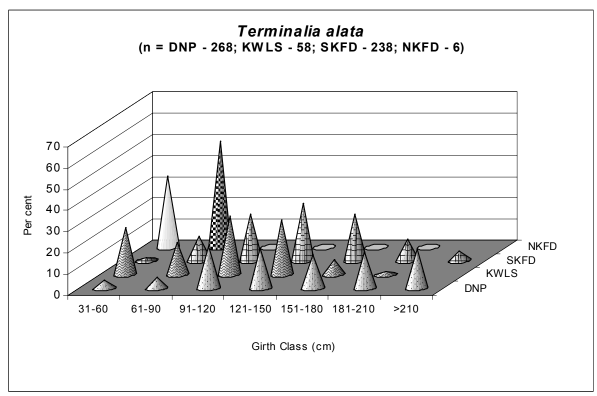
3.3.7.2 NTFP Species

Acacia catechu, Terminalia bellirica, Diospyros melanoxylon, Bombax ceiba, Madhuca longifolia, Aegle marmelos, Syzygium cumini, and *Emblica officinalis* are some of the important non-timber tree species widely used by local people for various purposes as well as a few of them have some industrial use also. Despite low occurrence of these species in sampled plots, a detailed assessment on the girth distribution undertaken in the case of *Diospyros* melanoxylon showed high proportion of young trees due to its coppice growth. However, all the four constituent areas lacked the middle aged and adult trees of *D. melanoxylon.*

The DNP distinctly exhibited inadequate regeneration and establishment of *Acacia catechu* on one hand while the absolute absence of adult trees (**Fig. 3.5**). The former can be due to the occurrence of dense grass and its severe fire effect. This was probably not the case when local people were allowed to harvest thatch and fodder grass in large quantities. The absence of adult and old trees might be due to their systematic removal in the past during logging operations. In contrast, two managed forests (SKFD and NKFD) showed adequate establishment and bulk (~95%) of trees in the young stage. Only less than 5% trees recorded were either middle aged or adult.

Aegle marmelos and *Terminalia bellirica* showed moderate regeneration, recruitment as well as adult trees attaining girth upto 150 cm. A small number of

Fig. 3.4 – Girth Class Distribution of *Terminalia alata* and *Tectona grandis* in Four Constituent Areas of TCA



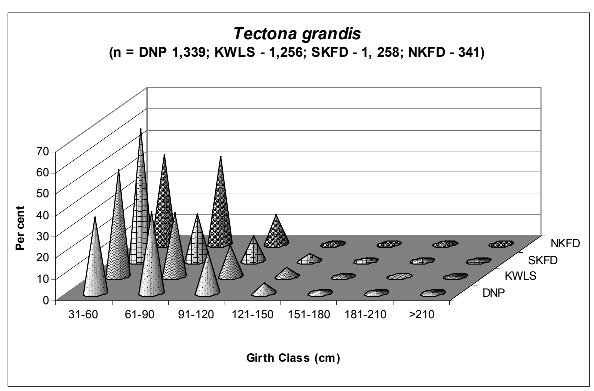
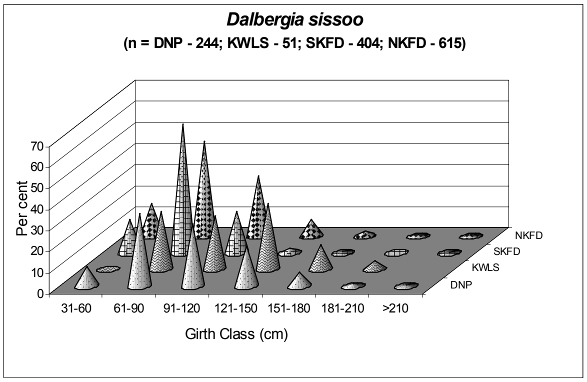
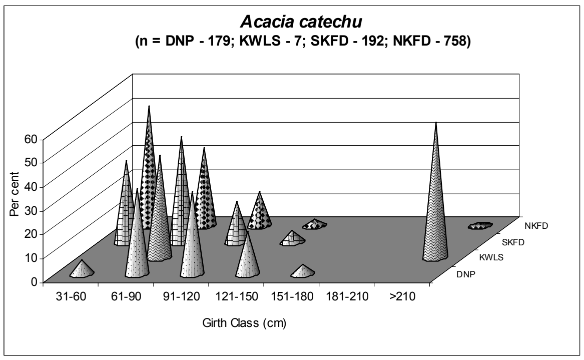


Fig. 3.5 - Girth Class Distribution of *Dalbergia sissoo* and *Acacia catechu* in Four Constituent Areas of TCA





Aegle marmelos trees in NKFD were larger than 150 cm girth. Likewise, DNP and SKFD harboured some bigger trees of *Terminalia bellirica* i.e. with >180 cm girth.

3.3.7.3 Fruit Bearing Tree Species

Several wild animals eat fruits of *Ficus* sp., *Syzygium cumini*, *Schelichera oleosa*, *Trewia nudiflora*, *Aegle marmelos*, *Diospyros melanoxylon*, *Ziziphus* sp., and *Madhuca longifolia*.

Syzygium cumini was probably only species in TCA which depicted a near normal distribution of girth in all the four constituent areas (**Fig. 3.6**). Regeneration was profuse in each constituent area. Ample middle aged as well as larger trees with girth >150 cm occurred.

Trewia nudiflora, a highly selected species for fruits by ungulates and rhinos showed good regeneration, recruitment, young, middle aged and adult trees in DNP and NKFD (**Fig.3.6**). Recruitment and young classes of *T. nudiflora* were inadequately represented in the case of KWLS. On the contrary, larger girth trees were present. Thus, it is evident that the existing conditions for the regeneration and establishment of *T. nudiflora* in KWLS were probably not conducive and therefore, calls for the management attention in this direction. Interestingly, the middle aged and adult trees of *T. nudiflora* were completely absent in SKFD. All recorded trees were of young age.

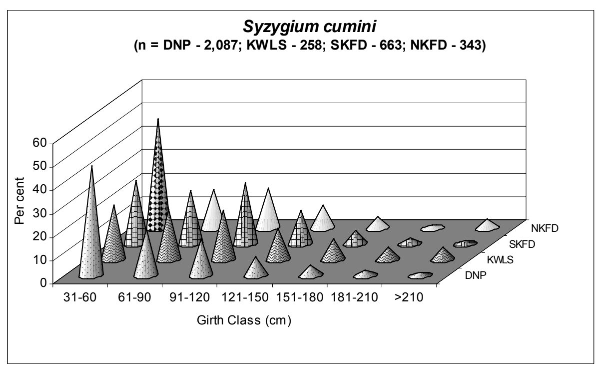
3.3.8 Grassland Diversity

3.3.8.1 Grassland Classification

Data on shrubs, herbs, grasses, sedges, and ferns collected in 293 plots (10m x 10m) sampled in select 12 relatively drier, Upland grassland patches and 12 moist/wet, Lowland grassland patches in TCA used for TWINSPAN analysis resulted into the following nine grassland species assemblages (**Fig. 3.7**). These assemblages include only indicator species and strongly preferential species.

The first division of samples separated the outlying *Typha elephantina* assemblage from the others at Eigen value 0.812. The species found in it were exclusive to this assemblage. The second split divided *Imperata cylindrica* as major component to one group and samples with *Saccharum narenga, Apluda mutica, Sclerostachya fusca* and *Themeda arundinacea* as major

Fig. 3.6 - Girth Class Distribution of *Syzygium cumini* and *Trewia nudiflora* in Four Constituent Areas of TCA



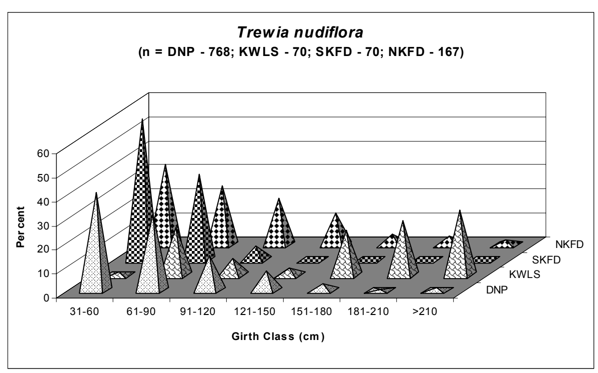
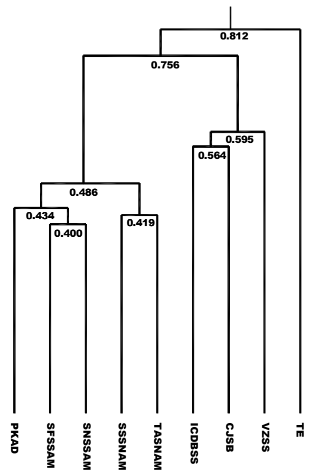


Fig. 3.7 – A Dendogram Showing the Plant Assemblages Identified from Grasslands in TCA using TWINSPAN Analysis



Plant Assemblages

TE	-	*Typha elephantina*
VZSS	-	*Vetiveria zizanioides – Saccharum spontaneum*
CJSB	-	*Cymbopogon jwarancusa – Saccharum bengalense*
ISDBSS	-	*Imperata cylindrica – Desmostachya bipinnata – Saccharum spontaneum*
TASAAM	-	*Themeda arundinacea – Saccharum narenga – Apluda mutica*
SSSNAM	-	*Saccharum spontaneum – Saccharum narenga – Apluda mutica*
SNSSAM	-	*Saccharum narenga – Saccharum spontaneum – Apluda mutica*
SFSSAM	-	*Sclerostachya fusca – Saccharum spontaneum – Apluda mutica*
PKAD	-	*Pharagmites karka – Arundo donax*

components to another group. In fact, these two groups broadly classified the grasslands of TCA into the Upland grasslands dominated by short grasses (upto 2m), particularly *Imperata cylindrica* and the Lowland grasslands characterized by tall (6m) grasses *viz., Sclerostachya fusca, Saccharum narenga* and *Themeda arundinacea.*

The Upland grasslands had the next split at the Eigen value 0.595 and divided into *Vetiveria zizanoides* as a major component to one group and *Imperata cylindrica* and *Desmostchya bipinnata* as major components to another group. The later group further divided and formed two assemblages. Thus, the Upland grasslands had altogether three assemblages *viz.,* (i) *Vetiveria zizanoides – Saccharum spontaneum (VZSS);* (ii) *Cymbopogon jwarancusa – Saccharum bengalense (CJSB);* and (iii) *Imperata cylindrica – Desmostachya bipinnata – Saccharum spontaneum (ICDBSS)* types.

The Lowland grasslands had the first split at the Eigen value 0.486, dividing into two groups. The first group was characterized by *Themeda arundinacea* as a major component while the second group having *Sclerostachya fusca, Saccharum narenga, Apluda mutica* and *Phragmites karka* as major components. The *Themeda arundinacea* group had the second split at the Eigen value 0.419 and resulted into two assemblages *viz.,* (i) *Themeda arundinacea – Saccharum narenga – Apluda mutica (TASNAM)*; and (ii) *Saccharum spontaneum – Saccharum narenga – Apluda mutica (SSSNAM)* types. The second group had next split at the Eigen value 0.434 and divided into two sub-groups. The first sub-group having *Saccharum narenga* and *Apluda mutica* as major components. The second sub-group having *Pharagmites karka* as a major component. The first sub-group had the last split at the Eigen value 0.400 and resulted into two assemblages *viz.,* (i) *Saccharum narenga – Saccharum spontaneum – Apluda mutica (SNSSAM);* and (ii) *Sclerostachya fusca – Saccharum spontaneum – Apluda mutica (SFSSAM)* types. The second sub-group was a distinct assemblage and named as *Phragmites karka – Arundo donax (PKAD)* type.

In the above manner, the dendrogram distinctly exhibited that the deciphered nine grass assemblages formed three separate groups. The first group was characterized by only one assemblage of *Typha elephantina.* The second group was deciphered as the Upland grassland having three grass assemblages whilst the third group of the Lowland grassland having five grass assemblages. Occurrence of these nine assemblages in TCA indicated a high grassland diversity, from early successional *Phragmites karka – Arundo donax, Saccharum spontaneum – Saccharum narenga – Apluda mutica* assemblages to tall grassland *Themeda arundinacea – Saccharum narenga – Apluda mutica* assemblage on old river terraces with developed soils on one hand whilst short grasslands dominated by *Imperata cylindrica, Cymbopogon jwarancusa,* and *Vetiveria zizanoides* and their associate species on the other hand.

The above nine grass assemblages actually represented the *Phragmites – Saccharum – Imperata,* one of the four *major* grass cover types as described by Dabadghao and Shankarnarayan (1973). They have identified 19 principal grass species, each forming a community those represented this major grass cover throughout its area of distribution i.e. the Gangetic Plains, the Brahamputra Valley and extened westwards into the plains of the Punjab. However, their classification does not acounted for the diversity of plant species assemblages in the *Terai* grasslands those have been identified by Lehmkuhl (1994), Peet *et al.* (1997), and also in the present study.

Lehmkuhl (1994) gave a more complex classification of grasslands and forest species assemblages in the Royal Chitwan NP, Nepal based on 188 plots from 2300 ha of the park. This study identified ten grassland associations, with six phases, and three forest associations through cluster analysis of samples with TWINSPAN. While Peet *et al.* (1997) sampled altogether 200 plots randomly located in grasslands, fifty in each of the selected four protected areas *viz.,* Royal Chitwan National Park, Royal Suklaphanta Wildlife Reserve, Royal Bardia National Park, and Koshi Tappu Wildlife Reserve. They identified nine grassland assemblages with eight phases as a result of the TWINSPAN analysis.

A number of similarities exist between the two earlier classifications (Lehmkuhl, 1994; Peet et *al.,* 1997) and the one presented in this study (**Table 3.18**). Accordingly, *Sclerostachya fusca, Vetivaria zizanoides, Cymbopogon jwarancusa* dominated assemblages lacked in the classification by Peet *et al.* (1997) despite they covered four protected areas in Nepalese *Terai.* Otherwise, rest of the assemblages in present study closely corresponded to various assemblages and phases described by them. However, the restricted area covered by Lehmkuhl's sampling resulted in the classification lacking *Imperata cylindrica, Typha elephantina, Vetiveria zizanoides, Cymbopogon jwarancusa,* and *Sclerostachya fusca* dominated assemblages or phases. The grassland assmeblages characterized by *Imperata cylindrica* and *Saccharum spontaneum* are extensively used by a number of endangered species *viz.,* swamp deer, hispid hare, and Bengal florican and are, thus of particular importance for the conservation (Schaaf, 1978; Inskipp and Inskipp, 1983; Peet *et al.,* 1997). Likewise, dense grasslands dominated by *Pharagmites karka, Arundo donax, Saccharum spontaneum* are of greater significance for the conservation of rhinos.

3.3.8.2 Species Composition

Altogether, 149 plant species representing 11 trees, 13 shrub, 89 herb, 25 grass, 6 sedge, and 5 fern species were recorded in grasslands of TCA through sampling in 293 plots (**Table 3.19**). Majority of these species occurred in low abundance and low frequency. Thus, only 13 species or 9.4% of the recorded species obtained values of percentage frequency >10%. This included four herbs *viz., Oldenlandia corymbosa, Eclipta prostrata, Blumea mollis,* and *Arisaema tortuosum;* eight grass species, namely *Saccharum spontaneum, Saccharum narenga, Imperata cylindrica, Apluda mutica, Sclerostachya fusca, Themeda arundinacea, Vetiveria zizanoides,* and *Desmostachya bipinnata;* and the only sedge – *Fimbristylis dichotoma*. Eleven tree species were recorded in the Upland grasslands of TCA. Prominent among them were: *Bombax ceiba, Bauhinia racemosa, Acacia catechu, Dalbergia sissoo,* and *Butea monosperma. Tectona grandis,* an exotic was extensively planted in 'grassy blanks'. Other species were *Catunaregam uliginosa, Haldina cordifolia, Ficus religiosa, Citrus medica* and *Randia tetrasperma*. These trees were widely scattered in the Upland grasslands, as their values of percentage frequency were less than 10%.

Thirteen (13) shrub species were recorded in different grasslands against a forest shrub richness of 29 species. Only three shrubs *viz., Helicteres isora, Ziziphus mauritiana,* and *Leea asiatica* were common between different forests and grasslands while other 10 shrub species exclusively occurred in grasslands. This included four species of genera *Desmodium (D. motorium, D. triflorum, D. pulchellum,* and *D. gangeticum), Flemingia chappar, Ventilago denticulata, Ichnocarpus frutescens, Tamarix dioica, Securinega macrophylla,* and *Calotropis gigantea. Helicteres isora* occurred in just 4.78% sampled plots (n = 293). Otherwise, all other shrub species occurred in low frequency and abundance.

Eighty-nine (89) herb species were recorded in grasslands of TCA. The herb species richness in grasslands was almost three times higher than that of forests (27 species).

Twenty-five grass species were recorded in grasslands of TCA. *Saccharum spontaneum* occurred in as many as 41.98% sampled plots (n = 293). This was followed by *Saccharum narenga* and *Imperata* cylindrica with values of frequency of occurrence, being 33.5% and 31.8%, respectively (**Table 3.20**). Other important species on the basis of their higher values of frequency of occurrence were: *Apluda mutica, Sclerostachya fusca, Themeda arundinacea, Vetiveria zizanoides,* and *Desmostachya bipinnata. Phragmites karka* occurred in just 8.9% plots sampled. Remaining grass species obtained frequency values <6.5%. Thus, it was inferred that two species of *Saccharum* i.e. *S. spontaneum* and *Saccharum narenga* and also *Imperata cylindrica* were widely distributed in grasslands of TCA. These three species alongwith *Vetiveria zizanoides* contributed for nearly 55% grass cover in TCA. *Imperata cylindrica* alone occupied almost one fifth of the ground cover in grasslands.

Table 3.18 – Grassland Species Assemblages in the Present Study and a Comparison with Two Earlier Studies

Present Study – TCA	Peet *et al.* (1997) – Four PAs	Lehmkuhl (1994) – Chitwan NP
Typha elephantina assemblage - Permanently waterlogged sites	*Typha elephantina* assemblage	Not identified, outside Lehmkuhl's study area
Vetiveria zizanoides – Saccharum spontaneum assemblage -Upland grasslands well developed soils, heavily grazed	Not identified	Not identified and found
Cymbopogon jwarancusa – Saccharum bengalense assemblage -Upland grassland, dry sites, frequently burned, least grazing	*Imperata cylindrica – Narenga porphyrocoma* assemblage, *Saccharum spontaneum – Saccharum bengalense* phase -Edges of wet sites, newer terraces	*Narenga porphyrocoma* * – *Saccharum bengalense* association -New river terraces influenced by fire and grazing
Imperate cylindrica – Desmostachya bipinnata – Saccharum spontaneum assemblage -Upland grasslands, dry sites, well developed soils	*Imperate cylindrica* assemblage, *Imperata cylindrica* phase, *Imperata – Saccharum* phase -Dry sites, well developed soils, previously cultivated	Not identified, found outside Lehmkuhl's study area
Themeda arundinacea – Saccharum narenga – Apluda mutica assemblage -Tall, dense grassland, often at forest edge, well developed soils influenced by fire	*Themeda arundinacea* assemblage -Tall, dense grassland, often at forest edge, well developed soils, influenced by fire	*Themeda arundinacea – Narenga porphyrocoma* association -Tall, dense grassland, fire maintained savanna, on fairly drained soils
Not identified	Not identified	*Themeda arundinacea – Imperata cylindrica* association -Sal forest meadows and Sal – grassland ecotone
Saccharum spontaneum – S. narenga – Apluda mutica assemblage - Floodplain grassland, alluvial soils, often inundated	*Saccharum spontaneum* assemblage, mixed *S. spontaneum* phase, *S. spontaneum* phase, *S. spontaneum – Dalbergia sissoo* phase -Floodplain grassland, alluvial soils, often inundated	*Saccharum spontaneum – Saccharum spontaneum* association, *Imperata cylindrica* phase, *Saccharum spontaneum* phase -Floodplain grassland, alluvial soils
Saccharum narenga – S. spontaneum – Apluda mutica assemblage -Tall, dense grasslands, old river terraces and wetter soils, influenced by fire	*Narenga porphyrocoma* assemblage -Tall, dense grasslands, old river terrances and wetter soils, influenced by fire	*Narenga porphyrocoma – N. porphyrocoma* association -Wet, well developed soils, influenced by fire and grazing
Sclerostachya fusca – Saccharum spontaneum – Apluda mutica -Seasonally inundated, tall dense grassland	Not identified	Not identified
Phragmites karka – Arundo donax assemblage -Tall, dense grassland, seasonal and permanent marsh	*Phragmites karka – Saccharum spontaneum* assemblage -Seasonally inundated, heavily grazed	Not identified, outside Lehmkuhl's study area
Not identified	*Phragmites karka – Saccharum spontaneum – S. arundinaceum* assemblage -Tall, dense grassland, seasonal and permanent marsh	*Saccharum spontaneum – Phragmites karka* association -Marshland

Saccharum narenga is the new nomenclature for Narenga porphyrocoma.

Table 3.19 – Percentage Frequency of Occurrence of Trees, Shrubs, Herbs, Sedges, and Ferns in Grasslands of TCA

Sl. No.	Species	Percentage Frequency
A.	**Trees (n = 134)**	
1	*Bombax ceiba*	8.2
2	*Bauhinia racemosa*	8.2
3	*Acacia catechu*	6.0
4	*Dalbergia sissoo*	3.0
5	*Butea monosperma*	3.0
6	*Tectona grandis*	2.2
7	*Catunaregam uliginosa*	1.5
8	*Haldina cordifolia*	0.7
9	*Ficus religiosa*	0.7
10	*Citrus medica*	0.7
11	*Randia tetrasperma*	0.7
B.	**Shrubs (n = 293)**	
1	*HHelicteres isora*	4.78
2	*Desmodium motorium*	2.05
3	*Desmodium triflorum*	1.37
4	*Ventilago denticulata*	1.37
5	*Desmodium pulchellum*	1.37
6	*Ichnocarpus frutescens*	1.37
7	*Desmodium gangeticum*	0.68
8	*Calotropis gigantea*	0.68
9	*Flemingia chappar*	0.68
10	*Tamarix dioica*	0.68
11	*Ziziphus mauritiana*	0.68
12	*Secrunega macrophylla*	0.68
13	*Leea asiatica*	0.68
C.	**Herbs (n = 293)**	
1	*Oldenlandia corymbosa*	17.06
2	*Eclipta prostrata*	12.29
3	*Blumea mollis*	10.92
4	*Arisaema tortuosum*	10.92
5	*Polygonum plebeium*	9.56
6	*Sphaeranthus indicus*	8.87
7	*Gloriosa supreba*	8.87
8	*Leucas mollissima*	8.19
9	*Parthenium hysterphorus*	7.51
10	*Typha elephantina*	7.51
11	*Argemone mexicana*	7.17
12	*Amaranthus spinosus*	6.83
13	*Coccinia grandis*	6.14
14	*Mimosa pudica*	5.80
15	*Cassia tora*	5.46
16	*Sonchus asper*	5.12
17	*Ipomea pes-tigridis*	5.12
18	*Amaranthus viridis*	4.78
19	*Cissampelos pareira*	4.78
20	*Hygrophila auriculata*	4.78
21	*Swertia angustifolia*	4.78
22	*Euphorbia hypericifolia*	4.78
23	*Polygonum hydropiper*	4.44
24	*Polygonum barbatum*	4.10
25	*Vicia hirsuta*	4.10
26	*Olax nana*	4.10
27	*Leucas cephalotes*	3.41
28	*Cleome gynandra*	3.41
29	*Croton bonplandianus*	3.41
30	*Cynoglossum zeylanicum*	3.41
31	*Crotalaria albida*	3.41
32	*Blumea lacera*	3.41
33	*Curculigo orchiodis*	2.73
34	*Evolvulus alsinoides*	2.73
35	*Curcuma amada*	2.73
36	*Curcuma angustifolia*	2.05
37	*Lysimachia candida*	2.05
38	*Rungia pectinata*	2.05
39	*Arnebia hispidissima*	2.05
40	*Biophytum sensitivum*	2.05
41	*Eulophia flava*	2.05
42	*Evolvulus nummularius*	2.05
43	*Borreria pusilla*	2.05
44	*Melilotus alba*	1.37
45	*Polygala arvensis*	1.37
46	*Withania somnifera*	1.37
47	*Dioscorea belophylla*	1.37
48	*Commelina attenuata*	1.37
49	*Cayratia trifolia*	1.37
50	*Rauvolfia serpentina*	1.37
51	*Solanum nigrum*	1.37
52	*Solanum surattense*	1.37
53	*Borreria articularis*	1.37
54	*Cannabis sativa*	1.37
55	*Anisomeles indica*	1.37
56	*Aeschynomene indica*	1.37
57	*Euphorbia hirta*	0.68
58	*Ageratum conyzoides*	0.68
59	*Corchorus aestuans*	0.68
60	*Dioscorea hispida*	0.68
61	*Exacum tetragonum*	0.68
62	*Polygala crotalarioides*	0.68
63	*Pentanema indicum*	0.68
64	*Piper longum*	0.68
65	*Atylosia scarabaeoides*	0.68
66	*Chenopodium album*	0.68
67	*Saussurea hetromalla*	0.68
68	*Lactuca dolichophylla*	0.68
69	*Gnaphalium luteo-album*	0.68
70	*Malvastrum coromandelianum*	0.68
71	*Selinm monnieri*	0.68
72	*Alternanthera sessilis*	0.68
73	*Erigeron sublyratus*	0.68
74	*Hemigraphis hirta*	0.68
75	*Martynia annua*	0.68
76	*Heliotropium zeylanicum*	0.68
77	*Rhynchosia minima*	0.68
78	*Trichodesma sedgwickianum*	0.68
79	*Uraria picta*	0.68
80	*Launaea acaulis*	0.68
81	*Naravelia zeylanica*	0.68
82	*Leea alata*	0.68
83	*Oxalis corniculata*	0.68
84	*Blumea hieracifolia*	0.68
85	*Heliotropium strigosum*	0.68
86	*Eulophia homusjii*	0.68
87	*Sida rhombifolia*	0.68
88	*Diclitptera roxburghiana*	0.68
89	*Abelmoschus crinitus*	0.68
D.	**Sedges (n = 293)**	
1	*Fimbristylis dichotoma*	12.29
2	*Scleria levis*	7.51
3	*Cyperus niveus*	5.46
4	*Cyperus kyllingia*	5.12
5	*Carex fedia*	2.73
6	*Cyperus iria*	0.68
E.	**Ferns (n = 293)**	
1	*Pteris vittata*	4.78
2	*Adiantum lunulatum*	4.78
3	*Lygodium flexuosum*	4.10
4	*Diplazium esculentum*	0.68
5	*Ceratoptris thalicteroides*	0.68

Table 3.20 – Percentage Frequency of Occurrence and Cover of Grass Species in TCA (n=293)

Sl. No.	Species	Percentage Frequency	Percentage Cover	Abundance
1	*Saccharum spontaneum*	42.0	11.00	26.22
2	*Saccharum narenga*	33.5	15.99	47.81
3	*Imperata cylindrica*	31.7	18.03	56.80
4	*Apluda mutica*	21.2	4.86	22.98
5	*Sclerostachya fusca*	19.1	8.58	44.91
6	*Themeda arundinacea*	17.8	8.76	49.35
7	*Vetiveria zizanioides*	17.4	10.23	58.78
8	*Desmostachya bipinnata*	13.0	3.77	29.08
9	*Phragmites karka*	08.9	2.80	31.50
10	*Saccharum bengalense*	06.1	0.87	14.22
11	*Cymbopogon osmastonii*	05.5	0.06	1.00
12	*Cymbopogon jwarancusa*	05.1	3.35	65.40
13	*Oryza rufipogon*	04.1	0.04	1.00
14	*Arthraxon prionodes*	04.1	0.20	4.83
15	*Cynodon dactylon*	03.4	0.03	1.00
16	*Heteropogon contortus*	02.7	0.027	1.00
17	*Eulaliopsis binata*	02.7	0.03	8.75
18	*Paspalum paspalodes*	02.1	0.02	1.00
19	*Hemarthria compressa*	02.1	0.02	1.00
20	*Bothriochloa bladhii*	01.4	0.01	1.00
21	*Dendrocalamus strictus*	00.7	0.01	2.00
22	*Sorghum halepense*	00.7	0.01	1.00
23	*Cymbopogon flexuosus*	00.7	0.01	1.00
24	*Seteria verticillata*	00.7	0.01	1.00
25	*Arundo donax*	00.7	0.50	72.50

Interestingly, *Phragmites karka* characterizing *Phragmites – Saccharum – Imperata* grass cover type just occupied 2.7% grass cover in TCA. It clearly indicates that a long history of cutting and burning has favoured *Saccharum, Imperata, Vetiveria,* and *Themeda* species in TCA. *Desmostachya bipinnata* and *Cymbopogon jwarancusa* indicators of frequent cutting, burning and resultant drier conditions occupied just 3.7% and 3.3% grass cover, respectively.

3.3.8.3 Grassland Distribution and Succession

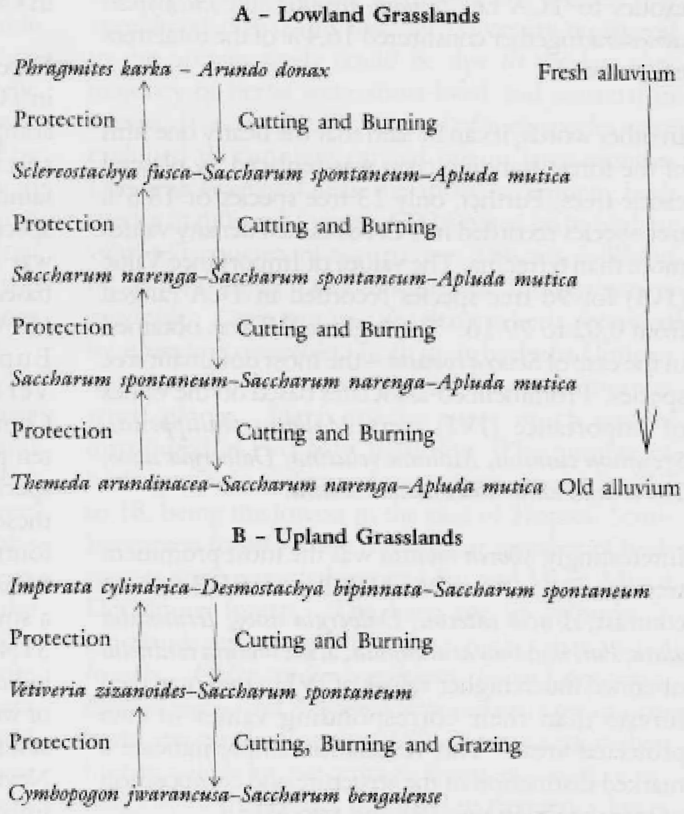
The Lowland grasslands consisting of tall, coarse grasses occurred in swampy and moist situations. Five assemblages deciphered in the Lowland grasslands seem to have a direct relationship with soil conditions, particularly seasonal inundation and soil moisture. Thus, the *Phragmites karka – Arundo donax* assemblage found in the Lowland grassland was favoured by extreme wet/marsh conditons while *Themeda arundinacea – Saccharum narenga – Apluda mutica* occurred on the relatively lower end of the moisture gradient. The later assemblage (*TASNAM*) was, thus inundated for a brief period only. Three other assemblages *viz., SSSNAM, SNSSAM,* and *SFSSAM* were probably intermediate with reference to their affinity to moisture regime. Likewise, in the Upland grassland also *Imperata cylindrica - Desmostachya bipinnata – Saccharum spontaneum* assemblage occurred in relatively moist areas whereas *Cymbopogon jwarancusa* dominated assemblages was found mostly in dry sites. All these assemblages were subjected to cutting and burning. These treatments are in practise for a very long time. Thus, the undisturbed swampy areas show the dominance of tall grass *Phragmites karka* and *Arundo donax*. The other undisturbed sites in relatively drier areas have dominance of *Sclerostachya fusca, Saccharum spontaneum* and *Themeda arundinacea*.

Frequent cutting, burning, harrowing and reduced inundation gradually results into drier habitat conditions replacing *Phragmites karka* by *Saccharum, Sclerostachya, Themeda* and *Imperata* species. Further, excessive grazing in addition to burning at this stage favour the establishment of unpalatable species *viz., Desmostachya bipinnata, Cymbopogon jwarancusa* and *Vetiveria zizanoides*. This is the reason that several pure stands of these grasses can be seen in TCA. In other words, hygrophytic habitat conditions are gradually replaced by mesophytic or even in some cases to near xerophytic conditions. The successional trends in grasslands of TCA are depicted in **Fig. 3.8.**

3.4 Conclusion

The *Terai* Conservation Area represents a unique landscape characterized by forest – grassland – wetland complex. Forests in TCA predominantly belong to the Tropical Moist Deciduous type and can be grouped in Moist Sal forests, Moist Mixed Deciduous forests, Swamp forests and Savannah (grasslands). These forests and grasslands exhibited rich plant diversity owing to a variety of factors – physiography, topography, climate, biotic interactions, long history of management, and resultant succession. Since 1886, successive Working Plans have guided forest management in TCA upto the present time except in two PAs i.e. DNP and KWLS wherein reserved forests were managed for the commercial production of wood products and for the subsistence needs of the local people upto 1977 and 1991, respectively. Present study aimed to assess and compare vegetation diversity in the four constituent areas of TCA (DNP, KWLS, NKFD, and SKFD) and to evaluate the effect of two broad management options i.e. PAs and MFs.

Fig. 3.8 - Succession in the Upland and Lowland Grasslands of TCA



The cluster analysis based on the similarities in tree abundance pattern grouped all Sal forest types. *Chandar* Sal and Sal Mixed forests could not be separated as they merged with dense Sal and moderately closed Sal forests. Khair and sissoo forests and the Upland grassland clustered together. The Tropical Seasonal Swamp forests showed affinity with Tropical Semi-Evergreen forests. Plantations were distinctly separated out. In addition to these major vegetation types, the Lowland grasslands and *Tamarix* scrub devoid of trees were also delineated in the present study. The TWINSPAN analysis resulted into nine grassland species assemblage in the Upland and Lowland grasslands of TCA. The Upland grasslands had altogether three assemblages characteriszed by *Imperata cylindrica, Saccharum spontaneum, Desmostachya bipinnata, Cymbopogon jwarancusa,* and *Vetiveria zizanoides* whilst the Lowland grasslands characterized by *Phragmites karka, Sclerostachya fusca, Saccharum narenga, Saccharum spontaneum, Themeda arundinacea,* and *Apluda mutica* had five assemblages. Further, *Typha elephantina* dominated assemblage occurred in permanently waterlogged sites.

In all, 31,467 trees (>30 cm girth) of 96 tree species were enumerated in 1,748 sampled plots (20m x 20m). *Mallotus phillippensis* occurred in 54.7% sampled plots, followed by *Syzygium cuminii*. *Tectona grandis,* an exotic to TCA occurred in as many as 16.3% sampled plots illustrating that this species has been widely planted throughout the forest land either in forest gaps or after clear-felling of native forests. Much of the tree species richness in forests of TCA resulted from a large number of low abundance, low frequency species. Out of 96 recorded tree species, 47 tree species had less than 1% frequency of occurrence. Only 10 species obtained values >10% frequency of occurrence based an extensive sampling.

A gradual increase in number of tree species i.e. from 33 to 56 was recorded while moving from the dense Sal to open Sal forests. The open Sal forests had favoured presence of several miscellaneous species.

The overall tree density computed for forests in TCA was 450.04 trees/ha. The highest tree density, being

115.5 trees/ha was obtained for *Shorea robusta*, followed by *Mallotus phillippensis*. Interestingly, two exotics to TCA i.e. *Tectona grandis* and *Eucalyptus citriodora* together constituted 16.4% of the total trees enumerated.

In other words, it can be said that the nearly one fifth of the forest standing crop was replaced by planted exotic trees. Further, only 13 tree species or 13.5% tree species recorded in TCA obtained density values more than 6 tree/ha. The values of Importance Value (IVI) for 96 tree species recorded in TCA ranged from 0.02 to 79.16. The highest IVI was obtained in the case of *Shorea robusta* – the most dominant tree species. Prominent co-associates based on the values of Importance (IVI) were *Mallotus phillippensis, Syzygium cuminii, Milliusa velutina, Dalbergaia sissoo, Terminalia alata and Acacia catechu.*

Interestingly, *Shorea robusta* was the most prominent tree species in two PAs (DNP and KWLS). In contrast, *Acacia catechu*, *Dalbergia sissoo, Terminalia alata, Barringtonia acutangula*, and *Haldina cordifolia* obtained much higher values of IVI in two managed forests than their corresponding values in two protected areas. This revealation amply indicate a marked distinction in the structure and composition of tree species in two PAs and two MFs.

The Value of Importance (IVI) for select tree species in the four constituent areas were also compared. Accordingly, values of *Acacia catechu* ranged from 0.30 to 40.86. *A. catechu* was, thus, a characteristic tree species in NKFD. This was mainly due to the occurrence of greater chunk of Khair and Sissoo forests in NKFD. The KWLS was characterized by *Bauhinia racemosa, B.squamosa* and *Lagerstromea parviflora.* The prominence of these species was due to the occurrence of extensive *Chandar* Sal and Sal Mixed forests in KWLS. *Barringtonia acutangula, Ficus benghalensis, Milliusa velutina*, and *Terminalia alata* characterized forests in SKFD based on their corresponding higher values. The prominence of these four tree species in SKFD was attributed to the fact that SKFD harboured a greater extent of Tropical Seasonal Swamp, moderately dense Sal, and open Sal Sal forests. *Tectona grandis* registered its highest IVI in KWLS among the four constituent areas while *Eucalyptus citriodora* obtained its highest value in DNP due to extensive plantations in grassy blanks or 'phantas'.

Shorea robusta distinctly occurred in just five Sal forest types. Its IVI values declined from dense Sal to open Sal forests. The maximum IVI of Sal was obtained in *Chandar* Sal forests.

Diperocarpaceae was the most important plant family in TCA based on the Family Importance Value (FIV) computed using the data on the occurrence of tree species, dominance and abundance in respective family. This family was represented by just one tree species i.e. Sal. The second important family in TCA was Euphorbiaceae. The order of first ten families based on descending values of Family Importance (FIV) was Dipterocarpaceae ⟶ Euphorbiaceae ⟶ Myrtaceae ⟶ Moraceae Verbenaceae ⟶ Mimosaceae ⟶ Fabaceae Combretaceae ⟶ Rubiceae ⟶ Anonaceae. These ten prominent families were represented by 52 tree species out of 96 species recorded in TCA. Thus, these 52 species contributed for more than three-fourth diversity, density and dominance. More than 86% tree species (83 out of 96) were represented by a small number (~250) of individuals, out of total 31,467 trees enumerated in TCA. This amply indicates that such species were either highly localized or were in low abundance. It is possible that naturally several of these species occur naturally in low number. Nevertheless, such species were of utmost ecological importance and calls for a priority attention and monitoring of their regeneration and establishment.

The Upland grasslands harboured widely scattered eleven tree species. Prominent ones were: *Bombax ceiba, Bauhinia racemosa, Acacia catechu, Dalbergia sissoo,* and *Butea monosperma. Tectona grandis* and *Eucalyptus citriodora,* exotics also occurred as these two species were extensively planted.

Clerodendrum viscous was the most widely distributed shrub in TCA as it occurred in as many as 56.9% sampled plots (n=1,674 plots of 10m x 10m), followed by *Flemingia macrophylla* and *Tiliacora acuminata*. *Ardisia solanacea* and *Murraya koenigii* occurred in almost 1/4th plots sampled. Other common species were *Glycosmis pentaphylla* and *Helicteres isora*. As many as 18 species out of 28 recorded shrub species obtained lower frequency values, being less than 5%. *Lantana camara*, an exotic weed occurred only in 5.7% sampled plots with density value, being 393.1 shrubs/ha. Noticeably, the values of percentage frequency of occurrence of *Tiliacora acuminata* was proportionately much lower in NKFD (28.2%) and SKFD (10.8%), against 52.3% in DNP. Similarly, the density values of *Tiliacora acuminata* declined from as high as

6,293.4 shrub/ha in DNP to 829.0 shrubs/ha and 234.1 shrubs/ha in NKFD and SKFD, respectively. This, amply indicates that relatively open canopy forests and other habitat factors were not favourable to *Tiliacora acuminata* in two managed forests while this species was highly favoured in majority of the forest types in DNP. The overall shrub density was highest in NKFD (20,737.1 shrubs/ha), followed by 19,755.7 shrubs/ha in DNP. The shrub density in SKFD was almost half as of DNP, being 9,017.8 shrubs/ha. One of the possible reasons for this low shrub density in SKFD can be attributed on the account of greater disturbance by livestock grazing, fire and even forest working.

A comparison of shrub layer composition across different forest types in TCA also allowed several noteworthy observations. Accordingly, the number of shrub species ranged from 8 to 22 in different forest types. The Tropical Semi-Evergreen forests had the lowest number of shrub species while open Sal forests had the highest number of shrub species. As in the case of trees, the number of shrub species also considerably increased while moving from dense canopy Sal to open Sal forests. *Tiliacora acuminata* was the densest shrub in dense Sal, Sal Mixed and Tropical Semi-Evergreen forests while *Clerodendrum viscosum* was the densest shrub in other forest types, except the Tropical Seasonal Swamp forests. *Ardisia solanacea* showed specific affinity to Tropical Seasonal Swamp forests. *Tiliacora acuminata* was conspicuous in its absence in *Chandar* Sal forests. Otherwise, it commonly occurred in all other forest types. *Lantana camara* was almost absent in dense Sal while Khair and Sissoo forests favoured this species. *Helicteres isora* was the prominent shrub in *Chandar* Sal forests. The density of *Helicteres isora* also increased considerably from dense Sal to open Sal forests. *Flemingia macrophylla* occurred widely and profusely in all forest types.

Against 13 shrub species recorded in different forests of TCA, interspersed grasslands harboured only 11 shrub species. Three species *viz., Helicteres isora, Ziziphus mauritiana,* and *Leea asiatica* were common between forests and grasslands while other 10 species exclusively occurred in grasslands. This included four species of *Desmodium, Fleminigia chappar, Ventilago denticulata, Ichnocarpus frubescens, Tamarix dioica, Securinega macrophylla,* and *Calotropis gigantea. Helicteres isora* occurred in 4.78% sampled plots. Otherwise, all other shrub species occurred in low frequency and abundance.

In all, 89 herb species were recorded in TCA. Forests harboured only 27 species while grasslands had representation of all the recorded herb species. It is apprehended that this low herb diversity registered in the present study could be due to the fact that majority of herbs were short-lived and seasonal in nature. It is possible that several of such species were excluded in sampling carried out in later months. *Dioscorea belophylla* was the most prominent herb species in different forests of TCA based on its highest value of frequency of occurrence. This was followed by *Sonchus asper, Dioscorea hispida* and *Ageratum conyzoides*. *Casia tora* was the densest herb, followed by *Ageratum conyzoides*. Both these herbs had little or no value to wild animals instead they were more as weed plants. Herb species were much widely distributed in two MFs than PAs. The number of herb species in different forest types ranged from 7 to 18, being the lowest in the case of Tropical Semi-Evergreen forests while the highest number of herb species were recorded in open Sal and Moist Mixed Deciduous forests. The herb species richness in grasslands was almost three times higher than that of forests. *Oldenlandia corymbosa, Eclipta prostrata, Blumea mollis,* and *Arisaema plebeium* were prominent herbs among the diversity of 89 species based on their higher values of percentage frequency otherwise, majority of the species occurred in frequency lower than 10%.

Present study recorded 25 grass species in TCA based on 293 plots sampled in the Upland and Lowland grasslands. *Saccharum* spontaneum was the most widely distributed species with the frequency value, being 41.98%. Three other prominent species were: *Saccharum narenga, Imperata cylindrica,* and *Vetiveria zizanoides* based on their higher values of percentage frequency of occurrence and per cent grass cover. Thus, these four species occupied nearly 55% grassland cover. *Imperata cylindrica* alone occupied one fifth of the ground cover in grasslands. A long history of cutting and burning has favoured *Saccharum, Imperata, Vetiveria,* and *Themeda* species. Despite Phragmites *karka* being the featured species of the *Phragmites – Saccharum – Imperata* grass cover characterizing the tall, wet grasslands in *Terai* occupied just 2.7% grassland cover in TCA. *Desmostachya bipinnata* and *Cymopogon jwarancusa* characterized sites experiencing frequent cutting, burning, other disturbance, and resultant dry conditions. Each occupied less than 5% grassland cover. Grasslands in TCA are always in a flux due to seasonal inundation,cutting, burning and grazing. A pattern of grassland succession was, therefore, observed and documented in this study. A large proportion of the Upland grasslands represent the mesophytic conditions. Several pure stands of coarse, unpalatabe grass atleast on maturity and dominated by *Desmostachya bipinnata, Cymbopogon jwarancusa,* and *Vetiveria zizanoides* also occurred.

Diversity indices computed for the four constituent areas allowed noteworthy observations. Accordingly, the DNP revealed the greatest tree species richness, followed by other PA i.e. KWLS. Two managed forest divisions (NKFD and SKFD) as well as two MFs combined had lower tree species richness than two PAs. In contrast, two MFs were more even in terms of distribution of species abundance. Likewise, the PAs were richer in shrub and herb diversity than MFs. The SKFD was the richest in shrub diversity while DNP was the richest in herb diversity.

Sal being the most prominent species in TCA in terms of its wide spread occurrence, high density and abundance, timber value, and long management history yielded a normal girth class distribution in PAs as well as MFs. However, a close scrutiny revealed that DNP area lacked young trees while middle-aged, and adult and larger trees existed in adequate proportion. The inadequate representation of young trees reflected poor regeneration as well as establishment, which have been particularly affected in past 2-3 decades. In contrast, three other constituent areas showed proportionately higher representation of younger trees. Interestingly, small and scattered forest patches of NKFD those are adjacent to DNP had the highest percentage of young Sal trees. Detailed assessment on girth class distribution of selected timber, NTFP and fruit bearing tree species revealed that regeneration and establishment of trees is a common problem. *Syzygium cumini* was probably only species in TCA, which depicted a near normal distribution of girth in all the four constituent areas. Regeneration and establishment of important tree species have been major concerns in the forests of TCA. On the one hand, high biotic disturbance, particularly grazing and burning are major factors for poor regeneration in managed forests while on other hand, probably passive management and resultant closed canopy was the cause of poor regeneration and recruitment in forests of DNP.

Chapter 4

Faunal Diversity, Habitat Use and Conservation Issues

4.1 Overview

The alluvial action of the many streams and rivers disgorging monsoon rainwater from the Himalayan and Shiwalik hill tract creates in the Gangetic plains a complex landscape of Sal dominated moist deciduous forests with interspersed tall grasslands, and swamps. This complex landscape harbours rich and diverse wildlife habitats. The original large herbivore community alone equaled the diversity and biomass of some better-known east African grassland-herbivore ecosystems (Lehmkuhl, 1989). Elephant (*Elephas maximus)*, wild buffalo (*Bubalus bubalis*), one-horned rhinoceros (*Rhinoceros unicornis*), five species of deer (sambar – *Cervus unicolor*, swamp deer – *C. duvauceli duvauceli*, hog deer – *Axis porcinus*, chital – *A. axis*, and barking deer – *Muntiacus muntjak*), and wild pig (*Sus scrofa)* were abundant, and supported a host of large and small carnivores such as tiger (*Panthera tigris tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus)* wolf (*Canis lupus*), jackal (*Canis aureua)*, and striped hyaena (*Hyaena hyaena*) (**Plate 4.1**). The numerous rivers and swamps supported exceptionally abundant and rich waterbird and waterfowl assemblages, both resident and migratory, and equally rich amphibian, reptile, and fish communities. Both wetland and upland habitats are home to over 450 species of resident or migratory birds.

Internationally, the TCA is a critical link in an informal network of Protected Areas that stretches across the *Terai* through India and Nepal. Although the *Terai* landscape is fragmented, and increasingly so with mounting population pressure, the TCA is the potential link between Nepal's Suklaphanta Wildlife Reserve and Bardia National Park. Elephants and rhinoceros still manage on occasion to reach the TCA through tenuous corridors that cross the intervening human-dominated landscape. It is likely that tigers have been making the same movements. The TCA could be vital for the metapopulation viability of those large species, as well as smaller wildlife species with sufficient dispersal capability.

4.2 Faunal Diversity in TCA

The following section briefly describes the faunal diversity in TCA. Information on wild animals has been taken from the available literature and field observations made during the present study.

4.2.1 Invertebrates

Little is known of invertebrate diversity in the TCA. De (2001) listed 120 species in several taxonomic groups, including 19 species of spiders, 36 species of butterflies and moths, and nine species of mollusks for the Dudwa Tiger Reserve (DTR).

4.2.2 Fishes

The swamps 'tals' and rivers of the TCA support a wide diversity of fish representing 20 families. De (2001) recorded 79 fish species in the DTR, which likely is representative of the fish fauna in the entire TCA because most rivers and 'tals' occur in and around the DTR. Fish in the family Cyprinidae dominate the fish fauna with 36 species in four sub-families documented in the DTR. Fish are important primary and secondary predators and important prey for other species in the aquatic systems of the TCA.

4.2.3 Amphibians

The numerous perennial and seasonal water bodies provide excellent and diverse habitat for amphibians. Ten species of amphibians in three families of the order Anura have been recorded in the DTR (De, 2001). With the exception of the common toad (*Bufo malenostictus*), the known amphibians are split among the frogs of the Ranidae and Hylidae families. Little attention has been given in the past to surveys of amphibian diversity, and much likely remains to be discovered. A previously unknown hylid species of the genus *Chirixalis* and a range extension of the leaping frog (*Racophorus taeniatus*) have been recorded during the last decade (De, 2001).

4.2.4 Reptiles

The TCA is relatively rich in reptiles, particularly turtles and crocodilians (mugger- *Crocodilus palustris* and gharial – *Gavialis gangeticus*) associated with wetland and aquatic habitats. As with amphibians, little intensive survey work has been done (Choudhury and Bhupathy, 1993). Thirty-five species in five families have been documented in the DTR (De, 2001). Sixteen turtle species in two families, primarily the Emydidae (hardshell turtles, 12 species) occur in the DTR. All are endemic to India and four species are listed in Schedule I (Indian Tent Turtle – *Kachuga tentoria,* Indian Peacock Sofshell Turtle – *Aspideretes hurum,* Indian Softshell Turtle – *A. gangeticus,* and Red-crowned Roof Turtle – *Kachuga kachuga)* of the Wildlife (Protection) Act, 1972. The Indian Eyed turtle (*Morenia petersi*) was reported in 1995 in DTR, which is a 600-km westward extension from West Bengal (Javed and Hanfee,1995). The snakes are similarly diverse with 12 recorded species. Python (*Python molurus*) is commonly found in Lowland grasslands.

4.2.5 Birds

The complex habitat diversity of forests, grasslands, and wetlands engenders a likewise high avian diversity in the TCA. About 450 species have been recorded in 54 families (De, 2001). The TCA is a north Indian stronghold for the endangered Bengal florican – *Houbaropsis bengalensis* (Sankaran and Rahmani, 1991; Rahmani *et al.* 1990 and 1991), as well as for other species associated with tall wet *Terai* grasslands such as the swamp partridge (*Francolinus gularis*) or swamp francolin (Javed *et al.*,1999). In order to assess the status of Bengal florican, all grasslands in TCA were searched during the breeding season (February-June) of 2000 and 2001. Thirty-six independent sightings (33 males and 3 females) were made that represented separate territories. The females and juveniles are extremely shy, therefore, seldom seen. However, with equal sex ratios, the total population was estimated to be atleast 70 adults. Nine bird species are listed in Schedule I. Fully 25% of the species (109) are accounted rare in the TCA (De, 2001).

4.2.6 Mammals – Focal Species

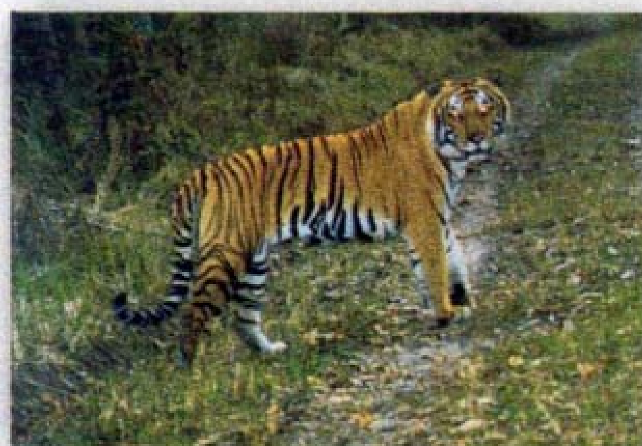
As with other classes of wildlife, the diverse landscape is habitat for an abundant and likewise diverse assemblage of small and large mammals for which it is famous. Forty-seven (47) species of mammals in 10 orders and 21 families have been recorded in the TCA (De, 2001). Many of those species are in jeopardy of local or global extirpation: nearly a third of those species (14) are nationally listed as threatened (7) or endangered (7), and another 5 are considered rare. Nationally listed endangered species include tiger, fishing cat (*Felis viverrina*), leopard cat (*Felis bengalensis*), sloth bear - *Melursus ursinus* (although locally common), Asian elephant, one-horned rhinoceros, and swamp deer. Nationally threatened and locally rare species are leopard, Indian fox (*Vulpes bengalensis*), and ratel (*Mellivora capensis*). At least two large mammals have been locally extirpated: the last wild buffalo and rhinoceros were killed in the area nearly 120 years ago. The rhinoceros, however, was reintroduced in 1984 in Dudwa National Park and currently numbers 17 animals in a carefully monitored and fenced population. Thus, this re-introduction programme makes the TCA the western most Indian location for the endangered species.

Along with rhinoceros, the TCA is a critical area for tiger, swamp deer, and elephant conservation. The TCA has an estimated 100 tigers (1999 estimate) and their population based on pugmark counts appears to be relatively stable (De, 2001), although poaching and international trade in tiger parts continues to be an issue (Sawarkar, 2000). Another estimate places the tiger population at 65-80 animals, and much reduced in number and range during the last 15 years

Plate 4.1 - Species of Conservation Concern in TCA

Bengal Florican

Hispid Hare



Tiger

Swamp Deer

Rhinoceros

due to habitat loss, increasing isolation of remaining habitat and poaching outside the PAs (Sawarkar, 2000).

Northen swamp deer also has its western-most Indian location in the TCA, and are found in only a handful of other locations in India and Nepal. Swamp deer were considered relatively numerous in 1980 when about 2,100 animals were estimated to occur in the TCA (Sawarkar, 2000). Current population estimates are conflicting, but there have been recognized declines in some areas of the TCA. Sawarkar (2000) estimated the 1998 swamp deer population to have declined to 700-750 animals as a result of grassland successional changes within PAs in the TCA, conversion of swamps and 'tals' in traditional use areas outside the PAs to agriculture, and poaching of animals leaving the PAs to use traditional habitats. De (2001), however, documented about 2200 swamp deer in Dudwa and Kishanpur areas during 1999. Both authors agree that some formerly prime contiguous swamp deer habitats inside (Sathiana) and outside (Ghola, Gajraula) the PAs have declined and that the local population in that area is in danger; whereas, other local populations appear relatively secure (Kakraha, Kishanpur). The TCA is also the last stronghold for hispid hare (*Caprolagus hispidus*) in the Upper Gangetic Biogeographic Province.

Elephants formerly were relatively common to the area, but deforestation, particularly in adjacent Nepal, has converted habitat to agriculture and disrupted travel corridors. Currently, an estimated 5-10 elephants use TCA, primarily DNP, on a permanent or seasonal basis.

4.3 Methods – Habitat Use

Effective management of natural resources requires the combination of high quality science and the availability of data-rich information. A wildlife manager thus often needs key information on the current state of knowledge of wildlife species and their habitats (Johnson and O'Neil, 2001).

Wildlife Habitat is a concept related to a particular wildlife species. More specifically, habitat is an area with the combination of the necessary resources (food, cover and water) and environmental conditions (temperature, precipitation, presence or absence of predators and competitors) that promotes occupancy by individuals of a given species (or population) and allows those individuals to survive and reproduce. Understanding species and their habitat relationships is paramount to predicting species response to past, present, and future land uses within a managed landscape. Keeping this in view, the present study aimed to develop an understanding of wildlife use of different habitats in TCA. The following methods were employed to assess the habitat use and selection by select featured species and species of conservation concern.

Field data on the presence/absence of indirect signs (dung/scat) in mapped vegetation types was collected during vegetation sampling for species of conservation concern. In all, 1,967 vegetation plots were sampled in different forest and grassland types. Out of this, 1,674 plots were sampled in nine different forest types, plantations and *Tamarix* scrub while 293 plots were sampled in Upland and Lowland grasslands. Within each 20m x 20m forested vegetation plot, dung or tiger scat were recorded in a nested 10m x 10m plots. Percentage frequency of occurrence was calculated for each species vegetation type-wise within each of two PAs (DNP and KWLS) and two MFs (NKFD and SKFD) in the TCA.

4.4 The Results

4.4.1 Wildlife Use

Field studies for this project revealed habitat use by several species based on an assessment the presence/absence of their signs (dung or scats). Values of percentage frequency of occurrence of assessed species in different vegetation types are given in **Table 4.1.** About 50% of the 1,967 vegetation plots sampled showed some formal use by selected species.

Sign of chital (26.2%), nilgai (12.5%) and hog deer (10.8%) was most frequently encountered. Cattle dung was also recorded in as many as 10.3% sampled plots. Sign of swamp deer was recorded in just 6.9% of the vegetation plots sampled. Frequency of occurrence of all other species was <5%.

Chital used almost all vegetation types except *Tamarix* scrub. Chital prominently used Upland grassland (44.8%), Tropical Semi-Evergreen forest (41.9%), dense Sal forest (41.6%) and Lowland grassland (41.5%) plots. A gradual decline in use pattern was observed while moving from dense Sal to open Sal forest. Relatively little use of Moist Mixed Deciduous forest (10.9%), Tropical Seasonal Swamp forest (15.2%) and Khair and Sissoo forest (8.8%) was made. Chital sign was encountered in only 20% of the plots in plantations.

In contrast to chital, sign of nilgai occurred minimally in grasslands (3%). Nilgai sign was most frequently encountered in Sal Mixed forest (32.8%), and Tropical Semi-Evergreen forest (29.0%), probably due to their peripheral locations in the case of DNP. Absence of nilgai sign in dense Sal forest, *Chandar* Sal forest and *Tamarix* scrub was conspicuous. Interestingly like chital, nilgai also used plantations only to the extent of 20%.

Sign of swamp deer, hog deer, hispid hare and wild pig were primarily encountered in grassland habitats indicating that they were mainly grassland dependent species. Swamp deer showed greater use of Lowland grassland (54.7%) than Upland grasslands (35.8%). Data revealed that hog deer used as much as 71.7% plots sampled in Lowland grassland while only 59.0% sampled plots in Upland grassland had the presence of hog deer sign. Hog deer also used Khair and Sissoo forest and *Tamarix* scrub. Hispid hare followed almost the same pattern as hog deer except its absence was conspicuous in *Tamarix* scrub. Sign of Indian hare were mainly encountered in *Tamarix* scrub (26.7%), followed by Khair and Sissoo forest (10.6%) and Lowland grassland (10.1%).

Sign of Blackbuck was encountered only in plantation areas of SKFD. Sign of domestic livestock (cattle) were pre-dominantly encountered in Khair and Sissoo forest (37.5%), *Tamarix* scrub (31.7%) and as well as in Upland and Lowland grasslands. This was mainly due to the availability of forage, water and proximity to village areas.

Scats of tiger were prominently found in Tropical Semi-Evergreen forest (6.5%), *Tamarix* scrub (5.0%) and Tropical Seasonal Swamp forest (3.5%). A disproportionate use of these habitats by tiger can be correlated to the greater abundance of prey (chital, hog deer, nilgai and cattle) in such vegetation types.

A comparative assessment on habitat use by above select species in different constituent areas of TCA based on indirect sign also allowed interesting observations (**Tables 4.2 and 4.3**). Accordingly, only 8.1% vegetation plots sampled in managed forests (NKFD and SKFD) had the presence of chital against 41.6% sampled plots in PAs having the presence of chital sign. Within MFs, plots sampled in SKFD has higher value of frequency of occurrence (10.1%) than NKFD (5.0%). This can be attributed to the fact that forests in NKFD were in smaller and in isolated patches, that too are in proximity to villages. Thus, they experience much more biotic disturbance. Strikingly, there was conspicuous absence of chital sign in sampled grasslands in two MFs while grassland habitats in two PAs (DNP and KWLS) harboured abundant chital population. This revelation can be attributed to the fact that grasslands in MFs were relatively small, isolated and experiencing much higher biotic pressure and disturbance.

The comparative assessment of nilgai sign in four constituent areas of TCA revealed that nilgai sign were completely absent in grasslands located in two PAs while about 11% grassland plots sampled in MFs had the presence of nilgai sign. Further, nilgai used Upland and Lowland grassland habitats in NKFD while there was no such sign in the case of SKFD. This finding can be attributed to the fact that nilgai made use of larger peripheral grassland patches in NKFD while completely avoided smaller grassland patches in SKFD surrounded by forest (**Table 4.2**). Data on indirect sign for other select species revealed absence of swamp deer, sambar, hispid hare, rhinoceros, elephant and sloth bear in two MFs (**Table 4.3**). In contrast, cattle sign (21.3%) were prominent in plots sampled in two MFs. Sambar in TCA occurred in very low number that too only in DNP. Likewise, sign of hispid hare and sloth bear was encountered only in DNP amongst two PAs.

Table 4.1 – Percentage Frequency of Occurrence of Animal Indirect Signs (Dung/Scat) in Different Vegetation Types in *Terai* Conservation Area (n=1,967)

Sl. No.	Species	Dense Sal Forest n=149	Moderately Closed Sal Forest n=260	Open Sal Forest n=291	Sal Mixed Forest n=61	*Chandar* Sal Forest n=58	Mixed Forest n=201	Tropical Seasonal Swamp Forest n=198	Tropical Semi - Evergreen Forest n=31	Khair & Sissoo Forest n=198	*Tamarix* Scrub n=60	Plantations n=205	Upland Grassland n=134	Lowland Grassland n=159	Overall TCA n=1,967
1	Chital	41.6	35.0	26.1	37.7	29.3	10.9	15.2	41.9	8.8	*	20.0	44.8	41.5	26.2
2	Barking deer	3.4	2.7	1.7	3.3	5.2	*	*	*	*	*	0.5	*	*	1.2
3	Sambar	*	*	1.4	*	*	*	*	*	*	*	*	*	*	0.2
4	Swamp deer	*	*	*	*	*	*	*	*	*	*	*	35.8	54.7	6.9
5	Hog deer	*	*	*	*	*	*	*	*	8.8	8.3	*	59.0	71.7	10.8
6	Hispid hare	*	*	*	*	*	*	*	*	9.4	*	*	17.9	20.8	3.7
7	Indian hare	*	0.4	0.3	*	*	*	*	*	10.6	26.7	*	5.2	10.1	2.9
8	Honey badger	*	*	*	*	*	*	*	*	1.3	*	*	6.0	*	0.5
9	Blackbuck	*	*	*	*	*	*	*	*	*	*	1.5	*	*	0.2
10	Nilgai	*	13.8	22.7	32.8	*	12.9	10.6	29.0	10.6	*	20.0	3.0	3.1	12.5
11	Wild pig	*	5.4	*	*	*	*	*	*	*	*	0.0	9.0	8.2	2.0
12	Rhinoceros	*	0.0	*	*	*	*	*	*	*	*	*	0.7	1.9	0.4
13	Elephant	1.3	1.2	0.3	*	*	*	*	*	*	5.0	0.5	3.0	3.8	1.0
14	Sloth bear	*	0.4	0.3	*	*	*	*	*	*	*	*	1.5	3.8	0.5
15	Tiger	1.3	1.2	1.0	*	*	*	3.5	6.5	*	5.0	1.0	0.7	2.5	1.4
16	Cattle	0.0	3.5	3.8	*	12.1	9.0	5.1	*	37.5	31.7	9.3	17.9	15.7	10.3

*denotes absence of indirect signs

Indirect sign (scat) of tiger were recorded as such in low number despite extensive sampling. However, these signs were absent in plots sampled in NKFD. This can be due to its small, isolated and disturbed forest patches (**Table 4.3**).

4.4.2 Cluster Analysis and Similarity Index

Above data on indirect signs in vegetation types was used to examine similarities in habitat use among species with cluster analysis and determination of similarity indices based on Jaccards Proximity Matrix.

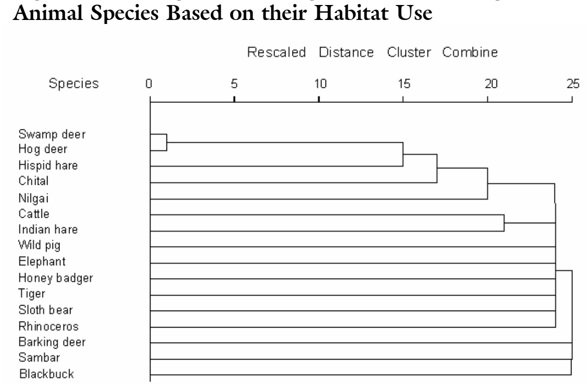
Cluster analysis broadly deciphered six assemblages as shown in a dendrogram (**Fig. 4.1**). Accordingly, the first cluster combined swamp deer and hog deer, showing a close similarity of vegetation types used. Hispid hare followed in similarity. Chital occurrence was similar to those three species that were predominantly dependent upon grasslands. Cattle and common Indian hare also showed proximity among them. Lastly, the remaining species clustered together, which may be due to their similarity in the habitat requirement or may be due to low encountered rate of indirect sign of these species.

Table 4.2 - Percentage Frequency of Occurrence of Chital and Nilgai Signs in Different Constituent Areas of TCA

Vegetation Types	TCA n=1,967	PAs n=1,087	MFs n=780	DNP n=812	KWLS n=375	SKFD n=477	NKFD n=303
1. Chital *(Cervus axis)*							
A. Forests							
Dense Sal (>60%) Forest	41.6	41.6	*	41.6	*	*	*
Moderately Closed Sal (40-60%) Forest	35.0	39.9	26.8	37.5	45.1	26.8	*
Open Sal (<40%) Forest	26.1	38.1	11.5	31.5	47.1	8.1	40.0
Sal Mixed Forest	37.7	37.7	*	60.0	16.1	*	*
Chandar Sal Forest	29.3	30.2	26.7	*	30.2	26.7	*
Moist Mixed Deciduous Forest	10.9	19.3	1.1	23.7	9.1	3.6	*
Tropical Semi-Evergreen Forest	41.9	41.9	*	41.9	*	*	*
Tropical Seasonal Swamp Forest	15.2	17.2	13.5	8.9	32.3	8.3	60.0
Khair and Sissoo Forest	8.8	38.9	*	38.9	*	0.0	*
Plantations	20.0	31.7	2.4	28.2	39.5	3.2	*
B. Grasslands							
Upland Grassland	44.8	66.7	*	50.0	100.0	*	*
Lowland Grassland	41.5	57.4	*	61.2	46.7	*	*
Overall	**26.2**	**41.6**	**8.1**	**37.8**	**38.7**	**10.1**	**5.0**
2. Nilgai (*Boselaphus tragocamelus*)							
A. Forests							
Dense Sal (40-60%) Forest	13.8	12.3	16.5	12.5	11.8	16.5	*
Moderately Closed Sal (<40%) Forest	22.7	18.8	*	32.6	*	30.6	6.7
Open Sal Mixed Forest	32.8	32.8	*	63.3	3.2	*	*
Moist Mixed Deciduous Forest	12.9	17.4	7.6	22.4	6.1	25.0	*
Tropical Semi Evergreen Forest	29.0	29.0	*	29.0	*	*	*
Tropical Seasonal Swamp Forest	10.6	11.5	9.9	8.9	16.1	12.5	6.7
Khair and Sissoo Forest	10.6	*	13.7	*	*	*	56.7
Plantations	20.0	22.0	17.1	27.1	10.5	22.6	*
B. Grasslands							
Upland Grassland	3.0	*	9.1	*	*	*	13.3
Lowland Grassland	3.1	*	11.4	*	*	*	16.7
Overall	**12.5**	**12.4**	**14.1**	**14.4**	**4.8**	**16.8**	**9.9**

***denotes absence of animal signs**

Fig.4.1- Dendrogram Showing Similarity Among Select Animal Species Based on their Habitat Use



The Jaccard Proximity Matrix of habitat use similarity also indicated highest proximity (0.584) between swamp deer and hog deer (**Fig. 4.2**). This was followed by a similarity index value of 0.224 for hispid hare and hog deer. Hog deer and chital habitat use was at 0.224. Nilgai and chital habitat use was at similarity index, being 0.155. Barking deer showed the least resemblance with other species in its habitat use (**Fig. 4.2**).

4.4.3 Habitat Selection

Ivlev's (1961) Electivity Indices (E) as described by Lechowicz (1982) was used to determine habitat selection of studied species using collected data on their indirect signs. Electivity indices measured the habitat selection in relation to their abundance or availability in the environment. The values range from zero random selection and deviates symmetrically from zero between plus and minus one as a habitat is selected or avoided, respectively. The Chi-Square Test was also performed to determine difference in animal use among different habitat types.

Results on habitat selection by chital and nilgai in TCA are presented in **Fig. 4.3**. Chital showed the maximum selection for Upland grassland (E = 0.26), followed by Tropical Semi-Evergreen forest (0.23), Lowland grassland (0.22) and dense Sal forest (0.22). While the species exhibited a negative selection towards Khair and Sissoo forest. Nilgai showed a maximum selection towards Sal Mixed forest (E = 0.35), followed by Upland grassland (E = 0.32). Nilgai had the extreme negative selection for Lowland grassland (E = - 0.72).

4.4 Wildlife Issues, Concerns, and Implications

4.4.1 Forest and Grassland Habitats

It is difficult to separate wildlife issues and concerns from those of vegetation and the habitat base. Wildlife

Table 4.3 - Percentage Frequency of Occurrence of Indirect Signs (Dung/Scat) of Select Animal Species in Different Constituent Areas of TCA

Species	TCA n=1, 967	PAs n=1, 087	MFs n=780	DNP n=812	KWLS n=375	SKFD n=477	NKFD n=303
Hog Deer	10.8	19.0	0.6	17.6	17.1	0.2	1.3
Swamp deer	6.9	12.4	*	14.5	4.5	*	*
Barking deer	1.2	2.0	0.1	2.3	0.8	0.2	*
Sambar	0.2	0.4	*	0.5	*	*	*
Hispid hare	3.7	6.6	*	8.9	*	*	*
Indian hare	2.9	1.6	5.3	0.1	4.3	1.9	10.6
Honey badger	0.5	0.9	*	1.2	*	*	*
Blackbuck	0.2	0.0	0.4	*	*	0.6	*
Wild pig	2.0	1.3	3.2	1.1	1.3	1.9	5.3
Rhinoceros	0.4	0.4	*	0.5	*	*	*
Elephant	1.0	1.8	*	2.1	0.8	*	*
Sloth bear	0.5	0.9	*	1.2	*	*	*
Tiger	1.4	1.7	1.2	1.5	1.6	1.9	*
Cattle	10.3	3.3	21.3	2.7	3.7	14.7	31.7

***denotes absence of animal signs**

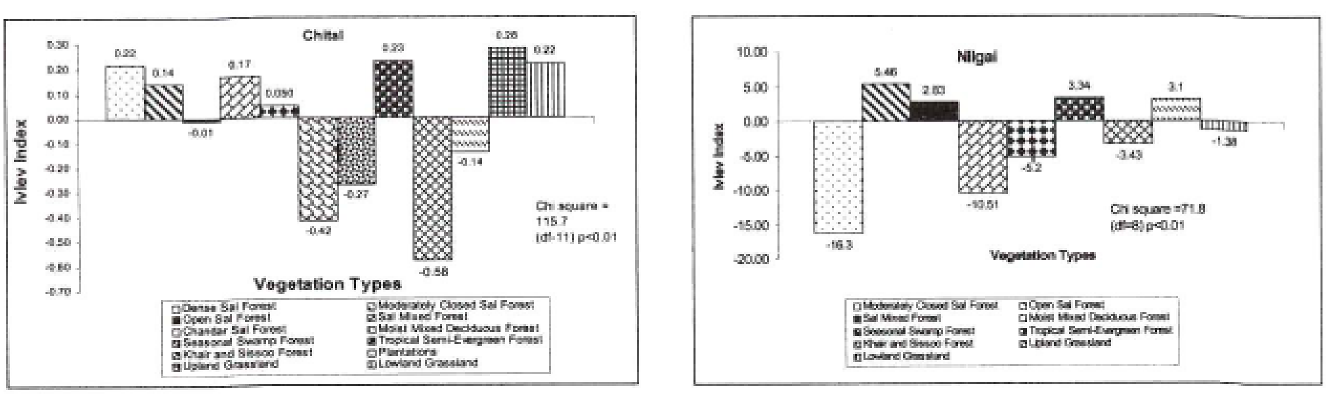
Fig.4.2 - Jaccard Proximity Matrix Incorporating Similarity Index Values for Habitat Use by Select Herbivores in TCA Based on their Indirect Signs

Species					
Chital	0.000				
Nilgai	0.155	0.000			
Barking deer	0.019	0.019	0.000		
Swamp deer	0.128	0.000	0.000	0.000	
Hog deer	0.224	0.002	0.000	0.584	0.000
Hispid hare	0.074	0.000	0.000	0.264	0.224
	Chital	Nilgai	Barking deer	Swamp deer	Hog deer

habitat within the TCA is changing as a result of processes within and outside the TCA boundaries. The effects of past selective tree harvest in altering forest composition, the stoppage of felling on canopy and resultant understorey development, removal of NTFP, and other human intervention (e.g. grass cutting) on habitat pattern and development has not been fully studied (De, 2001). For example, there is the perception that stoppage of felling has resulted in the closing of the Sal forest canopy and the resulting loss of ungulate forage plants with an increase in unpalatable *Tiliacora* cover. This hypothesis has been addressed in the present study and confirmed to a great extent through the vegetation analysis. Also, some feel that changes in human use of grasslands, e.g., stoppage of thatch grass cutting and grazing, has fostered the development of tall grasses over the shorter grasses (e.g., Imperata cylindrica) favored by ungulates like swamp deer in alluvial Lowland grasslands. Past planting of Teak and Eucalyptus in 'grassy blanks' and in forest gaps has also changed in varying degrees the nature of wildlife habitats from natural to cultured conditions. The later was shown by higher Importance Values (IVI) for these two planted species from the extensive vegetation sampling and assessment in the present study.

Current management practices are also a concern for wildlife habitat. Continued planting of Teak, *Eucalyptus* and other species designed to enhance wood production, primarily in managed forests and private lands is still practised. Salvage of dead or dying trees is an important loss of habitat for cavity-excavating species that use defective trees, and for species that use down wood for food or cover. For example, invertebrates that infest down wood can be important food for many species of birds and mammals and provide cover for terrestrial amphibians, reptiles and small mammals (Morrison *et al.*, 1998). Fire in the forest understory is a widespread unplanned event that is viewed as detrimental to the forest ecosystem. Extensive fire breaks have been built in both protected areas and managed forests, but ground fire remains widespread during the dry season. Other than effects on regeneration of favored timber trees, such as Sal, there is little known of the effects of fire on ecosystem patterns and processes, such as the successional dynamics in understorey forest species, and the implications for important wildlife or biodiversity in general.

Fig 4.3 - Habitat Selection of Chital and Nilgai Based on Electivity Indices



Well-intentioned widespread burning of grasslands provides dry-season forage for ungulates, but impacts on other species are poorly known. For example, complete burning of grasslands over the dry season may eliminate undisturbed breeding sites for some grassland birds, or cover for other species such as the hispid hare. Tilling of grasslands to restore short forage grasses is commonly practiced, but effects on grassland dynamics and wildlife use have not been systematically studied and may be negative for some important species such as the endangered Bengal florican.

Habitat change is being affected from the matrix outside the TCA boundaries. Habitat degradation by invasion of weedy species like *Lantana camara, Cassia tora,* and *Parthenium hysterophorus* occur along disturbed boundaries and along human use corridors such as roads and railroads. Human encroachment, illicit grazing and wood collection along TCA boundaries degrade habitat and shrinks the effective size of remnant habitat patches in the managed forest. Increasingly intensive use of agricultural lands and in river floodplains is eliminating remnant grassland, wetland, and forest patches and connectivity among remaining habitat patches. Changes in land use are affecting the hydrology and subsequent dynamics of downstream riverine systems.

4.4.2 Aquatic and Wetland Habitats

The hydrology of the TCA ecosystem is dynamic, and alterations in the hydrology are of major concern. Natural fluvial processes and the high water table have created the many 'tals' and oxbow lakes, but those same processes in many cases may gradually contribute to their disappearance. Sediments in rivers and streams are carried in floodwaters and deposited in 'tals'. The resulting shallower depth allows them to dry more quickly during the dry season. Many 'tals' are supplemented with water from bore wells in the DTR (De, 2001). Increased sediment loads brought in from deforested watersheds in the hill tracts of Nepal on the one hand appear to be contributing to increased sedimentation of 'tals' and alluvial grasslands. While on the other hand, some forest patches get inundated by flood water during rainy season, resulting into changes in plant communities. Natural successional processes also result in the gradual infilling of 'tals'.

Under a natural hydrological disturbance regime within a large landscape, many of those issues would not be problems. Changes in river channels would create and destroy wetlands over time, but the balance likely would change little across a large area. PA boundaries, however, often occur along major rivers, with agriculture on the opposite side. That situation alters the balance of give and take; hence, creates the possibility that changes in river channels may eliminate wetlands and other floodplain habitats in the PAs while creating them on the unprotected side of the river where they are subject to development. Although the converse can happen, i.e., carving away agricultural land to create floodplain habitats on the PA side, the loss of agricultural lands is viewed dimly by citizens who clamor for flood control structures or hardening of stream banks with check dams. Such changes are sure to alter the hydrology of the area, hence the dynamics of the dependent ecosystems. For example, in the central Nepal *Terai*, bank cutting on the Sauraha village side of the Rapti River in Chitwan National Park resulted in the installation of a system of check dams. Subsequent down-cutting of the river channel lowers the water table and is one potential reason for accelerated succession of prime rhinoceros floodplain grassland to riverine forest (Anon. 2002).

Fishing the rivers and streams within protected areas has been restricted in the past, but some poaching occurs. Poisoning streams has been used to catch fish, and has potentially affected populations of soft-shelled turtles (De, 2001).

4.4.3 Wildlife Populations

Wildlife population concerns are of direct and indirect natures. Poaching in protected areas is less a problem than in the more extensively used managed forests and in the outside matrix of agricultural lands. Animals in the boundary areas of the PAs that venture out into the matrix are subject to poaching. This is a particular concern for swamp deer in the Sathiana area of DNP where intensive development over the last 25 years has removed traditionally used monsoon habitats outside the PA, which also provided a linkage to swamp deer in the KWLS. Tigers venturing out into the sugarcane fields, which are abundant in the TCA agricultural matrix and in many ways mimic natural *Saccharum spontaneum* floodplain habitats, are subject to poaching.

Populations within PAs are isolated by intervening agricultural lands and perhaps by the loss of connective corridors within the PAs. This is a concern for large species like tiger and elephant that require large areas or connective corridors to maintain viable populations. Populations in scattered managed forest fragments are isolated, small, and subject to human disturbance that can lead to local extirpation. Roads, railways and canals have been barriers to movement, sources of direct mortality from collisions or drowning and avenues for human intrusion, disturbance, and habitat change (De, 2001). Small populations isolated from large sources of immigrating animals, such as the hispid hare, elephant, or reintroduced rhinoceros, have a tenuous hold on viability because of potentially devastating demographic or environmental change or disturbance. Finally, little is known about the distribution, population status, ecology, and effects of management for the large number of less-conspicuous plant and animal species that make up the bulk of biodiversity in the TCA and form the base of the intricate food webs and ecosystems that support the well-known species that the management typically focus on.

Chapter 5

Grassland Burning Practices – An Experimental Trial

5.1 The Tall Grasslands

Once extensive, sub-tropical tall riverine grasslands in the foothills of the Himalayas or in the valleys of the Ganga and Brahamputra Rivers and their tributaries are now confined to 10 protected areas in the northern India and four areas in the Nepalese *Terai* (Oliver, 1985; Peet *et al.,* 1999a). These grasslands are diverse and among the most productive in the world (Dinerstein, 1979a,b; Lehmkuhl, 1989). These grasslands harbour a variety of floral and faunal life, including several endangered, charismatic and obligate species *viz.,* tiger (*Panthera tigris*), Great Indian One-horned rhinoceros (*Rhinoceros unicornis*), swamp deer (*Cervus duvauceli duvauceli*), hispid hare (*Caprolagus hispidus*) and Bengal florican (*Hubaropsis bengalensis*).

The tall grasslands in *Terai* are described as stages in the succession continuum between the primary colonization of new alluvial deposits by flood climax grass and herbaceous species, and the non-flooded climax deciduous Sal (*Shorea robusta*) dominated forest (Champion and Seth, 1968; Dabadghao and Shankarnarayan, 1973; Lehmkuhl, 1989 and 1994). Fluvial processes and actions remain the primary disturbance effecting spatial pattern and the organization of tall grasslands along soil moisture gradients (Seidensticker, 1976; Lehmkuhl, 1989). Tall grasslands occur in the most hydric areas, and are considered an "edaphic climax" (Dabadghao and Shankarnarayan, 1973). Other disturbances known to influence the organization of contemporary grasslands *viz.,* fire and grazing pressure by abundant, large-herbivore fauna are also historically common to these grasslands.

Frequent floods, wide spread burning and heavy grazing together result into a highly dynamic, tall grassland and woodland mosaic in which a large and diverse mammalian fauna has evolved (Lehmkuhl, 1989 and 1994; Peet *et al.,* 1997 and 1999a,b).

Tall grasslands are also a most important resource for local villagers. Grasses are extensively used by local people, particularly 'Tharus' for a wide variety of uses (Brown, 1997; Peet *et al.,* 1999a; Qureshi *et al.,* 1991; De, 2001). Although, the direct consumptive value of grass products, thatch and fodder may not be significant in financial terms, however, they provide important subsistence resources to local communities. Without access to the grassland produces, traditional means of house construction could no longer be maintained and tall grasslands were virtually conspicuous in absence outside protected areas and managed forests. Lehmkuhl (1989) based on field assessment on grass and cane extraction by local people in Chitwan National Park in 1986 determined that grass (*Imperata cylindrica* only) was valued at Nepali Rupees 4.6 million and canes at NR 5.4 million. The benefit accrued to individual family was estimated at NR 2,500 (US$ 115). The study also examined the costs of alternative building materials, and concluded that most villagers close to the park do not have enough capital to invest in other supplies, but they do have the time to cut grasses for their own use. Brown (1997) concluded that there are several factors, which make attaching a monetary value to the collection of grass and canes problematic. In addtion, the economic value may not reflect or be indicative of the cultural significance of these resources. Despite the apparently low overall economic value, findings indicate that the grass is a very important resource, especially for the "Tharus". The grassland produces have also a great cultural value in terms of ceremonial uses.

Broadly, two types of tall grasslands – the Upland grasslands and Lowland grasslands have been recognized in the *Terai* region. The former occured on drier or well-drained soils while the later type in low lying waterlogged sites or sites inundated during the monsoon or subsequent months. Floristically, *Imperata cylindrica, Saccharum spontaneum, Vetiveria zizanoides and Saccharum bengalense* characterized the Upland grasslands. The Lowland grasslands were predominated by *Sclerostachya fusca, Phragmites karka, Arundo donax, Themeda arundinacea, Saccharum narenga* and *Saccharum spontaneum*. The grasses in Upland grasslands usually attained height upto 2m while grasses in Lowland grasslands were even 6m tall.

5.2 Current Knowledge

Researches during the past three decades or so on tall grasslands in India and Nepal have provided an insight on their distribution, origin, diversity, utilization, role in the conservation of several endangered faunal species, and management pratices (Spillet, 1967; Schaaf, 1978; Dinerstein, 1979a,b and 1980; Oliver, 1980; Laurie, 1978; Singh, 1984; Chaudhuri and Naithani, 1985; Bell, 1986; Lehmkuhl, 1989, 1994, 2000; Bell and Oliver, 1992; Inskipp and Inskipp, 1983; Qureshi *et al*., 1991; Rahmani *et al.,*1990; Peet, 1997; Peet *et al.,*1997 and 2000; Wegge *et al.,* 2000; Richard *et al.,* 2000; Mathur, 2000).

Mathur (2000) has reviewed the status of research and monitoring in protected areas of the Indian *Terai* and highlighted the need for experimental research on grassland management practices, which has lacked in the majority of Indian PAs. Peet *et al.* (2000) have reviewed researches on the tall grasslands in Nepal. They have summarized the research, and conclusions on management priorities based on the investigations addressing botanical diversity, plant-animal associations, effect of cutting and burning of grasslands and its impact on ungulates, and socio-economics of grassland harvesting. The following paragraphs summarize the current knowledge on tall grasslands and the challenges in managing them.

5.2.1 Grassland Diversity

Several botanists and foresters have provided valuable checklists, flora and illustrations, particularly in the case of grasses (Duthie, 1883; Raizada, 1931; Kanjilal, 1933; Bor, 1941 and 1960; Whyte, 1957; Champion and Seth, 1968; Dabadghao and Shankarnarayan, 1973; Chaudhuri and Naithani, 1985; Singh and Tomar, 1983; Hajra and Shukla, 1983; Singh, 1997).

Lehmkuhl (1989) first revealed the complexity of the tall grasslands by identifying eight grassland assemblages in Chitwan National Park, Nepal. Subsequently, Peet *et al*. (1997) described nine grassland assemblages with eight phases across the four *Terai* protected areas in Nepal. Present study also identified nine grassland species assemblages in the TCA (see **Fig. 3.7**). Interestingly, both these studies highlighted that these grassland assemblages were characterized by a few highly dominant and structurally important grass species while remaining species were of low frequency and abundance.

The early successional or Lowland grasslands consist of tall, perennial grasses (*Phragmites, Saccharum, Themeda* spp.). They are natural in the sense that they become established and are maintained as a result of fluvial action and flooding during the monsoon (Lehmkuhl, 1989; Wegge *et al.,* 2000). But they are considered to be successional and would develop into forest if periodic flooding ceases and the soil conditions were stabilized. On the contrary, assemblages on drier well-drained and better-developed soils (Upland grasslands) consist of shorter perennial grasses predominated by *Imperata cylindrica* and *Vetiveria zizanoides*. These Upland grasslands are considered to be originated following the anthropogenic interventions (forest clearing, burning, livestock grazing, and cultivation). Both, the Upland and Lowland grasslands share the characteristic of a high water table, which promotes extensive grass growth and provides graminoides a competitive advantage over trees and shrubs.

Traditionally, local villagers have utilized both types of grasslands for various purposes. The Lowland grasslands are cut and harvested mainly for canes, whereas the Upland grasslands were earlier grazed by livestock and grasses cut and removed for a variety of local uses (Brown, 1997; Wegge *et al*., 2000). Livestock grazing is now prohibited in the Indian national parks while regulated grazing can be permitted in sanctuary areas. It is believed that local communities that are traditionally dependent on forest and grassland resources either illegally enter the protected areas and collect grasses for 'thatch', fodder and other purposes or they harvest desired quantities of grasses for their sustenance in the knowledge and permission of PA management (De, 2001). Further, both type of grasslands are burned each year intentionally in early part of the dry season i.e. January-February by the PA management as a part of habitat management programme. On many occasions, fires are also set by peripheral villagers or as a result of carelessness. In the process, extensive areas of both the type of grasslands get burned annually except for a few localized patches where there is high level of soil moisture and grasses are still moist.

Studies have indicated that whilst burning, cutting, and grazing are important factors in influencing the structure and composition of the grasslands on sites not maintained by flooding, the overall distribution and diversity of grasslands is primarily influenced by the fluvial action. Changes in the spatial dynamics of river course, flooding, erosion, and alluvial deposition have direct implications for the establishment of early succession grasslands and their ultimate maintenance.

5.2.2 Grassland Management and Faunal Conservation

Researches on the tall grasslands have primarily focussed on larger mammals. Peet *et al.* (1997) have described faunal associations for a range of species in the tall grasslands. Likewise, the present study (Chapter 4) has also highlighted several grassland dependent and obligate species in the TCA. Oliver (1985) believed that grasslands maintained by regular and too frequent burning are characterized by poor species diversity and the extensive and rapid growth of fire-resistant species, notably the various 'thatch' grass e.g. *Saccharum, Themeda* and *Imperata* spp. In spite of this fact, Bell and Oliver (1992) were of a view that forest and wildlife managers in such areas justify the practice of early burning of grasslands for a number of reasons: (i) prevent incidence of 'spontaneous' and 'more damaging large scale summer fires by removing accumulated combustible fuel; (ii) to promote new grass and quality forage for herbivores; (iii) to check succession from grassland to forest by preventing invasion of woody species or encroachment of grassland by climax forest habitat; and (iv) to facilitate a 'thatch' crop in the ensuing year.

Several authors have documented that the faunal species respond differently to management of tall grasslands, and the implications of annual cutting and burning for faunal utilization of grasslands have been poorly understood. It has been well established that widespread cutting and burning has deleterious effect on smaller, less mobile, cover dependent and disturbance sensitive species. Studies on hispid hare (*Caprolagus hispidus*) and Pygmy hog (*Sus salvanicus*) have revealed that animals become confined to remnant patches of uncut and unburned grassland following fire where they are vulnerable to disturbance, predation, and hunting (Oliver, 1980; Bell, 1986; Bell *et al.,* 1992; Oliver and Deb Roy, 1993; Adhikari, 2000). In contrast, ungulates probably gain some benefit due to regenerating grasslands as they get quality forage (Jnanwali and Wegge, 2000; Wegge *et al*., 2000). Studies on contemporary grasslands have also shown that fire can influence species composition and abundance in small mammal communities and invertebrates (Peet *et al.,* 1999b).

Limited available information on the effects of cutting, burning, and grazing of tall grasslands has raised a number of important research and management questions. In particular, there is an urgent need to understand better the succession processes within the grasslands and the effects of disturbance, particularly cutting, burning, grazing on floral and faunal species composition, species abundance, and grassland productivity. The effects of current management practices on the patterns of habitat use by faunal species, particularly for poorly known taxonomic groups such as small mammals, grassland dependent birds (e.g. Bengal florican) and herpetofauna call immediate attention.

5.3 Grassland Management Practices in TCA

The present extent of tall grasslands in the TCA forms an integral part of the forestlands, controlled by the Forest Department which is the custodian of wildlife and natural ecosystems in India (Sawarkar, 2000). In the popular perception, the importance of grasslands is seen only in their utility for grazing livestock and other needs of sustenance. Till very recently, foresters considered them 'unproductive', and administrative and political decisions in favour of local or regional development have diverted large tracts of grasslands to other uses. Grasslands are overgrazed, subjected to uncontrolled fires, and taken over by an abundance of weeds, which ultimately leads to degradation.

The forest policies formulated in the country from time to time continued to ignore the biological values and ecological functions of grasslands, and *ipso facto* grasslands were considered unproductive in the foresters lexicon (Rodgers and Sawarkar, 1988; Sawarkar, 2000). The earlier policies do not have any reference to wildlife or, understandably to the ecological productivity of grasslands. Further, the TCA like the *Terai* elsewhere, was malarious and inhospitable for other reasons, such as its swampy nature. The extensive tracts of tall grasslands had abundance of wild animals, several of which were formidable and potentially dangerous to human life. The post-independence policy encouraged refugees from western Pakistan to settle in these areas. These homeless and hardworking people drained swamps, reclaimed grasslands, and set up the origins of an agricultural system of rice and sugarcane that now occupy large tracts of the TCA, causing extensive fragmentation of *Terai* forests and grasslands. Although, the tall grasslands are unique in their structure, composition, biological and physical attributes, and ecological functions, they can not be seen in isolation from the matrix of forests and other categories of land uses within which they are located.

The forests, grasslands, and wetlands are part of a landscape that has rich agriculture, human habitations, cattle, and other indicators of progress of human society. Therefore, there are a wide range of interacting influences, including the powerful socio-economic interests of humans, that affect the ecological integrity of the *Terai* ecosystem (Sawarkar, 2000).

The forests and grasslands in TCA have been managed under forest working plans on a regular basis since the turn of twentieth century, with the principal interest of producing timber or other economically valuable products. Thus, extensive plantations of *Acacia catechu, Dalbergia sissoo, Syzygium cumini, Tectona grandis,* and *Eucalyptus citriodora* were raised on 'grassy blanks' and are being continued even now in the managed forests. *Tectona grandis and Eucalyptus citriodora* are the exotics in this region. The non-timber forest produces (NTFPs) collected from different forests in TCA included 'thatch' grass. Seven species of tall grasses for 'thatch', *Eulaliopsis binata* for making rope and several grass species are being harvested for fodder purpose by local people. Till recent past, cattle grazing was also allowed throughout the forested tract except areas earmarked under regeneration programme. The present wildlife law in Indiaprohibits cattle grazing and other uses in a national park area while regulated grazing only is permitted in the case of wildlife sanctuaries.

Over the years, a combination of tools and methods like grass cutting, removal, harrowing, uprooting, planting and burning have been used in different PAs in the Indian *Terai* so as to maintain grassland diversity and productivity (Mathur, 2000; Anon., 1997). Unfortunately, the complexities of different management practices and their effects on biodiversity or species of conservation concern are poorly understood. Experimental researches on grassland management practices, particularly use of fire as a management tool have long been advocated (Rodgers, 1986; Deb Roy, 1986; Qureshi *et al.,* 1991; Mathur, 2000). Some PAs are providing intensive management inputs at a high cost with potential risks involved therein. The TCA is no exception.

5.4 The Experimental Trial

It is evident that the tall grasslands in TCA have been ignored their ecological significance for a very long time, and potentially faulty or ad hoc management practices have been continued. The tall grasslands in TCA have also been extensively grazed, harvested, and annually burned except in the Dudwa National Park wherein livestock grazing and grass harvesting have been officially curbed for more than 20 years (**Plate 5.1**). However, some level of illegal grazing in peripheral areas and harvest of grass takes place. Occasionally, some grasslands have also been harrowed by tractor and burnt to promote new grass growth. In view of the above, the first experimental study on the tall grasslands in TCA was initiated in 1998 as a part of the major WII-USDA Forest Service Collaborative Project with the support of PA management. The experimental study aimed to assess the effect of various grassland burning regimes in TCA on grass composition, production and ungulate use. Specifically, the study was planned to test the following hypotheses.

(i) Treatments would increase dry season forage for ungulates; and
(ii) Harrowing and burning would simulate the agricultural processes formerly keeping tall grasses down when people were allowed to graze and cut in the Park, thus providing more forage and maintain composition in favourable forage species.

5.4.1 Experimental Design

Two experimental sites were selected in homogenous stands of Upland and Lowland grasslands, respectively in the compartment number 4 (Madria area), Sathiana block of the DNP. The former grassland was characterized by the *Imperata cylindrica – Desmostachya bipinnata* assemblage while the later type was characterized by the *Sclerostachya fusca – Saccharum spontaneum* type of grass assemblage. The Sathiana

Plate 5.1 - Grassland Management Practices in TCA

block of DNP used to be the main stronghold of swamp deer (Schaller, 1967). Schaaf and Singh (1976) counted 627 swamp deer in Sathiana area in 1972 while they estimated a population of 1200 deer. Later, Singh (1984) counted 950 swamp deer in 1977 in the same area. The population drastically reduced in subsequent years. Sankaran (1989) thus, counted 287 swamp deer only in 1989 and estimated a population of 300 deer in the once prime habitat.

Split plots of 100m x 260m were used (**Fig. 5.1**) to assess the effect of different burning treatments. Three replicates of split plots were taken in each of the grassland type. Each experimental plot was split into five equal blocks (100m x 50m) so as to provide four different treatments *viz.,* (i) grass cut and burned; (ii) grass cut, removed, and burned; (iii) grass harrowed and burned; and (iv) grass burned as standing. The fifth block separated by a strip of 10m buffer was provided no treatment including unburned. This block served as the control in the present experimental trial.

5.4.2 Field Sampling

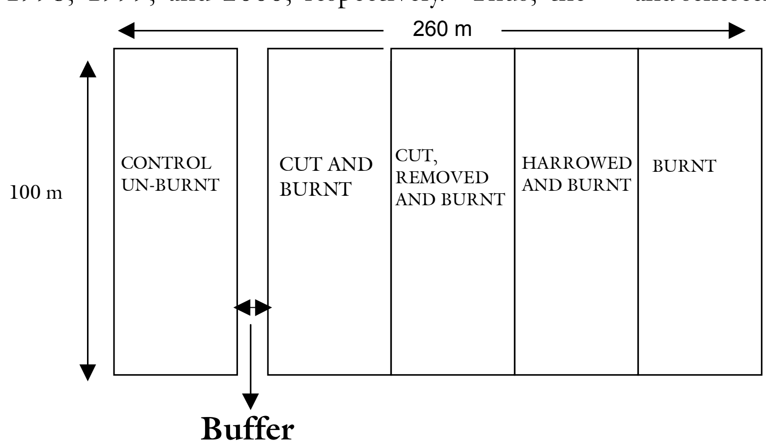
Prior to the proposed four treatments and burning of experimental plots, baseline measurements on plant species composition, phenology, grass height, aboveground total biomass and pellet count (swamp deer and hog deer) were made in the respective control block of the Upland and Lowland grasslands split design. These measurements were commenced in the first week of January, 1998 and completed before 10 January. Later, different treatments (e.g. grass cutting, removal, harrowing) were provided in different plots and completed by 25 January. The cut, removed and harrowed grass plots were ultimately burned on 28 January, 3 February, and 5 February in 1998, 1999, and 2000, respectively. Thus, the experimental treatments were continued for three consecutive years. Likewise, various field sampling and assessments were also periodically carried out from January, 1998 till the termination of experimental trial in January, 2001. Details of different field assessments made during the three-year experiment are presented below. In all, four sets of measurements were repeated every year i.e. in January, April, July and October for each parameter so as to gain a better understanding of life cycle of grass growth, grass production, grazing occurrence, and seasonal use by two selected wild ungulates. These four data sets included one sampling prior to the commencement of experimental treatments each year and three times at an interval of three months thereafter. As far as possible, all field data collection was undertaken and completed in the first week of corresponding month itself.

5.4.2.1 Biomass Production

Standing biomass was assessed in ten 1m x 1m random plots in each treatment and control block. Standing biomass (live and dead) was cut at the ground level with sickles and weighed in the field with spring balances. Subsequently, biomass was sorted species-wise and fresh weight for each species was immediately recorded. Small sub-samples weighing about 100g of each species were chopped, transferred to separate paper bags and weighed. These sub-samples were later dried in a hot-air oven at 80^0 C and ultimately weighed to determine dry weight in each case. The values for the 10 plots were averaged to yield a biomass estimate for treatment plots at each sample date.

5.4.2.2 Phenology and Ungulate Use

Field data on grass phenology (sprouting, flowering, and senescence), grazing signs and ungulate use was also collected in each of the split block prior to the treatment and afterwards as in the case of standing biomass. For the assessment of phenology and grazing signs, occular observations in each treatment block were made and documented. Two belt transects (100m x 2m) were marked at 17m intervals from the left side in each split plot for the assessment of ungulate use through pellet counts. Total pellet groups of the two wild ungulates (swamp deer and hog deer) were counted in two belt transects and later



collected and removed so as to avoid any confusion during the next reading.

5.4.3 Data Analysis

In all, 1830 plots (1m x 1m) were sampled in each of the grassland type for the quantification of aboveground biomass (AGB) under different treatments. Thirty plots were clipped in the control block prior to the initiation of experiment. Subsequently, 12 periodic data sets covering different seasons were collected from April, 1998 to January, 2001 wherein 150 plots (5 treatments x 10 plots x 3 replicates) were sampled at the time of each reading. The preliminary data analysis revealed that there was no significant difference in values of total biomass among multiple plots sampled at any given replicate and year as well as treatment. Thus, values of total biomass (dry weight) for a given treatment at the time of each reading for the Upland and Lowland grasslands were separately summed up and a mean value with standard deviation was computed. Likewise, field data on relative pellet occurrence for swamp deer and hog deer was also pooled together by adding values of pellet group count in six belt transects of three replicates for corresponding treatment and periodical measurement in each grassland type. The values of pellet density (Pellet groups/ha) were computed in each case.

Aboveground biomass data set was later used to first investigate the effect of treatments and seasons individually using 2-way Analysis of Variance (ANOVA). This was followed by a multiple range comparisons for each grassland using Tamhane's T2 Test so as to see the effect of interactions among different treatments and seasons. The SPSS/PC+ based software was used for all analysis (Norusis, 1994). Two-way ANOVAs followed by multiple comparisons were also made on data sets on relative pellet occurrence.

5.5 The Results

The results illustrating the effect of different burning practices on grass composition, phenology, standing biomass, grazing intensity and ungulate use are described below.

5.5.1 Aboveground Biomass (AGB)

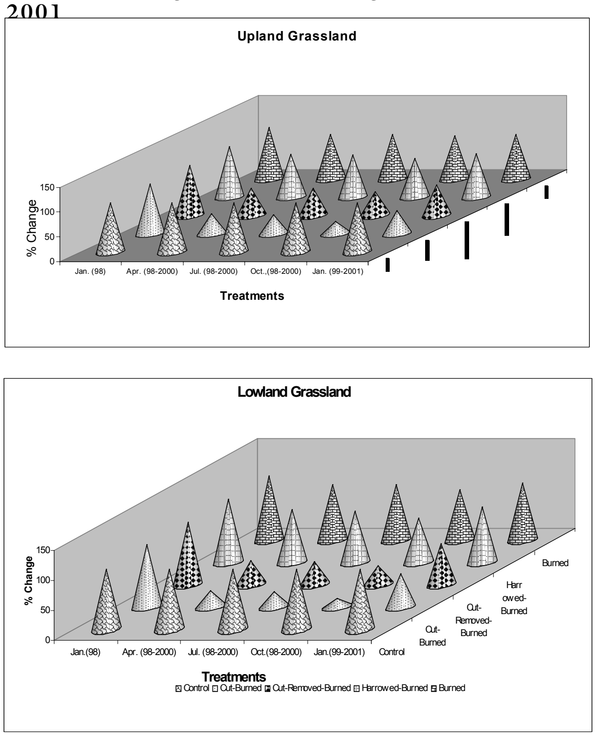
The effect of four burning treatments on the total aboveground biomass (AGB) in two type of grasslands is presented in **Table 5.1**. Interestingly, only a slight variation in mean values of AGB in the corresponding control block of both the type of grasslands was observed over a 3-year experimental trial. Accordingly, the aboveground biomass, being 10.74 t/ha was registered in the Upland grassland prior to the initiation of different treatments (January, 1998) while the corresponding value in the case of Lowland grassland was 24.66 t/ha. Hence, values of AGB were nearly 2.5 times higher in the Lowland grassland than the Upland grassland. In contrary to the control, values of biomass were markedly lower in all the treatments three months after the initiation of experimental trial or once the treatments given. The values of AGB in the Upland grassland, therefore, ranged from 2.72 t/ha to 5.09 t/ha in the four treatments in the month of July. The lowest value was registered in the harrowed-burned treatment, presumably as a result of the late response of different grass species and their delayed sprouting after the disturbance of sub-soil by harrowing as well as likely uprooting of grass tussocks along with the rhizome. The highest value (5.09 t/ha) in burned treatment in comparison to other three treatments can be attributed to the fact that in burned alone treatment, some portion of culms remained unburned and there was also prompt grass sprouting from the base after burning leading to higher standing biomass. While in cut-burned and cut-removed-burned treatments, there was hardly any remnant portion of culms as grass was either completely cut at the ground level or removed once it was harvested. Similar pattern was observed in the case of Lowland grassland. The lowest values of AGB were registered in the harrowed-burned treatment. Drastic reduction in the standing biomass was recorded immediately after the harrowed-burned treatment. However, a rapid gain in total aboveground biomass in subsequent months was observed. In general, a gradual increase in the aboveground biomass in all the four treatments and only a marginal increase in control was observed in later months i.e. July, October, and January every year.

In order to get a better understanding of the effect of four treatments on AGB, the values of percentage change in the aboveground biomass in relation to the initial control were worked out (**Fig. 5.1**). Different treatments resulted into substantially reduced standing biomass immediately after each of the treatment. Biomass in the Upland grassland was as low as 25% in the harrowed-burned treatment in April month, followed by 39% in cut-removed-burned, 41% in cut-burned, and 47% in burned treatments, respectively.

Table 5.1 – Effect of Grassland Burning Practices on the Aboveground Biomass (t/ha) Recorded during the period: 1998-2001

Sl. No.	Period	Treatments				
		Control	Cut -Burned	Cut - Removed - Burned	Harrowed – Burned	Burned
A.	**Upland Grassland**					
1	January (1998)	10.74 ± 0.36	10.74 ± 0.36	10.74 ± 0.36	10.74 ± 0.36	10.74 ± 0.36
2	April (1998-2000)	10.87 ± 0.19	04.49 ± 0.10	04.27 ± 0.10	02.72 ± 0.10	05.09 ± 0.18
3	July (1998-2000)	10.94 ± 0.19	06.13 ± 0.17	05.97 ± 0.17	05.38 ± 0.12	06.82 + 0.15
4	October (1998-2000)	11.07 ± 0.21	09.60 ± 0.21	09.47 ± 0.20	08.51 ± 0.16	09.72 + 0.19
5	January (1999-2001)	11.14 ± 0.36	10.12 ± 0.29	10.02 ± 0.20	09.82 ± 0.14	10.10 ± 0.29
B.	**Lowland Grassland**					
1	January (1998)	24.66 ± 0.54	24.66 ± 0.54	24.66 ± 0.54	24.66 ± 0.54	24.66 ± 0.54
2	April (1998-2000)	25.32 ± 0.21	06.83 ± 0.25	06.58 ± 0.24	03.59 ± 0.19	14.22 ± 0.24
3	July (1998-2000)	25.58 ± 0.37	10.21 ± 0.29	09.77 ± 0.22	07.78 ± 0.18	17.30 ± 0.37
4	October (1998-2000)	25.78 ± 0.22	22.41 ± 0.37	21.78 ± 0.34	19.10 ± 0.42	23.63 ± 0.32
5	January (1999-2001)	25.88 ± 0.19	23.92 ± 0.55	23.66 ± 0.40	21.39 ± 0.60	24.26 ± 0.67

Fig. 5.1 - Percentage Change in the Above Ground Biomass of the Upland and Lowland Grasslands Consequent to Different Burning Treatments During the Period : 1988-2001



In later months, rapid recovery in the standing biomass was registered in all the cases. At the end of three consecutive years of different treatments, only a marginal difference of maximum 16% lower AGB in reference to control was observed in the harrowed-burned treatment. The Lowland grassland also responded in a similar manner to the four treatments over a period of three years. In this case also, the lowest biomass as low as 14% was recorded in the harrowed-burned plot immediately after the treatment. However, as in the case of Upland grassland, the harrowed-burned treatment subsequently gained standing biomass almost comparable to other three treatments.

The effect of different burning treatments on the aboveground biomass in the Upland and Lowland grassland was investigated using 2-way ANOVA, which is presented in **Table 5.2**.

The Null hypothesis tested to prove that there is no effect of treatments and seasons on the aboveground biomass in both the type of grasslands was rejected. Different treatments, four periodical seasonal data (Seasons), and Treatments * Seasons on the aboveground biomass in the Upland and Lowland grasslands showed significant difference at the 0.05 level (**Table 5.2**).

Multiple comparisons performed using Tamhane's T2 Test showed that there was no significant differences between (i) cut-burned and cut-removed-burned; (ii) cut-burned and burned; (iii) cut-removed-burned and burned treatments in the Upland grassland on the basis of their corresponding AGB values (**Table 5.3**). Likewise, the cut-burned and cut-removed-burned treatments in the Lowland grassland had no significant difference. All other comparisons among treatments in the both grassland types were highly significant at the 0.05 level.

Table 5.2 – Results of Analysis of Variance (ANOVA) for Aboveground Biomass (AGB) in the Upland and Lowland Grasslands in Split-Block Burning Experimental Design

Source of Variation	Degree of Freedom (df)	F-Ratio	Significance (p)
A. Upland Grassland			
Model	20	226.2	.000***
Treatments	4	387.7	.000***
Seasons	4	585.8	.000***
Treatments * Seasons	12	45.5	.000***
Total	1830		
B. Lowland Grassland			
Model	20	605.2	.000***
Treatments	4	1174.8	.000***
Seasons	4	1417.5	.000***
Treatments * Seasons	12	131.7	.000***
Total	1830		

*** - Significant at the 0.001 level; NS – Non Significant

Tamhane's T2 Test revealed that the values of AGB in January, 1998, i.e. the control plot prior to the initiation of experimental trial and at the time of termination of experiment after three years in January, 2001, were not different in both the type of grasslands (**Table 5.4**). This amply explains that despite repeated four different burning treatments for consecutive three years there was hardly any discernible difference in the aboveground biomass. Likewise, there was not a significant difference between the values of AGB recorded in October (1998-2000) and January, 2001 in the Lowland grassland.

5.5.2 Species Composition

Data analysis on the prominent grass species that significantly contributed for the total aboveground biomass under the different burning treatments revealed several striking findings. These are described below individually for the Upland and Lowland grasslands.

5.5.2.1 Upland Grassland

Imperata cylindrica and *Desmotachya bipinnata* were two prominent grasses in the Upland grassland stand. This grassland was given four different burning treatments from 1998 to 2000. In general, the aboveground biomass contribution by *Imperata cylindrica* was nearly three times higher than *Desmostachya bipinnata*. *Imperata cylindrica* registered a considerable decline (40-53%) in AGB in all the four treatments at the end of three consecutive years of experiment (**Fig. 5.2**). The greatest loss of AGB, being 53% was in the harrowed-burned treatment while the minimal loss (40%) was in the burned alone treatment. However, the control block at the time of termination of experiment showed a 10% gain in *Imperata cylindrica* AGB than what it had at the time of initiation of the experiment.

On the contrary, the other prominent grass i.e. *Desmostachya bipinnata* registered 3% to 37% increase in AGB under different treatments at the end of experiment. The minimal increase was in the cut-burned treatment while the maximum biomass gain

Table 5.3 - Multiple Comparisons for the Aboveground Biomass Among Different Treatments in the Upland and Lowland Grasslands Using Tamhane's T2 Test

Treatment (I)	Treatment (J)	Upland Grassland Mean Difference (I-J)	Upland Grassland Significance (p)	Lowland Grassland Mean Difference (I-J)	Lowland Grassland Significance (p)
Control	Cut-Burn	340.0	.000***	994.6	.000***
	Cut-Removed-Burned	356.0	.000***	1055.8	.000***
	Harrowed-Burned	455.7	.000***	1311.3	.000***
	Burned	302.4	.000***	471.7	.000***
Cut-Burned	Cut-Removed-Burned	16.0	.998 NS	61.2	.961 NS
	Harrowed-Burned	115.7	.000***	316.7	.000***
	Burned	-37.6	.510 NS	-422.9	.000***
Cut-Removed-Burned	Harrowed-Burned	99.6	.000***	255.5	.000***
	Burned	-53.6	.099 NS	-484.1	.000***
Harrowed-Burned	Burned	-153.3	.000***	-739.6	.000***

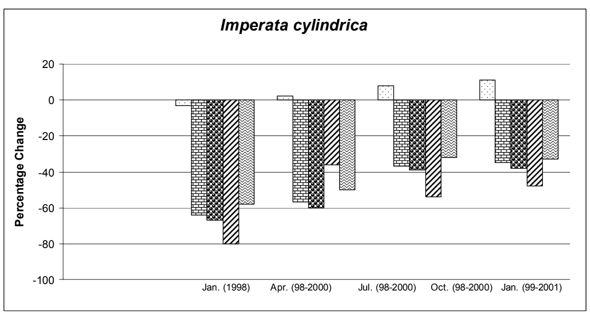
*** - Significant at the 0.001 level; NS – Non Significant

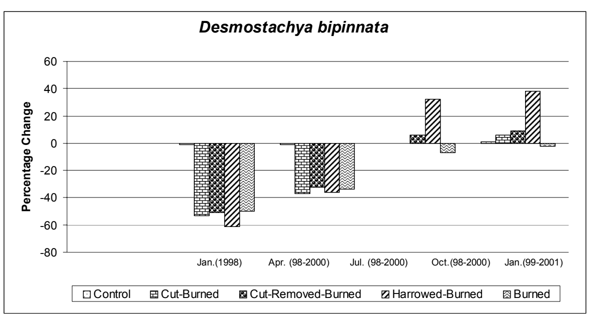
Table 5.4 - Multiple Comparisons for the Aboveground Biomass Among Different Seasons in the Upland and Lowland Grasslands Using Tamhane's T2 Test

Treatment(I)	Treatment (J)	Upland Grassland Mean Difference (I-J)	Upland Grassland Significance (P)	Lowland Grassland Mean Difference (I-J)	Lowland Grassland Significance (p)
January (98)	April (98-2000)	525.1	.000***	1306.7	.000***
	July (98-2000)	369.2	.000***	1025.7	.000***
	October (98-2000)	106.7	.073 NS	184.4	.014***
	January (99-2001)	63.9	.610 NS	154.7	.060***
April (98-2000)	July (98-2000)	-155.9	.000***	-281.1	.000***
	October (98-2000)	-418.4	.000***	1122.3	.000***
	January (99-2001)	-461.1	.000***	1152.1	.000***
July (98-2000)	October (98-2000)	-262.6	.000***	-841.3	.000***
	January (99-2001)	-305.3	.000***	-871.1	.014***
October (98-2000)	January (99-2001)	-42.7	.011***	-29.8	.939 NS

*** - Significant at the 0.001 level; NS – Non Significant

Fig 5.2 – Effect of Grassland Burning Practices on the Percentage Change in AGB of *Imperata cylindrica* and *Desmostachya bipinnata* in the Upland Grassland Recorded During the Period: (1998-2001)





was in harrowed-burned treatment. A marginal increase (1%) in control was also recorded. The burned alone treatment among the four managed grassland plots showed a reduction of 4% in AGB. The ANOVA results showed highly significant differences in the aboveground biomass of *Imperata cylindrica* and *Desmostachya bipinnata* under the different treatments and seasons (**Table 5.5**). However, a multiple comparison showed no significant differences between the cut-burned and cut-removed-burned treatments on AGB of two grasses. The multiple comparison between the cut-burned and burned alone treatments in the case of *Desmostachya bipinnata* also showed no significant difference (**Table 5.6**).

5.5.2.2 Lowland Grassland

Sclerostachya fusca and *Saccharum narenga* were the two major grasses in the Lowland grassland contributing >80% of the total aboveground biomass. *Sclerostachya fusca* contributed nearly double AGB than *Saccharum narenga* in all the cases. Generally, the grass composition under the different treatments remained unaltered except in the harrowed-burned treatment wherein after the second year treatment *Desmostachya bipinnata* suddenly appeared and eventually established (**Fig. 5.3**). It is noteworthy here that *Desmostachya bipinnata* was otherwise absent in the Lowland grassland. Definitely, *Desmostachya bipinnata* is an undesirable grass species in Lowland grasslands, being a coarse and unpalatable species on its maturity. Its presence also indicates retrogression of such grasslands. As in the case of total aboveground biomass and grasses in the Upland grassland, *Sclerostachya fusca* and *Saccharum narenga* registered a considerable reduction (53% to 92%) in values of the aboveground biomass immediately after the four burning treatments (**Fig. 5.3**). However, the control block showed gradual and marginal increase in AGB till the completion of experiment. The maximum reduction, being 92% in AGB was registered in

Table 5.5 – Results of Analysis of Variance (ANOVA) for the Aboveground Biomass (AGB) of *Imperata cylindrica* and *Desmostachya bipinnata* in the Upland Grassland

Source of Variation	Degree of Freedom (df)	F Ratio	Significance (p)
A. *Imperata cylindrica*			
Model	20	408.4	.000***
Treatment	4	1315.8	.000***
Season	4	613.2	.000***
Treatment *Season	12	20.8	.000***
Total	1830		
B. *Desmostachya bipinnata*			
Model	20	237.1	.000***
Treatment	4	122.6	.000***
Season	4	781.9	.000***
Treatment *Season	12	92.1	.000***
Total	1830		

***- Significant at the 0.001 level

Saccharum narenga under the harrowed-burned treatment immediately after the treatment i.e. in April. This was followed by a gradual increase in AGB in all the cases till the last measurement. Despite this gradual increase, three times consecutive similar treatments during 1998-2000 ultimately led to a 15% to 47% reduction in AGB of *Sclerostachya fusca* in the burned and harrowed-burned treatment, respectively. Likewise, *Saccharum narenga* obtained a reduced AGB to the extent of 15% to 53% in the burned and harrowed-burned treatment, respectively. Thus, in simple terms the burned alone treatment had minimal adverse effect on AGB of both species, while the harrowed-burned treatment had a remarkable influence on AGB of both the species of the Lowland grassland.

The ANOVA results showed highly significant differences in the aboveground biomass of *Sclerostachya fusca* and *Saccharum narenga* under the four different treatments and seasons (**Table 5.7**). Like the Upland grassland, in this case also the multiple comparisons showed no significant 2-way differences between the cut-burned and cut-removed-burned treatments on AGB of two grasses (**Table 5.8**).

5.4.1 Phenology

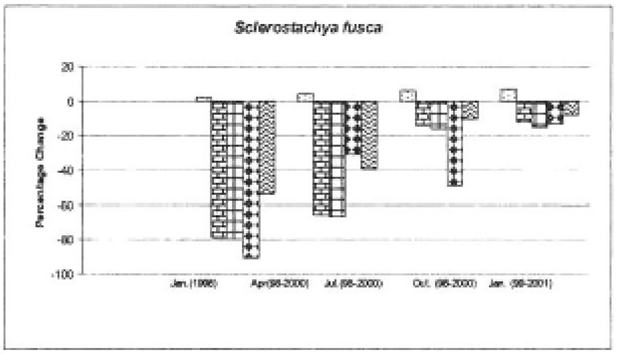
Generally, perennial grasses in the unmanaged Upland and Lowland grasslands start sprouting from the base of old tussocks immediately after the onset of monsoon in the month of July and thereafter continued growing till the end of rainy season i.e. September. Thus, the rainy season (July – September) was the active growth period for the majority of grasses and other plants growing in tall, wet grasslands. This was followed by the senescence and the Upland grassland started looking pale and dry by mid October while the Lowland grasslands remained green for a much longer period till the end of November or beyond depending upon the available soil moisture. Usually, both the

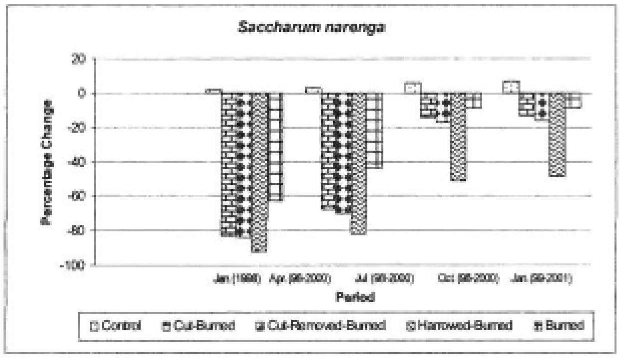
Table 5.6 – Multiple Comparisons for the Aboveground Biomass of *Imperata cylindrica* and *Desmostachya bipinnata* in the Upland Grassland Among Different Treatments Using Tamhane's T2 Test

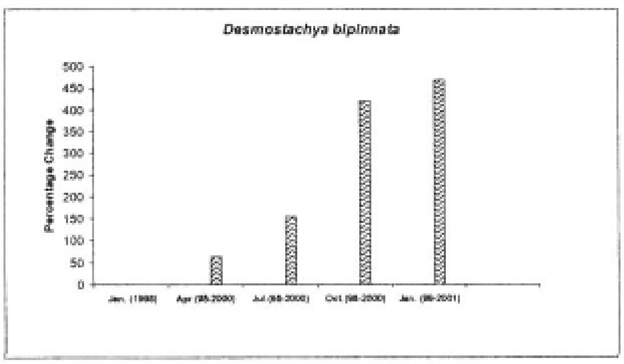
Treatment (I)	Treatment (J)	*Imperata cylindrica* Mean Difference (I-J)	*Imperata cylindrica* Significance (P)	*Desmostachya bipinnata* Mean Difference (I-J)	*Desmostachya bipinnata* Significance (P)
Control	Cut – Burn	314.4	.000***	49.2	.000***
	Cut - Removed - Burned	336.5	.000***	40.4	.000***
	Harrowed – Burned	416.6	.000***	17.1	.050***
	Burned	280.1	.000***	56.0	.000***
Cut - Burned	Cut – Removed – Burned	22.1	.302NS	-8.8	.626NS
	Harrowed – Burned	102.1	.000***	-32.1	.000***
	Burned	-34.3	.010***	6.8	.812NS
Cut – Removed - Burned	Harrowed -Burned	80.1	.000***	-23.3	.008***
	Burned	-56.4	.000***	15.6	.017***
Harrowed - Burned	Burned	-136.5	.000***	38.9	.000***

** - Significant at 0.001 level; NS – Non Significant

Fig 5.3 - Effect of Grassland Burning Practices on the Percentage Change in AGB of *Sclerostachya fusca*, *Saccharum narenga* and *Desmostachya bipinnata* in the Lowland







grassland types also had peak flowering and were full with inflorescence during August–September. The Upland grasslands were in a position to be burned after mid December while the Lowland grasslands could be earliest burned in mid January depending upon the moisture content. Burning followed by occasional winter rains in the months of January–February again promoted new grass growth and in majority cases new flush remained green upto March or early April. However, even this phenomenon could be observed in later months depending upon late grass burn and available soil moisture. The following description describes specific phenological changes

Table 5.7 - Effect of Different Burning Practices on the Aboveground Biomass of *Sclerostachya fusca* and *Saccharum narenga* in the Lowland Grassland in a Full Factorial ANOVA Design

Source of variation	Degree of Freedom (df)	F Ratio	Significance (p)
A. *Sclerostachya fusca*			
Model	20	780.6	.000***
Treatment	4	1415.1	.000***
Season	4	2086.5	.000***
Treatment *Season	12	120.9	.000***
Total	1830		
B. *Saccharum narenga*			
Model	20	1036.4	.000***
Treatment	4	2349.8	.000***
Season	4	2173.4	.000***
Treatment *Season	12	191.7	.000***
Total	1830		

*** - Significant at the 0.001 level

in the Upland and Lowland grasslands once they were subjected to different burning treatments.

5.5.3.1 Upland Grassland

Imperata cylindrica was the first to respond and sprout in early February among the four prominent grasses of the Upland grassland after different treatments were given. It promptly sprouted in the burned alone and cut-burned treatments probably due to greater severity of burning in those two treatments. This was followed by sprouting in the harrowed-burned treatment. The cut-removed-burned treatment was last in the sequence to respond. The overall time difference in sprouting among the four treatments was of maximum 4-5 days. Intensity of sprouting was much reduced in the harrowed-burned treatment among the four treatments due to obvious disturbance of tussocks and rhizomes by harrowing. Except in the harrowed-burned treatment, *Imperata cylindrica* began to flower by the end of February and its senescence started in March. *Desmostachya bipinnata* and *Vetiveria zizanoides* responded simultaneously and sprouted by the end of February. These grasses ramained tender for much longer period in the harrowed-burned treatment and thus, there was delayed senescence. *Saccharum spontaneum* was last to sprout in March and by this time, *Imperata cylindrica*, *Desmostachya bipinnata,* and *Vetiveria zizanoides* were in profuse flowering. This way, staggered response of four species was quite evident

Table 5.8 - Multiple Comparisons for the Aboveground Biomass of *Sclerostachya fusca* and *Saccharum narenga* in the Lowland Grassland Among Different Treatments for Using Tamhane's T2 Test

Treatment (I)	Treatment (J)	*Sclerostachya fusca*		*Saccharum narenga*	
		Mean Difference (I-J)	Significance (P)	Mean Difference (I-J)	Significance (p)
Control	Cut - Burn	482.8	.000***	326.8	.000***
	Cut - Removed - Burned	486.6	.000***	340.3	.000***
	Harrowed – Burned	748.7	.000***	513.1	.000***
	Burned	306.4	.000***	227.2	.000***
Cut – Burned	Cut – Removed – Burned	3.8	1.000NS	13.5	.998NS
	Harrowed – Burned	265.9	.000***	186.2	.000***
	Burned	-176.3	.000***	-99.5	.000***
Cut – Removed - Burned	Harrowed - Burned	262.1	.000***	172.7	.000***
	Burned	-180.2	.000***	-113.1	.000***
Harrowed - Burned	Burned	-442.3*	.000***	-285.8	.000***

** Significant at the 0.001 level; NS-Non Significant

after the four treatments. *Olax nana*, a undershrub was commonly grown in all the treatments and control block except the harrowed-burned treatment in summer months. Herbs *viz., Eulophia flava* and *E. homusjii* have prominently appeared in summer (April–May) months in the control plot as well as in the harrowed–burned and burned treatments. These two herbs were not favoured by the cut–burned and cut–removed–burned treatments.

5.5.3.2 Lowland Grassland

Lowland grassland showed a much delayed (15-20 days) response than the Upland grassland after the four different treatments. *Sclerostachya fusca* and *Saccharum narenga* were first to respond and they sprouted in late February. However, these species sprouted little later in the month of March in the case of harrowed–burned treatment. As in the case of the Upland grassland, *Saccharum spontaneum* was last to sprout in April. *Cyperus kyllingia (*Cyperaceae*), Selinum monnieri (*Apiaceae) profusely grown in the cut–burned and cut–removed–burned treatments in summer (April-May) months. In addition to these two plant species, *Solanum surattense* and *Argemone mexicana* were grown abundantly in the harrowed–burned treatment for nearly a month during April–May. In contrast, the control block and the burned alone treatment lacked occurrence of such herb, undershrub and sedge species. The disturbed and exposed situation arising due to grass cutting, removal and harrowing favoured such unpalatable species. *Lygodium flexuosum,* a fern species commonly occurred in the control plot and the burned alone treatment during rainy and post-rainy seasons. However, it was conspicuously absent in the cut–burned, cut–removed–burned, and harrowed–burnt treatments during the rainy season due to the exposed ground situation. Once grasses have grown therein during the post-rainy season, *Lygodium flexuosum* was seen in such areas also.

5.5.4 Ungulate Use

Values of the relative pellet density (pellet groups/ha) for swamp deer and hog deer were computed on the basis of pellet group counts in the Upland and Lowland grasslands given different burning treatments for three consecutive years (1998-2000). The results are presented in **Fig. 5.4** and **5.5**. In general, the relative pellet density for both the wild ungulates was low in January, 1998 prior to the commencement of experiment trial. The relative grassland use based on the pellet counts increased many folds in all the four treated areas in the first set of assessment i.e. in the month of April immediately after the different treatment were given. However, there was a marginal change in the case of unmanaged control block. The ungulate use gradually declined to low levels in July and October, and finally to the lowest level closer to the initial control level in January, 2001. These retrogressive changes reflect the gain in grass height in subsequent months. Before the commencement

Fig.5.4 – Effect of Different Burning Practices on the Relative Pellet Density of Swamp Deer and Hog Deer in the Upland Grasslands

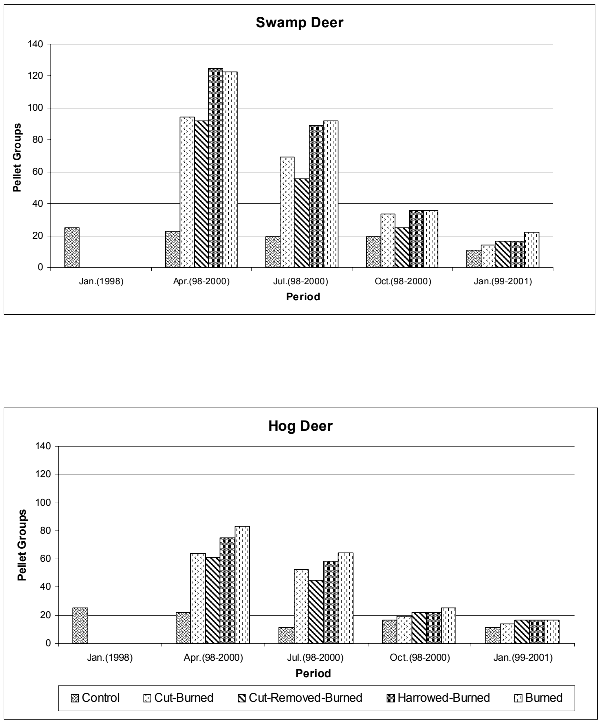
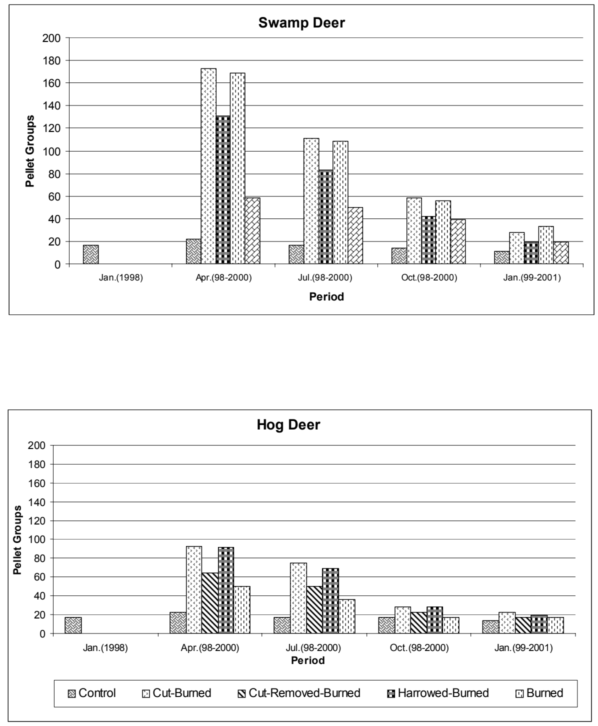


Fig. 5.5 – Effect of Different Burning Practices on the Relative Pellet Density of Swamp Deer and Hog Deer in the Lowland Grassland



of treatments the grass height was quite high; after the different treatments grasses were short and in the early months their palatability was quite high due to tender green shoots. As the time lapsed, the grass height increased and the palatability decreased and this was accompanied by a decline in the relative pellet occurrence. Specific observations made in the case of Upland and Lowland grasslands after different treatments are described below.

5.5.4.1 Upland Grassland

The *Imperata cylindrica–Vetiveria zizanoides* community in the Upland grassland supported grazing throughout the year, particularly in the harrowed-burned and burned alone treatments. Hog deer grazed more heavily in the harrowed-burned and burned alone treatments, but selected plots subjected to burning alone since this type of treatment left more cover to hide in. Hog deer selected relatively much less two other treated areas. Swamp deer also used more the harrowed-burned and burned alone treatments than the two other treatments (**Fig. 5.4**).

ANOVA results showed a highly significant difference between all the treatments and seasonal use of managed Upland grassland by swamp deer and hog deer (**Table 5.9**). The multiple comparisons among treatments revealed a highly significant difference in use of the control *vs.* treatment plots. However, a 2-way comparison between any two treatments showed a non-significant difference in the use of managed Upland grassland by two wild ungulates (**Table 5.10**).

5.5.4.2 Lowland Grassland

The relative pellet occurrence of swamp deer and hog deer substantially increased in the four managed Lowland grassland plots than the control plot immediately after they were treated (**Fig. 5.5**). The values of relative pellet density ranged from 58.3 pellet groups/ha to 172.5 pellet groups/ha in the burned alone and cut-burned treatments, respectively in April (1998-2000). This was followed by a considerable decline in the ungulate use in all the four managed Lowland grassland plots. Gradual decline further continued in all the cases even in the month of October

Table 5.9 – Effect of Different Burning Practices on the Relative Pellet Occurrence of Swamp Deer and Hog Deer in the Upland Grassland in a Full Factorial ANOVA Design

Source of Variation	Degree of freedom (df)	F-Ratio	Significance (p)
A. Swamp Deer			
Model	24	24.257	.000***
Treatments	4	28.477	.000***
Seasons	4	72.112	.000***
Treatment *Seasons	12	6.366	.000***
Total	366		
B. Hog Deer			
Model	24	10.7	.000***
Treatments	4	6.8	.000***
Seasons	4	39.8	.000***
Treatment *Seasons	12	2.9	.000***
Total	366		

*** - Highly significant at the 0.001 level

(1998-2000) and finally the lowest values were recorded in January, 2001 after the three years of repeated treatments. The open ground situation due to the cut-burned, cut-removed-burned, and harrowed-burned treatments was more selected than the burned alone treatment. Both the ungulates used open areas for resting while new tender shoots for foraging. In all the cases, the values of pellet counts in the unmanaged plot (control) remained low. These low values can be attributed to the fact that the unmanaged grassland continued to have tall, dense coarse grass, which could not attract swamp deer and hog deer. It is also possible that the dense grass situation might have also affected an efficient counting of pellets while it was easier to locate pellet groups and count them in the four managed grassland plots.

The ANOVA results showed a highly significant difference in the pellet counts of swamp deer and hog deer under the four different treatments given to the Lowland grassland. There were highly significant differences between the different treatments and seasons (**Table 5.11**). Likewise, the multiple comparisons between the different treatments revealed highly significant differences in the majority of cases. However, there was no significant difference between the relative pellet occurrence in the cut-burned, cut-removed-burned, and harrowed-burned treatments based on the multiple comparison using Temhane's T2 Test (**Table 5.12**). In other words, except the burned alone treatment, rest other three treatments provided more or less similar favourable conditions to two ungulates for resting, foraging and cover.

5.6 Discussion

The present management oriented experimental study was probably the first attempt in the Indian *Terai* to investigate the effect of different burning regimes over a period of three consecutive years (1998-2000) on the species composition, aboveground biomass and ungulate use in the Upland and Lowland grasslands.

Table 5.10 – Multiple Comparisons for the Relative Pellet Occurrence of Swamp Deer and Hog Deer in the Upland Grassland Using Tamhane's T2 Test

Treatment (I)	Treatment (J)	Swamp Deer		Hog Deer	
		Mean Difference (I-J)	Significance (p)	Mean Difference (I-J)	Significance (p)
Control	Cut-Burn	-.723	.000***	-.4306	.000***
	Cut-Removed-Burned	-.612	.000***	-.3750	.000***
	Harrowed-Burned	-1.001	.000***	-.6250	.000***
	Burned	-1.015	.000***	-.6250	.000***
Cut-Burned	Cut-Removed-Burned	-.278	.691 NS	-.009	1.000 NS
	Harrowed-Burned	-.278	.691 NS	-.009	.994 NS
	Burned	-.292	.563 NS	-.1944	.755 NS
Cut-Removed-Burned	Harrowed-Burned	-.389	.109 NS	.1528	.850 NS
	Burned	-.403	.109 NS	-.009	.993 NS
Harrowed-Burned	Burned	-.001	.109 NS	.009	.995 NS

*** Highly Significant at 0.001 level; NS-Non-Significant.

Table 5.11 – Effect of Different Burning Practices on the Relative Pellet Occurrence of Swamp Deer and Hog Deer in the Lowland Grassland in a Full Factorial ANOVA Design.

Source	Degree of freedom (df)	F-Ratio	Significance (p)
A. Swamp Deer			
Model	24	15.0	.000***
Treatments	4	14.4	.000***
Seasons	4	49.9	.000***
Treatment *Seasons	12	3.9	.000***
Total	366		
B. Hog Deer			
Model	24	31.9	.000***
Treatments	4	39.3	.000***
Seasons	4	90.2	.000***
Treatment *Seasons	12	9.1	.000***
Total	366		

*** - Highly significant at the 0.001 level

The earlier two well documented studies (Lehmkuhl, 1989; Peet *et al.*, 1997) were undertaken in the Chitwan National Park and Royal Bardia National Park, respectively and both were thus, confined to Nepal. Lehmkuhl (1989) examined the effects of fire and by grazing wildlife herbivores on aerial net primary production and annual herbage dynamics in three major grassland types *viz.*, *Saccharum spontaneum*, *Saccharum narenga*, and *Imperata cylindrica*. Basically a comparison between the early burned and late burned and grazed with ungrazed plots was made. Grazing was short-lived on early burns compared to late burns. The reason attributed for this was that the area surrounding the plots was burned early, which is the norm, and a super abundance of forage diffused grazing pressure. Instead, late burns provided a flush of new growth much more palatable than surrounding vegetation. Unburned plot showed no evidence of grazing. Herbivores probably found it much easier to forage in burned areas where new growth was unobstructed by the mat of dead leaves or unburned plots. Burning had significant effects on *Imperata cylindrica* and *Saccharum spontaneum* standing biomass, but not on *Saccharum narenga* biomass. In the case of *Imperata cylindrica*, late burn production was 81% of early burn production; unburned production was 38% of early burn production. Grazing removed the greatest biomass from the late burn plots, probably because burned plots were surrounded by older and less palatable forage. No significant fire and grazing effects were found with *Saccharum narenga* standing biomass. Lehmkuhl (1989) highlighted problems with the *Saccharum spontaneum* experimental plot. Villagers and departmental elephant handlers surreptitiously cut grass from the plots, and ruined the treatment design. Large herbivore grassland consumption in the study area averaged 6% of the aboveground production. The literature reports less than 10% consumption for most natural grazing systems, except the Serengeti.

Peet *et al.* (1997) carried out a randomized block experiment with four treatments (cutting, burning, cutting and burning, and no management) to examine the effect of these treatments on plant species

Table 5.12 – Multiple Comparisons for Relative Pellet Occurrence of Swamp Deer and Hog Deer in the Lowland Grassland Using Tamhane's T2 Test

Treatment (I)	Treatment (J)	Swamp Deer		Hog Deer	
		Mean Difference (I-J)	Significance (p)	Mean Difference (I-J)	Significance (p)
Control	Cut-Burn	-.751	.000***	-1.527	.000***
	Cut-Removed-Burned	-.446	.000***	-1.096	.000***
	Harrowed-Burned	-.654	.000***	-1.485	.000***
	Burned	-.251	.026***	-.513	.000***
Cut-Burned	Cut-Removed-Burned	.306	.149 NS	.431	.373 NS
	Harrowed-Burned	.009	.999 NS	.004	1.000 NS
	Burned	.500	.000***	.001	.000***
Cut-Removed-Burned	Harrowed-Burned	-.208	.571 NS	-.389	.494 NS
	Burned	.194	.369 NS	.583	.002**
Harrowed-Burned	Burned	.403	.004**	.972	.000***

*** - Highly significant at the 0.001 level; ** - Significant at the 0.05 level; NS - Non Significant abundance, species richness and grassland structure. The studied grassland was dominated by *Imperata cylindrica*. The study revealed that in the year three, i.e. two years after first treatment, *Imperata cylindrica* remained the dominant grass species under all treatments, but increased in abundance in unmanaged plots and declined in abundance in managed plots. *Desmostachya bipinnata* showed the opposite response. Plant species richness was significantly higher in managed plots, which were structurally more heterogeneous. Interestingly, no significant difference was documented in cutting alone, burning alone and cutting and burning combined. Further, the study suggested that patches of grassland could be left unmanaged on a two year rotation without significantly altering the composition of the plant community, thereby providing refugia for cover dependent faunal species.

Both the afore-described studies (Lehmkuhl, 1989; Peet *et al.,* 1997) had their own strengths and constraints. The duration of study by Lehmkuhl (1989) in Chitwan NP was of just one year and productivity estimates were made in small caged plots those have their own limitations. For this reason, the study recommended that the production and consumption estimates computed with the cage-plot technique should be treated with caution. The study could compare between the early and late burned options those have been extensively discussed in the available literature (Rodgers, 1986; Deb Roy, 1986). Whilst Peet *et al.* (1997) could investigate the effect of different cutting and burning treatments on only one of the grassland assemblages recognized in the Royal Bardia National Park i.e. *Imperata cylindrica* grassland.

The present study made the following noteworthy findings:

5.6.1 Species Composition and Standing Biomass

- Primarily three grasses *viz., Imperata cylindrica, Desmostachya bipinnata,* and *Vetiveria zizanoides* contributed overwhelmingly to the vegetation cover and standing bomass in the Upland grassland whilst *Sclerostachya fusca, Saccharum narenga* and *Saccharum spontaneum* were the main contributors in the Lowland grassland. The dominance of these species was maintained under all the treatment regimes despite repeated treatments for the three consecutive years. The only exception in the present study was of the harrowed-burned treatment in the Lowland grassland wherein *Desmostachya bipinnata* has suddenly appeared immediately after second treatment and continued to grow and gain standing biomass till the termination of experiment.

- The managed (treated) plots showed an increase in the number of undershrubs, herbs, sedges and ferns. Thus, treated plots were heterogeneous in composition and structurally while the unmanaged plots were more homogeneous. The increase in number of herbaceous and other species was a result of disturbance by different burning regimes. These disturbances resulted in an increased gap in the managed grassland plots and decreased the density of canopy. Earlier studies have inferred that the herbaceous species had a greater capacity to colonize gaps than the dominant grasses while they were probably inferior competitors (Horn and MacArthur, 1972; Crawley and May, 1987; Peet *et al.,*1997).

- Different burning regimes yielded substantially reduced standing biomass immediately after each of the treatment. However, at the end of three consecutive years of different burning treatments only a marginal difference in values of the aboveground biomass was registered in each case. Lowest aboveground biomass, being 16% was registered under the harrowed-burned treatment given to the Upland grassland. The Lowland grassland also responded in a similar manner in response to four treatments over a period of three years and there was a maximum decline of aboveground biomass to the extent of 14%. Thus, marked negative effect of the harrowed-burned treatment on AGB was evident in both the type of grasslands and also at all stages of the experiment.

- Results of Analysis of Variance (ANOVA) showed significant difference among four treatments and their effects on the aboveground biomass. However, the multiple comparisons among them using Tamhane's T2 Test showed that there was no significant difference between the (i) cut-burned and cut-removed-burned; (ii) cut-burned and burned; (iii) Cut-removed-burned and burned alone treatments on their corresponding values of AGB in the Upland grassland. Likewise, the cut-burned and cut-removed-burned treatments in the Lowland grassland also had no significant difference. This, revelation is more or less in conformity with the earlier findings of Peet *et al*. (1997) wherein it was clearly illustrated that there was no significant difference in cutting alone, burning alone and cutting and burning combined. In short, in the present study all the four treatments except the harrowed-burned treatment yielded more or less same aboveground biomass indicating that other three treatments resulted almost similar effect on AGB.

- Nevertheless, the effect of four burning treatments on the species composition and standing biomass of major grass species was prominent in both the type of grasslands. *Imperata cylindrica*, the dominant as well as the major contributor to the standing biomass in the Upland grassland registered a considerable decline (40-53%) in its aboveground biomass in all the cases at the end of three consecutive years of repeated treatments. The maximum loss, being 53% was in the harrowed-burned treatment while the minimal loss (40%) was in burned alone treatment. In opposite, the control block attained 10% gain in AGB at the end of experiment. In contrast to the *Imperata cylindrica*, *Desmostachya bipinnata* showed gain in its aboveground biomass ranging from 1% to 37% in three treatments (cut-burned; cut-removed-burned; and cut-burned) and the control. The maximum gain was in the harrowed-burned treatment indicating that the harrowed-burned treatment favoured *Desmostachya bipinnata* by replacing *Imperata cylindrica*.

- The burned alone treatment was the only exception wherein the *Desmostachya bipinnata* also registered a decline by 4% in its aboveground biomass at the end of three years. The above loss of *Imperata cylindrica* and gain in the case of *Desmostachya bipinnata* can be attributed to the fact that the former is a sod-forming species that grows in dense swards (Lehmkuhl, 1989). *Desmostachya bipinnata* and other grasses *viz., Vetiveria zizanoides, Saccharum spontaneum* and *Saccharum narenga* have a clumped habit often with wide spacing between clumps. *Imperata cylindrica* is known to be very susceptible to shading; perhaps the dead material on the unburned (control) plots and burned alone treatment with remnant unburned portions shaded the surface sufficiently to depress surface temperature, nitrogen mineralization and growth from basal meristems (Weaver and Rowlands, 1952; Lehmkuhl, 1989). Thus, on one hand the shading effect must have influenced new growth and AGB atleast in the case of unburned control block while on the other hand intense grazing and utilization of new growth by wild ungulates in the four burned treatments might have resulted in reduced AGB of *Imperata cylindrica*. However, it can be inferred that *Desmostachya bipinnata* was definitely favoured by the open conditions created in the Upland grassland by different burning treatments except the burned alone treatment.

- Strikingly, *Desmostachya bipinnata* which was otherwise absent in the Lowland grassland prior to the commencement of experiment in January, 1998, abruptly emerged and established in the harrowed-burned treatment. In opposite, *Sclerostachya fusca* and *Saccharum narenga* were adversely affected in the harrowed-burned treatment as both the species registered substantially reduced aboveground biomass by 47% and 53%, respectively at the end of three years.

5.6.2 Phenology

- Broadly, all major grass species in both the type of grasslands responded variedly under the different burning treatments. Thus, a staggered response in sprouting by different species was noticed. *Imperata cylindrica* was the first to sprout in early February among the four prominent grasses of the Upland grassland while *Saccharum spontaneum* was last to sprout in March. Initial sprouting as well as its intensity were severely influenced in the harrowed-burned treatment. The Lowland grassland had a delayed response in terms of sprouting to different treatments in comparison to the Upland grassland. *Sclerostachya fusca* and *Saccharum narenga* were first to sprout while *Saccharum spontaneum* was again last to respond as in the Upland grassland. *Olax nana,* a undershrub and herbs *viz., Eulophia flava* and *E. homusjii* occurred solely in the managed Upland grassland plots while *Cyperus kylingia, Selinum monnieri, Solanum surratense,* and *Argemone mexicana* exclusively appeared in the managed Lowland grasslands. *Lygodium flexuosum*, a fern species commonly occurred in the control plot and burned alone treatment of the Lowland grassland. The species was conspicuously absent immediately after the cut-burned, cut-removed-burned, and harrowed-burned treatments. However, once grasses have grown in these treatments by the post-rainy season, *Lygodium flexuosum* found favourable conditions to grow even in such managed areas.

5.6.3 Ungulate Use

- The managed Upland and Lowland grassland plots distinctly favoured wild ungulates, particularly immediately after the treatments were given and during the summer season. Thus, the management objective of promoting new growth and palatable grass during the lean season was definitely achieved. The harrowed-burned and burned alone treatments in the Upland grassland were more used by both the wild ungulates based on their relative pellet occurrence i.e. swamp deer and hog deer. Even in the Lowland grassland, the harrowed-burned treatment remained favourable to swamp deer and hog deer. However, the burned alone treatment was relatively avoided. Instead, in this case the cut-burned treatment was relatively selected more based on the observations on pellet occurrence. Extensive remnant unburned grass in the burned alone treatment due to higher moisture and lack of adequate dry fuel was relatively less used by two ungulates.

5.6.4 Management and Conservation Implications

The present study on one hand has allowed several interesting observations and significant findings as in the previous studies (Lehmkuhl,1989; Peet *et al.,* 1997; Karki, 1997; Ghosh, 1997) while on the other hand has posed a number of issues relevant to the management of tall grasslands and conservation of biodiversity. Despite the afore-described three major grassland experimental studies in the *Terai*, it is still difficult to answer the basic premise: (i) Whether the continuous grass cut (harvest) and burning are harmful to grassland diversity and productrivity?; (ii) Which management treatment is ideal for the long term conservation goals?; (iii) Which burning option is more favourable and less harmful i.e. early or late burn?; and (iv) What is the effect of current management practices on the species of conservation concern as well as lesser known in the absence of adequate information?. Nevertheless, the following section attempts to provide a better insight on the above premise based on the synthesis of existing information and present findings.

- A large number of researches on the contemporary grasslands have revealed deleterious effects of well known disturbances *viz.,* continuous grass harvest, wide spread burning, and heavy grazing (Daubenmire, 1968; Vogle, 1974; Heady, 1975; Pandeya *et al.,* 1997; Coupland, 1979; McNaughton, 1979; Mishra, 1982; Brown, 1997). However, studies by Karki (1997), Mishra (1984), Lehmkuhl (1989), Brown (1997), Peet *et al.* (1997) have indicated that the *Terai* system is maintained in part by human intervention, and current rates of biomass removal are not adversely affecting tall grasslands. Instead the current practices bring benefits to both local communities and to wildlife. However, whether the practices are sustainable, and in what way they can be regulated, is open to question.

- The present study has also revealed that at the end of three years, there was no significant difference in the overall standing biomass among the four treatments when compared to the control plot. At the same time, the earlier study by Peet *et al.* (1997) and the present study have amply indicated that *Desmostachya bipinnata*, a species of poor value to wildlife and local people showed increased abundance and aboveground biomass at the cost of other preferred prominent grass species in the managed plots, particularly the harrowed-burned treatment. The resultant likely change of the Upland grassland predominated by *Imperata cylindrica* and the *Sclerostachya fusca, Saccharum narenga* and *Saccharum spontaneum* dominated Lowland grassland to *Desmostachya bipinnata* due to repeated harrowed-burned treatment is a major management concern. This calls for a regular monitoring of the species composition and their abundance.

- It is also clear that ending the current practices of cutting and burning would remove the benefit of new and palatable grass to ungulates during the lean period. Grass removal and burning are also helping in controlling hotter and destructive summer fires by reducing fuel loads. Local communities wherever permitted would no longer be able to cut and collect grassland resources. Therefore, maintaining the *status quo*, by annual cutting and burning would provide ungulates with summer forage from the regenerating grassland (Lehmkuhl, 1989; Peet *et al.,* 1997; Karki, 1997; Mishra, 1984; Deb Roy, 1986; Rodgers, 1986) and an important subsistence resource to local communities.

- At least three studies (Lehmkuhl, 1989; Peet *et al.*, 1997) including the present one have clearly demonstrated that the short term variation between different treatments (cutting, grass removal, burning) in studied grasslands were insignificant. Interestingly, over a short period (2-3 years) of experimental trials the biomass removal of whatever form resulted into a more or less same species composition, abundance, structure, and standing biomass at the time of termination of experiment. However, the harrowed-burned treatment in the present study has marked influence on the species composition, standing biomass, phenology, and ungulate use. The study by Lehmkuhl (1989) has earlier revealed that grazing was short-lived on early burns compared to late burns while grazing removed the greatest biomass from the late burned plots.

- In the case of *Terai*, the fluvial processes seem to have profound effect in the formation of large scale spatial patterns and the creation of grassland communities along moisture gradients instead of cutting and burning practices as the fluvial action remains an important and primary disturbance. The influence of rivers on the grasslands in *Terai* is a double-edged sword to field managers. On the one hand river action may maintain or increase the area of grassland through deposition of silt, removal of forest and flooding. On the other, being highly dynamic, the rivers are liable to alter their course away from such forest/protected areas so that current grasslands are no longer flooded and sites for colonization by grasses are no longer created. Resultant soil development subsequent to flooding, available soil moisture, fire and grazing are other important factors leading to community organization and succession.

- The present study could assess the effect of different burning regimes on two wild ungulates only. None of the previous studies have been able to study concurrently the effect of such practices on different faunal species including the mega herbivores, small mammals, birds and herpatofauna. Bell (1986) and Oliver (1980) have shown adverse effects of above management practices on hispid hare and pygmy hog, respectively. Whilst Laurie (1978 and 1982) and Dinerstein (1979a,b; 1980; and 1987) have documented that cutting and burning practices are essential to create the mosaic of habitats so as to maintain the viable populations of one horned rhinoceros and other wild ungulates in the *Terai* region, respectively. Likewise, Braithwaite and Estbergs (1987) studied the effect of different stages of post-fire vegetation regeneration on birds while Fyfe (1980) studied the effect of fire on lizard communities. Fa and Sanchez-Cordero (1993) studied the responses of small mammals to grassland fire. These studies advocated 'patch burning' as a conservation measure in fire-prone areas.

- Javed (1996) while working in Dudwa National Park observed that bird species such as Yellowbellied wren warbler (*Prinia flaviventris*), Large grass warbler (*Graminicola bengalensis*), Fantail warbler (*Cisticola exilis*), Yelloweyed babler (*Timalia pileata*) and Redeyed babler (*Chyrosoma sinense*) were restricted to the patches of tall grasses. Whereas species like bushchats, larks and pipits preferred more open areas and patches of short grasses. Burning of tall grass stands had two type of effects on the composition of dependent avian species: (a) it altered the habitat by creating openness, and (b) easy and possibly increased food availability. Opening in habitat was not suitable for species such as the Large grass warbler, Yellowbellied wren warbler and the Yellow and Redeyed babblers. These birds responded to such management activities by either moving into nearby grassland or restricted themselves to the unburned patches of the tall grasses. It is clear that on one hand the unburned patches would continue to provide ideal habitat for such bird species while on the other hand would act as temporary refugia for species such as hispid hare and pygmy hog. The new grass growth after burning harboured a greater diversity of insect and there was increased invasion of insectivores such as bushchats. The clear visibility, and plenty of perches in the form of incompletely burned grass culms provided an ideal foraging ground to these birds. There was an influx of such insectivorous birds leading to increased bird densities in the post-burn period.

- Intensive study on Bengal Florican (*Houbaropsis bengalensis*) undertaken by Sankaran and Rahmani (1991) in Dudwa National Park revealed that floricans start arriving in the grasslands sometime after the burning is completed in February. Males are highly territorial and the breeding season can be said to have commenced once the display has begun. The breeding season of Bengal Florican at Dudwa extend from early March to end June with April and May being the peak season. Study thus, inferred that the late burning of grasslands and particularly harrowing of ground grasslands during the breeding season were detrimental to floricans and other nesting birds (Swamp Partridge - *Francolinus gularis* and Peafowl - *Pavo cristatus*) as they also begin their nesting in March. Study specifically recommended that grasslands traditionally used by floricans for their territories and breeding must not be harrowed.

In view of the above, it is evident and essential that patch cutting and burning of both the type of grasslands or a mosaic of habitats created by cut, uncut, burned and unburned patches would provide suitable habitat for the persistence of diverse faunal species in *Terai*. Staggered cutting and burning would also create different patches providing varying forage and cover conditions. Lehmkuhl (1989) has indicated that staggered burning foster the formation of pasture like grazing lawns. Staggered burning of grasslands in small patches could provide tender and palatable forage for a longer time during the lean season. Grazing lawns would produce high quality forage year round, may decrease crop depredation by attracting wild herbivores away from agriculture.

Patch size would be critical for success; a patch too large would be hard for herbivores to crop fast enough to keep the grass short, and a patch too small might be overgrazed and may not provide adequate benefits to warrant management. Thus, design of a patch management system should consider a variety of factors *viz.,* grassland type, patch size, quality and distribution, the ability of different species to disperse to neighbouring or newly created patches, temporal and spatial heterogeneity and dynamics of the landscape and disturbance factors, in particular uncontrolled fire and flooding (Rodgers, 1986; Lehmkuhl, 1989; Peet *et al.,* 1997). A planned strategy for using different burning practices in the case of TCA keeping above facts in mind would be desirable. Likewise, a long term monitoring system to investigate changes in the composition of the Upland and Lowland grassland are essentially recommended. The harrowing will have to be completely avoided or judiciously used on at least 2-3 years interval.

Chapter 6

Social and Economic Situation

6.1 Introduction

Forests, grasslands and wetlands contribute various goods and services to mankind. Since time immemorial, resource dependent communities have colonized and exploited these natural resources for their sustenance and prosperity. Rapid development in recent times, social structures and culture have played a significant role in shaping environmental outcomes relevant to those natural resources. Development is widely considered synonymous with increase in consumption while culture has a direct bearing on population, economic activities, settlement patterns, political structures, resource use patterns and other factors affecting biodiversity (Stedman–Edwards, 2000). This means that environmental and social concerns in a given situation are inextricable woven together.

The landscape (TCA) under consideration is no exception. Once, rich in natural forests, grasslands, swamps and wild animals has also witnessed a sea change. The living memory thus testifies the significant changes brought in, particularly conversion of natural areas into vast agriculture and extensive plantations. Despite this, the natural elements of ecological complexity, species diversity and tribal culture abound in a remnant portion of the landscape. In this context, it is imperative to examine and understand the social conditions, their relationships with forest-grassland-wetland complex, economic concerns, people's perceptions, and aspirations. Therefore, this chapter specially describes the social milieu and highlights socio-economic issues and their implications. This synthesis is largely based on the secondary information, household survey in select villages, field observations and participation in the micro-planning process initiated by the Forest Department.

6.2 The Existing Situation – Location and Extent

The *Terai* Conservation Area (TCA) includes the largest remaining natural habitat representing the Gangetic Plains biogeographic zone or the *Terai* ecosystem on the Indian side. As stated earlier, TCA predominantly (>95%) lies in the Kheri district which borders with the international Indo-Nepal boundary on its north. A small proportion of the landscape also lies in two adjacent districts *viz.,* Pilibhit and Shahjhanpur. Otherwise, boundaries of TCA by and large coincide with the district boundaries of Kheri. Kheri is the largest district in the State of Uttar Pradesh and is located in the northern region of the Lucknow division. Total area of the district is 7,680 sq km (Banthia, 2001). On the east side, it is bounded by Bahraich district being separated by Ghagra river. On the south by Sitapur district and for a short length by Hardoi district, on the west by Shahjhanpur and Pilbhit districts and on the north by the territory of Nepal. The district headquarters is located at Lakhimpur-Kheri.

The river Sharda divides the district into North Kheri and South Kheri Forest Divisions and forest areas occurring in small patches are mainly spread along both the riverbanks. A small northwestern part of the North Kheri Forest Division (NKFD) falls in the district Pilibhit. Besides, the two managed forest divisions (MFs), an area of 883.7 sq km belongs to Dudwa Tiger Reserve (DTR).

The Dudwa Tiger Reserve includes Dudwa National Park (DNP), Kishanpur Wildlife Sanctuary (KWLS), and the northern and southern buffer areas of DNP. The two Protected Areas (PAs – DNP and KWLS) though separated physically are by themselves compact and consist of contiguous forest blocks. The DNP lies north of the river Sharda along the Indo-Nepal international boundary while KWLS lies on the south of Sharda river. Thus, northern and northwestern parts of the National Park border with the Kanchanpur and Kailali districts of Nepal. Dhangarhi, the headquarters of Kailali district is the nearest Nepali town. It is only 4 km from the international check post at Gauriphanta. The areas of Nepal abutting the National Park are rural with villages dotting the landscape (De, 2001). On the Nepal side, agricultural fields extend unto the no-mans land. Only small, scattered forest patches are left. This is in stark contrast to the contiguous forest block on the Indian side. Permanent reference pillars mark the international boundary. The Mohana river flows along a large part of the boundary. Over the years the Mohana has changed its course. This has resulted into inaccessibility of some parts of the national park and its northern buffer directly from the Indian side during the monsoon season. The DNP is elongated in shape resulting into a large PA-People interface. The total boundary length is 114 km. There are no major habitations in the Park except 5.78 sq km forest land under eleven different small encroachments occupied by 3,725 people and 2,173 cattle (De, 2001). Among these encroachments, the most prominent one is Surma village wherein 69 families of the 93 original families rehabilitated have still remained. Efforts are on to shift these families out of the Reserve area. The northern buffer (124 sq km) of the DNP lies between the major portion of the core (National Park) area and the international border. It almost enclaves 37 revenue villages inhabited by 'Tharus'. A southern buffer (66 sq km) to DNP was placed under the administrative control of the Field Director, DTR in 1994. A few scattered forest patches still remain under the control of NKFD. The forested buffer to DNP is highly fragmented. Thus, at several places the agricultural fields extend right unto the Suheli river, bordering DNP on its southern side.

The Kishanpur Wildlife Sanctuary (KWLS), yet another compact block of forest lies south of river Sharda. Thus, the river Sharda makes the northern boundary of KWLS. The northeastern areas interface with habitation. The Kheri Branch Canal of the Sharda Canal System constitutes the western boundary. Forests belonging to the South Kheri Forest Division (SKFD) and Shahjhanpur Forest Division border rest of the sides. The forests of Pilibhit Forest Division are also not very far. The Ull river after its origin in Pilibhit flows for about 23 km in the KWLS. The KWLS forms an important part of its catchment.

As stated earlier, two PAs (DNP and KWLS) are independent large forest blocks, lying about 15 km apart on either side of the Sharda river. The intervening part is largely rural and with vast stretches of agriculture.

6.3 Land and the People

The landscape mainly includes the four types of lands: (i) forestland (PAs and MFs) owned by the State Forest Department, (ii) state owned revenue land (other than forest department), (iii) community owned '*Panchayat*' land, and (iv) private lands. The landscape is a vast alluvium plain. Two distinct tracts in geological formations are found in the landscape. These are the *Terai* tract in the north and the alluvium tract in the south. In the former, soils have been formed by alluvial and fluvial action of river. Deposits made by rivers and their tributaries have formed the later tract. Gomti and Ghagra are two important river systems of the tract. The tract is often flooded.

The Kheri district comprises of 5 *Tehsils* and 15 Community Development Blocks. It has 10 towns and 1,811 villages. Prominent towns are Lakhimpur, Palia, Bhira, Mailani, and Gola Gokarnath. Out of 1811 villages, 1712 are inhabited while 99 are uninhabited. The total human population of the district is 3,200,137 as per the 2001 Census. A marked increase in the population during the period from 1981 to 2001 has been registered as the decadal growth rate during this period has increased from 23.89% (1981-1991) to 32.28% (1991-2001). This has ultimately resulted in the increase in the human population density i.e. from 315 persons per sq km in 1991 to 417 persons per sq km in 2001, against the much lower country's average density, being 324 persons per sq km in 2001. Nearly 11% of the total population in the district was urban while rest was rural those lived in villages. The sex ratio (females per 1000 males) was 875. Only 29.71% persons were literate in 1991 while the literacy rate in 2001 rose to 49.39%. Likewise, a general increase in the literacy rate in the case of males as well as females during the past decade was recorded. Despite this, a larger proportion of females (64.11%) remained illiterate against 39.97% illiterate males in 2001.

As mentioned before, presently there are no major habitations in the National Park, except a small remaining human population in Surma village, which was otherwise earlier rehabilitated, or on other small patches of encroached lands. However, there are 37 'Tharu' tribal revenue villages enclaved between the National Park and its northern buffer. The Sanctuary (KWLS) had two enclave villages namely Chaltua and Kishanpur. Except for 34ha under encroachments, rest of the area is free of habitation. A timber depot of the UP Forest Corporation is located inside the KWLS.

The South Kheri Forest Division has now got one forest settlement village (FSV) *viz.,* Devipur in the Mohammadi range. The FSV is located in the interiors of the reserved forest and occupies 1.22 sq km land area. The village has got small human and livestock populations of 700 persons and 242 animals, respectively. However, a large number of revenue villages surround forests patches falling under the jurisdiction of SKFD.

De (2001) has listed 125 village in and around (within 5 km boundary) of Dudwa Tiger Reserve. These villages thus form its ecodevelopment area. A human population of 1,80,163 persons with their about 80,000 livestock population inhabit these villages and exert pressure on two PAs and their buffer areas.

As mentioned earlier, prior to the abolition of 'Zamindari' (landlord) system, the Zamindars used to own large land holdings of arable and forestlands. They brought farm laborers from eastern U.P. and Bihar. Once Zamindari was abolished, the acquired excess cultivable land was distributed to the land less agricultural laborers. A large number of displaced persons due to the partition at the time of country's independence were also brought and settled in the area. Later, they were provided cultivable land mainly by clearing private forests those were acquired under the Land Ceiling Act. Likewise, some farmers also migrated from Punjab so as to avail cheaper and fertile land. Thus, the present inhabitants of the TCA can be broadly grouped into four categories: (i) locals including 'Tharu' tribes, (ii) migrant laborers from eastern U.P., (iii) post-independence displaced persons from Pakistan including Punjabis and Bengalis, and (iv) migrants from Punjab.

These broad groups try to maintain their interests and identity. The migrant labourers and the Bengalis are the weakest economically but have a growing political clout. Displaced Punjabis and migrants are wealthiest among all and they are thus politically influential persons. The locals are strongest in the process of decision making and they are always anxious to safeguard their interests against the immigrants.

6.3.1 Ethnic Identities, Traditions and Customs

'Tharu' tribal constitutes a prominent section among the locals. They are among the most ancient people inhabiting the *Terai* today. They have a distinct cultural identity. They have their own tribal religion, which is based on Hinduism and may also hire 'Brahmin' priests for some ceremonies. Their religion traditionally animistic, it is now overlaid with Hinduism. They worship various animals such as the monkey, snake and cow. They are settled cultivators, keep large herd of cattle, some sheep and goats. Most of 'Tharu' villages are enclave in the northern buffer of the park. Rests are located elsewhere in the landscape within close proximity of the DNP. Tharu settlements are easy to recognize, being scattered and in some cases very picturesque clustered villages. Tharus are Mongloid. Tharu tribal are considered as descendents of the 'Ranas' of Rajasthan who settled in Nepal (De, 2001). At present, they include number of indigenous sects such as 'Ranas', 'Dengaurias' 'Kathauriyas', etc. Marriages between these groups are very uncommon. They usually live very close to the thick forest. A great number of the villages are found in small clearings in the middle of the forest itself.

The Tharus depend on the forests for food, fodder, medicine, small timber for construction of huts and agricultural implements, handicrafts, and social and religious ceremonies. Tharus tend to live in large joint families, often with two or more sons and their families. Generally, women are dominating members of the family and the eldest female member invariably happens to be head of the household. Gradually, this situation is changing and males are acquiring dominant role. Once their habitations were forest villages but now their status has been converted to the revenue villages. Various tribal area development schemes have been implemented and they have benefited these people. Over the years, these indigenous people have adopted modern farming techniques and have slowly shifted from subsistence level farming to raising cash crops. Some now own tractor and other farm implements.

Liquor, locally prepared from rice or jaggery, plays an important role in social life, any function or festival. Traditionally, Tharus are non-vegetarian in food habits. However, a small number of families are adopting new sect and switching to vegetarianism. Tharus are fond of fish and for fishing they use umbrella shaped nets. Each Tharu village is having a village head ('Padhana'), usually a respected man of the village. Traditionally, he is empowered to resolve village disputes and to take decisions about village welfare. 'Padhana' comes from the same family generation after generation and he is never elected (WII, 1997). However, now a days under the 'Panchayat' system, the Village Gram Sabha elects one 'Padhan' and thus he/she takes decisions for the welfare of the village. Traditionally, Tharu women decorate the walls of their one storied mud homes with colourful paintings of elephants, horses, parrots and flowers. Married women adorn their hands, legs other body parts with elaborate and artistic tattoos, although this practice is becoming more rare.

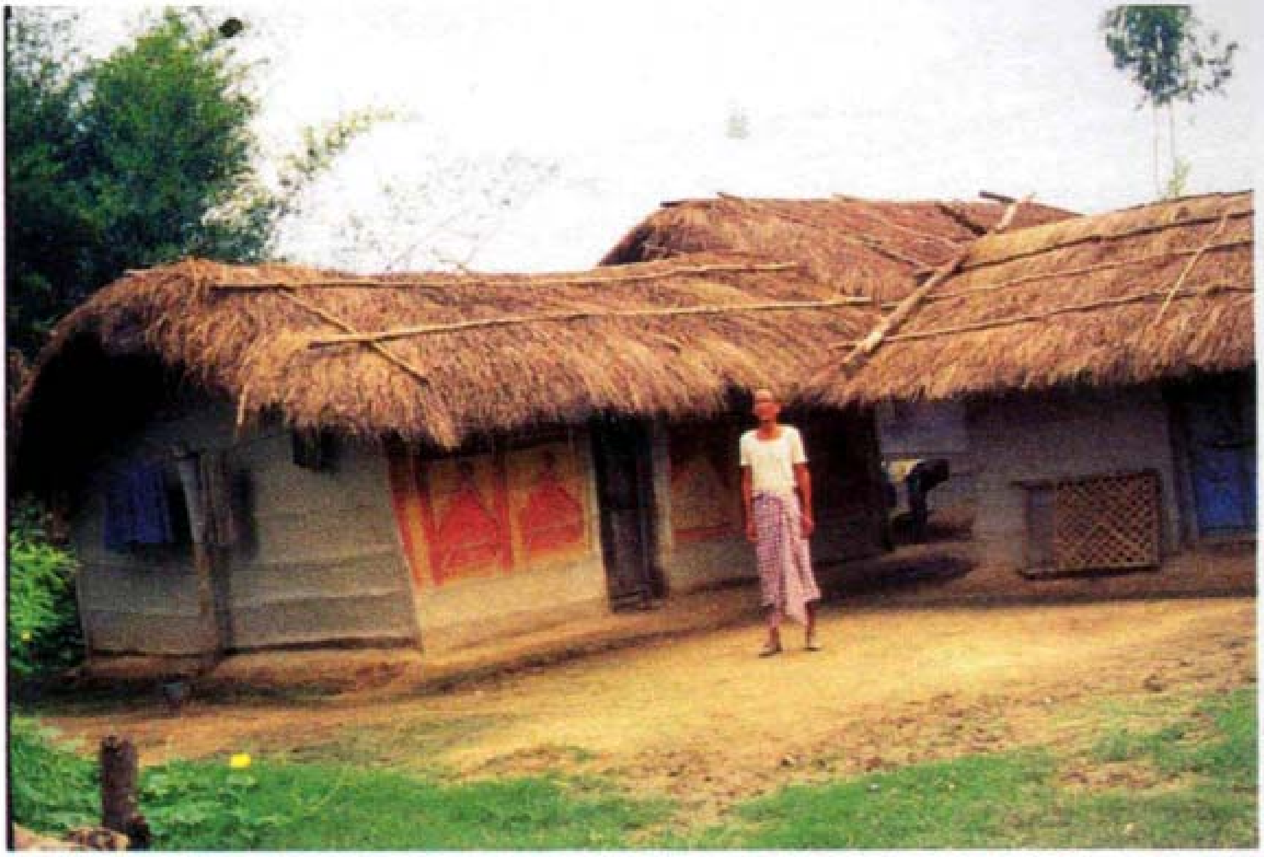
People of Kheri district due to their above varied background speak mainly three languages *viz.,* Hindi, Punjabi and Urdu. Among these, Hindi is being spoken by about 92% of the population while little over 6% people speaks Urdu and about 2% people speak Punjabi. Only a small fraction of the population speaks Bengali and other regional languages. The religion wise break up of the population indicates that a majority (>80%) of people follows Hinduism. The second important region is Muslim, followed by almost 17% of the population. Nearly 2% people follow Sikhism while Christians, Buddhists, Jains and others together constitute less than 1%.

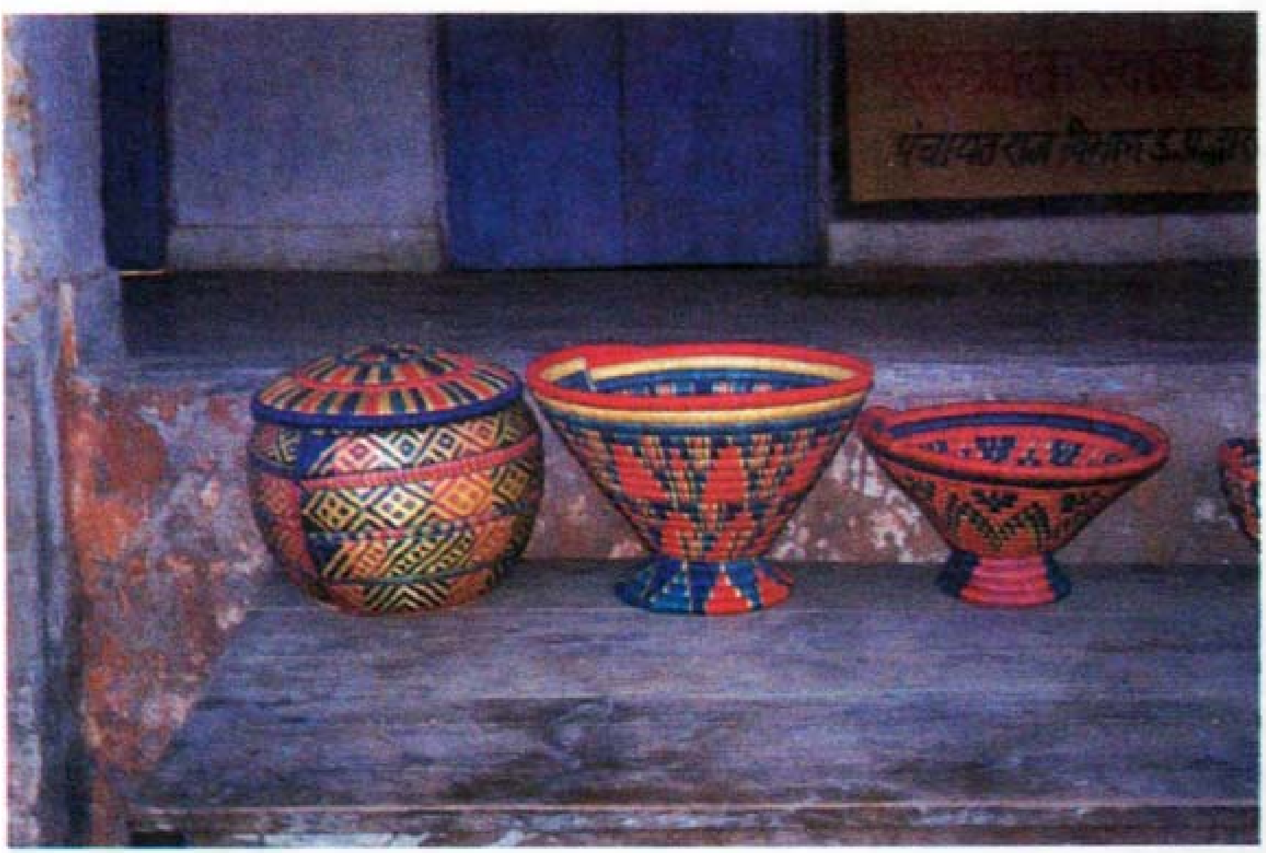
6.3.2 Resource Dependency and Relationship with Forests

A large proportion of the population in TCA, particularly Tharus, locals and migrant laborers inhabiting villages in proximity to forests and their livestock depend upon forest resources. Thus, they try to meet their requirements of food, fiber, fuel wood, grazing, thatch (grass), medicinal plants, small timber, gums and resins. Maheshwari *et al.* (1981) and Singh (1977) have provided an Ethanobotanical account of Tharu tribe in Kheri district. De (2001) has described the resource dependence of 125 villages located in within 5 km periphery of Dudwa Tiger Reserve. Nearly, 100 micro plans have been prepared for different village located in proximity of DTR under the U.P. Forestry Project. These village micro plans summarize socio-economic conditions, resource dependence, PA-people conflict and highlight strategies for village development alongside strategies for reduction in adverse impact of PA on villages and *vice versa*. The following section describes current biotic pressure and attempts to establish their relationships with forests and grasslands in the landscapes.

Forests in TCA have been providing several direct and indirect benefits to locals. A large number of people get permanent, seasonal or daily wage basis employment in routine forest works *viz.,* protection, logging, plantations, construction, road and fire line maintenance, collection of NTFPs, etc. Thus, different forest operations directly help them in wage earnings. Likewise, local transport companies and other allied industries also heavily rely on various operations and raw material obtained from forests. Bulk of the local population, particularly ladies and unskilled laborers go to forest for collection of fuel wood, thatch grass and other NTFPs. Normally lady members bring fuel wood and grass head loads while gents generally uses

Plate 6.1 – Tharu Tribes in TCA





bullock-carts to collect and carry fuel wood from the forest and brings comparatively longer and thicker pieces of fallen wood. The fuel wood collection intensity is more in the months just before the arrival of monsoon and again in post-rainy months. Increasingly, people are required to visit forest interiors for collection of fuel wood, as the same is no more available in adequate quantity in the peripheral areas. The well appreciated Micro Plan from all quarters for Mornachni village under the jurisdiction of North Sonaripur forest range of DNP provides an assessment on resource dependence. Accordingly, the average fuel wood requirement of this village with 67 families (575 population) was estimated to be 410 t/annum. This was based on an average requirement of 20 kg fuel wood/15 members/day for cooking or 290 t/annum, and 10 t/annum for the preparation of liquor. This village also required about 80 t/annum fuel wood for maintaining higher temperature during the winter season. About 30 t/annum fuel wood was estimated for the purpose of fencing, festivals, marriages, etc. Likewise, small timber is also required for making wooden pillars, wooden poles and small pieces those are used in house construction. On an average, small villages need adequate material (50 wooden pillars of Sal, 20 wooden poles of any suitable species) for making a new house every year due to family expansion or other reasons. Few of the houses in each village need renewal. One village alone requires approximately 25 wooden poles for making agricultural implements.

Majority of rural houses is thatched. For construction of one thatched house, one cartload of wooden stem of grass *Erianthus munja* or *Themeda arundinacea* and about 2-3 cartloads of thatch grass (*Imperata cylindrica, Saccharum spontaneum*) are usually required. On an average, two houses need to be constructed/replaced every year in a small size village like Mornachani. All told houses also require repair every year wherein 40% of the old thatch grass needs to be replaced. Mornachani village thus, required about 150 cartloads of thatch grass every year which is being mainly collected from the PA.

Livestock grazing is yet another major biotic pressure on PAs and MFs. About 40,000 head of cattle graze in the buffer zones of the DNP and Kishanpur Sanctuary. Otherwise, about 80,000 head of livestock depend on resources of DTR. The Nepalese villagers also drive their cattle into the DNP for grazing. Villagers do not pay any grazing fee. Two managed forests also face severe grazing pressure. Most of the cattle are of poor quality and primarily kept for producing drought animals.

Tharus and other people depend upon several plant species for producing fibers used in preparing ropes, animal straps, fishing nets, etc. Prominent species are: *Desmostachya bipinnata, Eulaliopsis binata, Bauhinia vahlii, Helicteres isora* and *Cannabis sativa.* People collect fruits of *Emblica officinalis, Terminalia bellirica, Terminalia chebula, Aegle marmelose, Holarrhena antidysentrica* and *Cassia fistula* for medicinal values. Fruits of *Syzygium cumini, Tamarindus indica, Madhuca longifolia, Emblica officinalis* are eaten by local people. The kernel and fruits of *Buchnania lanzan* are edible and local people thus collect them. Tubers of *Dioscorea pentaphylla* and leaves of *Amaranthus spinosus, Chenopodium album* and *Ipomoea aquatica* are used as vegetables. The fruits of *Catunaregam uliginosa* are used as vegetables by Tharus (Singh, 1997). A large number of herbs are used for medicinal purposes. Seeds of *Madhuca longifolia, Mallotus philippensis, Semecarpus anacardium, Schleichera oleosa* and *Shorea robusta* are good source of oils which are prepared and used by local people in making soaps, hair oil, for burning and edible purposes.

Gums and resins are usually obtained from a variety of plants species growing in different forests. Prominent species are *Sterculia villosa, Ficus religiosa, Azadirachta indica, Butea monosperma, Acacia catechu, Acacia nilotica* and *Shorea robusta.*

Tharus also collect several edible fungus (mushrooms) growing on the floor of the forest down logs or termite mounds. The climber *Tiliacora acuminata* is being collected for making ropes after drying. The Mornachani village alone collects about 5 cartloads of *Tiliacora acuminata* every year from adjacent forests. Honey is also being collected in small quantities for domestic needs.

Thus, in above manner local people heavily depend upon a large number of plant species for their sustenance.

6.4 State of the Economy

Once the economy of the people inhabiting the landscape was primarily forest based. However, agriculture is now the mainstay of the local economy. The favourable conditions in terms of plain land, fertile soils, high water table, cheaper labor and improved agricultural practices have led to the rapid expansion of agriculture and its increased productivity. Currently, little over 60% of the land is being ploughed or net sown. Almost 1/3rd of the net sown area is cultivated more than once i.e. both in 'Kharif' (monsoon crop) and 'Rabi' (winter crop) seasons. Thus, double-cropped area is quite high. The proportion extent of Kharif to Rabi crops is 1.57:1. Little over 1/3rd of the cultivable area is irrigated. The landscape suffers from the constraints of smallness of land holdings. More than 54% operational holdings are less than 1 ha in size. Almost 44% land holdings are 1.56 ha in size. Only 1.7% land holdings are of 5 ha and above. It clearly indicates that the majority of farmers are just having subsistence type of agriculture while only a few large farms practicing highly profitable agriculture on commercial scale also exist. Immigrants from Punjab generally own such farms.

The 'Kharif' crops are sown in July-August and harvested in October-November well before the preparation of fields for 'Rabi' crops. Rice (paddy - *Oryza sativa*) is by far the most important crop of Kharif. Different varieties of paddy are sow. Rice is grown in almost one third of the cultivated land. Sorghum (*Sorghum bicolor*), maize (*Zea mays*) and bulrush millet (*Pennisetum typhoides*) are grown in Kharif season. The production of maize comes next to rice among the Kharif crops. Several pulse crops are also undertaken during the Kharif season.

'Rabi' crops are sown in October-November and harvested in April-May. Wheat (*Triticum aestivum*) dominates the list of Rabi crops. Wheat is grown alone as well as mixed with crops like gram (*Cicer arientinum*), pea (*Pisum sativum*), mustard (*Brassica compestris*) or barley (*Hordeum vulgare*). Barley is next to wheat but its production has been declining. 'Arhar' or pigeon pea (*Cajanus cajan*) is sown as pulse crop in Kharif and harvested in Rabi.

Among the non-food crops, sugarcane (*Saccharum officinarum*), oil seeds, potato (*Solanum tuberosum*), vegetables and spices are to be mentioned. Potato is one of the important tube crops while sugarcane is the most important commercial crop covering about 5% cultivated land.

Small farmers and land less work as farm laborers on large farms. Gradually, agriculture in TCA is being improved due to increasing use of high yielding varieties of crops and modern methods of plant protection, various weedicides and pesticides and better implements for plough, irrigation and harvest.

TCA is also famous for cattle breeding. The bullock bred and reared in the landscape are of good stock suited for heavy drought work and these find market in the adjoining districts and bring additional income to the cattle breeders. Horses, ponies and donkeys, which were used for transportation purposes, are declining in their number with the greater mechanization of transportation system. Poultry and piggery development in TCA are also being encouraged.

The only mineral of importance that found in the Kheri district is 'Kankar'. Lime of good quality is obtained from the silica-Kankar, found in abundance in the nearby areas of Gola Gokarnath. Brick earth is also found in most parts of Lakhimpur and Mohammadi Tehsils. In the absence of mines or other raw material, about 50 small or medium size industries exist. Among large-scale units, there are four sugar mills located at Palia, Gola, Lakhimpur and Belraya. The M/s Bajaj Hindustan Limited is the prominent ones. Four sugar mills employ more than 3,000 persons. In addition to this, 427 small-scale industrial units employ another about 2,000 persons. This sector mainly comprises manufacturing sugar, jaggery ('Gur'), molasses, bagasse, rice and oil. Wood work, general engineering, metal ware, agriculture implements, metal casting, bone crushing are some of the main industries in small-scale sectors. Among village and cottage industries, leatherwork, oil and jaggery production are prominent.

Wildlife or nature tourism is gradually increasing in TCA. DTR attract largely local and national tourists. There is ample scope to promote ecotourism, particularly foreign tourists by providing better access to DTR and other required infrastructure. DTR is the only Tiger Reserves and one of the prominent wildlife areas in the entire state of Uttar Pradesh.

During the past 2-3 decades, nearly more than half of the available forest area in TCA has been designated as wildlife protected areas (PAs) in view of the priority conservation need. Thus, the era of commercial exploitation forests in TCA almost seized by 1970s. Density of the tree crop is NKFD and SKFD is average and the site quality varies from II to III/IV. Now felling is restricted to dead, dry, diseased and uprooted trees only. A significant part of two managed forest divisions therefore comes from auctioning of NTFP lots (Rawat, 1996). The annual revenue generated by both the MFs during 1990-95 ranged from Rs. 19.20 to 24.22 million. The annual average revenue generated has gone up after 1995 as it is evident from the available figures of annual average revenue during 1988-99 to 1998-99 from SKFD alone. Accordingly, the average revenue for recent 10 years in the case of SKFD has been to the tune of Rs. 21.5 million against average annual expenditure of Rs. 16.92 million. It reveals that the SKFD is now able to contribute only a small sum of Rs. 4.61 million per annum to the State economy.

The modernization of agriculture, rapid transportation of agricultural products by trucks, tractor-trolleys and conservative felling in shrunken managed forests have definitely reduced the employment opportunities on one hand. While on the other hand there is still 2.14% human population growth per annum. Considering the current scenario, one would expect enhanced land hunger and more competition for rapidly declining opportunities of employment.

6.5 Implications of Land Use and Resource Dependency

Burgeoning human population and its increasing demands have resulted into the need of more and more land for cultivation. Thus, rampant encroachment of forest land and reclamation of swamps for agricultural purposes have greatly reduced wildlife refuge in TCA and also the loss of vital linkages for movement and dispersal of wildlife from one area to the other.

A large section of the local population traditionally depends upon the forest resources for sustenance and livelihood. These biotic pressures have increased many folds.

This is evident from the fact that the forests in TCA or Kheri district are prone to encroachment. As per the recent report, more than 20% of the total encroached forest land in the entire U.P. State was in NKFD and SKFD alone (Rawat, 1996). Accordingly, 116.5 sq km forest area of NKFD and SKFD was encroached. Encroached area is so large and spread that it deserves urgent planned action.

Subsequent to the abolition of 'Zamindari' system in 1952, the forests vested in the State were scattered and erstwhile landowners had heavily exploited them before actual vesting. Further, land hungry people started unauthorized cultivation on these tree less tracts and the situation persisted even after the final notification under Section 20 of the Indian Forest Act, 1927. Inadequate demarcation of boundaries and inordinate delay in the process of forest settlement gave a further boost to encroachment.

TCA forests are vulnerable to illicit felling of trees of important timber species. In a period of five years (1991-92 to 1995-96) as many as 6,171 trees were illegally felled in two MFs. The volume of felled trees estimated was 2,601.5 cubic meters with a value of nearly Rs. 5 million (Rawat, 1996). Likewise, De (2001) has reported 265 cases of illicit felling during 1995-2000 in two PAs. Altogether, 1,167 trees having timber volume to the tune of 639.8 cubic meters and worth Rs. 2.58 million were felled. Details of other offences and fire incidences provided by Rawat (1996) and De (2001) further illustrate the problems arising due to biotic pressure in two MFs and two PAs, respectively.

Resultant forest fragmentation, widely scattered small forest patches and irregular shapes have ultimately given rise to enhanced man-wildlife conflicts. Prominent problems of crop raiding by wild animal's goes on unabated. There is no provision for compensation of crop damage caused by wild herbivores. These wild herbivores are prone to poaching.

Often carnivores follow ungulates and wild pigs out of the forestland. On many occasions, these carnivores either predate on easy prey i.e. livestock or encounter human beings while they are busy in farm working. The sugarcane and other crops in close vicinity to MFs and PAs provide continuous cover as well as lure for foraging. Examination of data on livestock predation in PAs for the period 1988-1999 revealed loss of 307 animals including 133 cow, 108 buffaloes, 45 bullocks, 17 calves and 4 goats. This indicates that on average nearly 30 animals per year are lost due to predation by wild animals. Owners of these livestock were cash compensated. The Field Director, DTR paid cash compensation of Rs. 3,30,500 during the period 1990-99 for the claims of previous years. On an average, a sum of Rs. 36,722 was paid annually towards compensation for loss of livestock.

During encounter with wild carnivores, 27 persons got killed while 24 persons were injured during the period 1991-99. There was spurt of man eating and mauling cases between 1991 and 1994. No man-eating case was registered for the next three years. However, again one and two man-eating cases were recorded during 1977-78 and 1998-99, respectively. 229 offence cases of illegal hunting of wildlife were registered in two PAs just in a period of 5 years (1995-2000). Only 60 cases were sent to the court. 134 cases were compounded and a cash compensation of Rs. 5,52,090 was obtained from the offenders.

Above incidents of crop damage, livestock predation and man killings and injuries result into a sore point in the PA-people relationship. The presence of high density of humans and livestock on park interface gives rise to a greater probability of such encounters. The chances of tiger occurrence outside the Reserve during the monsoon and post-monsoon seasons increase when in search of food they follow the wild herbivores out to the crop fields. Consequently, the man-kill rate is highest even if it is accidental. These are some of the serious implications of resource dependency and change in land use in the surrounds of forestland.

The biotic pressure in terms of illegal collection of forest resources and livestock grazing from across the international border further aggravates the degradation of peripheral forests. Smuggling across the Indo-Nepal border is a significant illegal activity. It continues despite the presence of several law enforcement agencies as the borders are open and the forests provide excellent cover. The TCA is also identified as being a part of the illegal trade route of wildlife and its products. Several offence cases have been registered in the recent year (December, 2001).

Increasingly, anti-social elements and even dacoits find a safe shelter in the forests or they use them as transit zone. It is for this reason, police and other law enforcement agencies desire to have a greater presence in the forests and access to all the areas.

Till recent past, movement of wild animals across the landscape and forest areas on Nepal side was frequent due to wide spread availability of forest patches, tall grasslands and swamps. Biotic pressure was limited. However, with spurt in developmental activities, intensification of agriculture and multifold increase in human population, the corridors/connecting links critical for animal migration have been severally affected.

6.6 Implications of Forest Management Practices on People

The history of forests in TCA dates back to 1860 when the Government at the time of the annexation of Avadh region under the Wasteland Rules of 1860 acquired the proprietary rights over the forests. Forests were then simply regarded as wastelands.

They were transferred to the Forest Department between 1870 and 1875, and were notified as Government Forests under Section 2 of Act VII of 1865. These forests were subsequently gazetted as 'Reserved Forests (RFs)' under Section 34, Act VII of 1878 by notification Nos. 194 and 195 dated February 28, 1979. The maximum extent of these reserved forests was in a few compact blocks. In addition to these RFs, the Forest Department also acquired some Vested forests after the abolition of 'Zamindari' in 1952 and imposition of Land Ceiling Act, 1960. Gram Sabha's Wastelands acquired by the State also comes under the category of Vested forests. Bulk of the Vested forests have been later declared as Reserved Forests whereas rest others are still in the process of settlement (Rawat, 1996; Srivastava, 2000). Majority of the Vested forests were small and scattered.

Thus, basically forests in TCA can be divided into two broad types: (a) Reserved Forests, and (b) the erstwhile private Vested forests. Former have been under the control and management of U.P. Forest Department from the beginning while later were vested in the state under the U.P. Zamindari Abolition and Land Reforms Act, 1952 or the Land Ceiling Act, 1960. Furthermore, in 1976 strips along roads, canals and railways have also been transferred to the Forest Department for management. These strips have now the legal status of Protected Forests.

The systematic forest working of Reserved Forests in TCA commenced in 1886 with the first Working Plan by Brown during the year 1886. Since then, there has been regular succession of Working Plans. Till 1970s, the Old Reserved Forests and Vested forests were managed separately and they came to be managed jointly afterwards. Comparatively, the vested forests were heavily exploited in past by erstwhile Zamindars, whereas the old Reserved Forests were commercially exploited. Early development of the railway transport through the dense forests of the landscape clearly catalyzed the process. The management of forests was largely directed towards commercial timber species *viz.*, Shorea *robusta, Acacia catechu, Dalbergea sissoo* and *Syzygium cumini* followed by introduction of *Tectona grandis, Eucalyptus citridora*, etc. where regeneration remained deficient.

The present Dudwa National Park (490 sq km) was carved out in three successive stages (1958, 1968 and 1977) from the North Kheri Forest Division while the Kishanpur Sanctuary created in 1972 was carved out from the South Kheri Forest Division. DNP and KWLS were brought under the Project Tiger Scheme of the Government of India and declared as the Tiger Reserve in 1987-88.

Local people have continued to enjoy various rights and concessions in different Reserved, Protected, Vested forests and later two PAs. The grantees that held possession of the lands, before they were constituted, as reserved forests were not obliged either to provide the neighboring villages with wood, grass or other forest produce or to permit their cattle to graze in the forests. Instead they were required to pay for road and other uses. When the grants were resumed by the Government, they continued for a number of years to be held free of all forest rights and privileges (Chandra, 1972). A considerable amount of forest produce was, however, perhaps removed on payment. Despite this no rights have ever been recognised and the reserved forests are completely free from rights of any kind. Various concessions, have, however, been granted to villages bordering on the forests and from time to time government have issued orders for the regulation of these privileges. These concessions are chiefly pertaining to the supply of timber, thatch grass, fuel wood, livestock grazing and collection of other NTFPs. The government issued successive notifications relevant to these concessions in 1907, 1933 and 1956 respectively. The government has also proposed necessary changes in 1957 in the existing rules regulating concessions and free grants of forest produce and invited comments and objections if any in a stipulated period. However, no objections were received. Subsequent to the proposed changes, just in SKFD alone the reduced quantity of timber to be granted was 97,300 Cft., the quantity of thatch grass to 8031 cartloads and the number of villages to whom the concessions and free grants were admissible were 42. Later, the Divisional Forest Officer, SKFD and Deputy Commissioner, Kheri submitted their comments to the government on above proposal, the government orders are still awaited and the position remains as it was at the time of writing of Working Plan for the period 1960-1970. In the case of Vested forests, the government has allowed continuance of all concessions enjoyed by villagers before the vesting of these forests. In the vested forests which have been subsequently notified as reserved forests to date, the Forest Settlement Officer has admitted no rights. However, only concessions have been granted and continued till date as in the case of old reserved forests. The vested forests those have not been notified as reserved forests continue to provide concessions as per the interim office order issued in 1953.

In the case of DNP, before its creation eight species of trees were permitted to be cut by villagers under forest rules within a belt of 7.5 km width along the reserved forest boundary line. The Tharu tribals were allowed to graze their cattle free and permitted to collect thatch grass, firewood and NTFPs. Other villagers were allowed to graze their cattle and collect NTFPs for a fee. After the creation of the National Park, all concessions were commuted. Only grass cutting and collection of firewood was permitted during winter till 1983 on payment. The villagers were given this concession on the condition that they would help in fighting forest fires. Similar concessions were continued in the case of Kishanpur Sanctuary. However, after the 1991 amendment in the Wildlife (Protection) Act, 1972, these concessions were required to be siezed in KWLS, except regulated livestock grazing.

Further, the Hon'ble Supreme Court of India has passed on a historical judgement in December 1996 in response to a writ petition. Accordingly, the literal dictionary meaning of term 'forest' was adopted in the case of Forest Conservation Act, 1980 irrespective of the ownership of such land. All non-forestry operations in forestlands those have not been approved by the Government of India were stopped with immediate effect. Further, the Government of India also imposed the immediate ban on felling of trees other than those in duly approved forest working plans. Hence, the importance of Working Plans in the management of forests in India has acquired a greater significance.

It is evident from the above facts and description that local people have enjoyed wide scale rights and concessions from various forests in TCA for a very long time. The rights have significantly reduced over the past 6-7 decades, particularly in the case of vested forests. However, large scale varied concessions are being availed by local people. Thus, forests in TCA still have greater responsibility to cater the requirement of timber, firewood, thatch grass, livestock grazing and other NTFPs of traditionally dependent local people.

Gradual reduction in old rights and concessions, enforcement of stricter prohibitive rules and significant decline in commercial forestry operations that had direct implications on the management authorities as well as the local people, particularly tribals and others those have solely depended on forest resources and activities. The hunting of wild animals was also prohibited throughout the country in 1972 under the Wildlife (Protection) Act, 1972.

The problems for the dependent people and field mangers have been further compounded in the absence of adequate alternatives to traditional resource use (timber, thatch, firewood, etc.) and spurt in human population due to immigrants. The current wildlife law prohibits any resource use in PAs, particularly the National Park. However, local people despite their much exposure to modern development have continued with traditional life styles and as such they still depend upon forest resources from DNP. The micro planning exercise in Mornachni village and other villages have revealed such dependence. Such uses are either being continued illegally or to some extent in the knowledge and with approval of concerned field managers. Therefore, there is an urgent need to examine this issue of resource dependence in a greater depth, provision of appropriate alternatives and rationalization of current law *vis-à-vis* traditional uses.

6.7 Development Programmes and Conservation Issues

In recent decades the Government has been mainly able to promote wide scale development of agriculture and its allied activities, tribal development programmes, and to some extent the development of small and medium size industries, and schemes related to wildlife tourism in TCA. These developmental activities have immensely boosted the local economy. This is evident from bustling business activities in once slippy villages or towns *viz*., Palia, Bhira, Lakhimpur, Mailani, Gauriphanta, Chandan Chowki, etc. One can observe all around development of agriculture, use of modern technology (tractors, combined harvesters, thrashers, insecticides, pesticides, chemical fertilizers, hybrid varieties) and rapid road and rail transportation systems. However, a larger proportion of land is rain-fed and lack desired irrigation facilities. In the process of so called development, people have learnt to avail Government subsidies and borrowings from Banks or private moneylenders. The external market forces have also influenced the local communities. Increasing use of modern gadgets *viz*., Television, Telephone, Fan, Refrigerator, Cycle, two wheeler automobiles and packaged food items, bottled soft drinks and mineral water through out the landscape is now uncommon. Several multi-national brands relevant to home appliances, garments and food items are easy to find in the local markets. Tribal development schemes have provided technical knows how, equipment, subsidy and also developed marketing facilities. Besides this, basic facilities of education, health, communication and other required infrastructure have been greatly expanded and improved over the years. Despite all this, growing needs and several other social requirements have led many poor people in debt trap. In such circumstances, poor or marginal farmers are compelled to either sell out agricultural produce at lower rates or hypothecate agricultural fields, produce or other properties to moneylenders or middleman. Thus, there is much to do in all those sectors for ever-increasing demands.

Further, thirty seven Tharu tribal villages located on the northern side of DNP were earlier having the status of forest settlement villages till 1975 and people inhabiting these villages have been dependent upon forest resources for their basic needs. These villages were subsequently declared as revenue villages and the control and management shifted to the Revenue Department. PA officials have always realized their problems and try to help them within the permissible and legal limits. The changed status, new relationships and enforcement of several new conservation strategies have brought more hardships to these people.

Some efforts have been made to promote wildlife tourism considering the unique and diverse flora, fauna and cultural heritage in the landscape. However, participation of local people in this potential sector is virtually absent. Local communities have not been made target to obtain economic benefits accruing from such activities. Hence, there is an urgent need to spell out such incentives or benefits those local people can derive and also to adopt appropriate strategies to make local communities an integral part of such activities.

The Ecodevelopment approach has also emerged as an important strategy for effective conservation and PA management. In recent years, the PA management has implemented the Central Government sponsored scheme on Ecodevelopment around PAs. These activities have basically focussed on the reduction of biotic pressure. However, most of these Ecodevelopment activities have been implemented in a piecemeal manner, largely annual target driven with scant regard to the requirements and aspirations of the people (De, 2001). There has been a quantum jump in these activities due to the initiation of World Bank aided U.P. Forestry Project. There is also a change in the thrust. New activities aim to address the adverse impact of people on PA and vice-versa.

6.8 Socio-economic Issues and Conservation Implications

People inhabiting the TCA have observed an unexpected transformation of the landscape within their living memory. In the first stance, a greater expanse of wilderness got either occupied by the outsiders those were settled here by the Government or immigrants those moved in to avail employment opportunities. The enterprising migrant farming community from Punjab and favourable policy facilitating green revolution ultimately turned the vast extent of natural areas (forests, grasslands and swamps) into crop fields. Changed policies and resultant land use pattern manifest current challenges faced by local communities, and field practitioners. Following is the summary of perceivable socio-economic issues and concerns those affect the management of conservation area.

- Varying cultural background of immigrants to the TCA have influenced the traditions and culture of local people, particularly of Tharu tribals. Different population groups constantly endeavour to maintain their interests against the migrants. Affluent migrants, their culture and agricultural technology brought in by them have greatly encouraged Tharu tribals and other locals to expand and improve their agriculture and its income. This has resulted in a drastic reduction of wilderness. The land hunger of burgeoning population, small land holdings and aggravated greed have led to the extension of crop fields right upto the forests/ protected areas. This has given rise to large forest/PA-people interface and associated problems *viz.,* crop depredation, man killings and injuries, and other wildlife offences. Increasing man-wildlife conflict is a serious issue in TCA while evoked hostility and antagonized local people are major concerns for the PA managers.

- A larger proportion of the local population traditionally depends upon forest resources for subsistence and livelihood. There is ever-increasing demand for timber, firewood, thatch grass and other NTFPs; illegal felling; collection; extraction and transportation of forest resources cause disturbance to wildlife, proliferation of weeds, reduced regeneration, and fire. These problems are being aggravated in the absence of adequate alternatives and similar pressure from the Nepal side.

- Encroachment of forest land is a major issue in TCA. A greater effort and resources are thus required to protect forests.

- There is an increasing demand for more and more roads linking different villages and access to forest areas. A small segment of old rail network was dismantled in recent years. However, rail and road traffic pose severe protection problems to the management. At the same time, any type of restrictions imposed on people movement and vehicular traffic from the PAs and MFs lead to yet another conflict and often politicization of the issue.

- A very large number of local people keep fire arms. Traditionally, wild animals have been widely moving and dispersing from one area to the other. Small fragments of forest patches, grasslands and swamps once widely distributed have almost vanished. In the process, some of the traditional habitats used as rutting grounds by swamp deer (*Cervus duvauceli duvauceli)* have declined/lost. Often, people indulge in poaching of wild herbivores those have moved out in search of desired habitat or foraging. The intensity of offences related to wildlife poaching and illegal wildlife trade has also increased. This needs to be curbed.

- High rate of illiteracy, particularly among females is also a social issue. This also causes several management challenges. There is an urgent need to enhance the current literacy level by implementing mass awareness programmes.

- Rapid agricultural development and other land uses have intensively fragmented the landscape. Local people are thus required to go long distances to fetch forest resources. At the same time enhanced fragmentation and widely spread smaller forest fragments have prohibited dispersal of free ranging animals from one area to the other. Restoration and maintenance of corridors is thus the priority conservation need.

Chapter 7

Conclusion and Management Implications

7.1 Introduction

Forests, grasslands and wetlands contribute various goods and services to mankind. Since time immemorial, resource dependent communities have colonized and exploited these natural resources for their sustenance and prosperity. Rapid development in recent times, social structures and culture have played a significant role in shaping environmental outcomes relevant to those natural resources. Development is widely considered synonymous with increase in consumption while culture has a direct bearing on population, economic activities, settlement patterns, political structures, resource use patterns and other factors affecting biodiversity (Stedman–Edwards, 2000). This means that environmental and social concerns in a given situation are inextricable woven together.

The *Terai* Conservation Area (TCA) is an important regional, national, and international center of biodiversity. The whole range of biodiversity or the "little things that run the world" are known poorly – including many species and the functions that link them and their habitats. The TCA includes the largest remaining natural habitat representing the *Terai* ecosystem on the Indian side. Despite intense human pressure, the persistence or reintroduction of most species indicates management generally has been a success. However, continued success is uncertain. Large flagship species have been the focus of research and management (Sale and Singh, 1987; Singh, 1982; Singh, 1984; Qureshi *et al.,* 1991; Sawarkar, 2000; De, 2001; Mathur, 2000). Populations are small for some important species, such as swamp deer, rhinoceros, tiger, elephant.

Once rich in natural forests, grasslands, swamps and wild animals, the TCA has witnessed a sea change. The living memory thus testifies the significant changes brought in, particularly conversion of natural areas into vast agriculture and extensive plantations. Despite this, the natural elements of ecological complexity, species diversity and tribal culture abound in a remnant portion of the landscape.

7.2 Key Stressors

Stressors to the TCA ecosystem are numerous. De (2001), Srivastava (2000) and Anon. (2002) have summarized the primary threats to wildlife as habitat change, illicit felling, encroachment, grazing, and fire. The spread of weeds, invasion of woody species and changes in composition from short to tall coarse grasses threaten grasslands. *Lantana* invasion is alarming in forested buffer zones. Changes in hydrology and associated siltation are causing changes in forest and grassland composition and structure. Passive management of forests in protected areas (PAs) has resulted in increasing dominance of unpalatable and other undesirable species.

Poaching is a potential threat, primarily for animals that venture out of forest areas, and along the international border with Nepal. Illicit felling of trees on the periphery of the PAs and within the managed forests (MFs) is a concern, especially with increasing population density. Large-scale operations are uncommon, but small-scale felling for household use is common. Encroachment on forest lands for agricultural conversion is a serious ongoing threat (Rawat, 1996). Grazing and the demand for livestock fodder is a persistent issue. Fire occurs over most all the area either as controlled burns in grasslands, or uncontrolled ground fires in forests. Consequences of fire or its exclusion are poorly known. Disease from livestock is a concern for wildlife.

7.3 The Landscape Approach

In the above context, it was imperative to use a holistic landscape assessment approach for the various type of field quantifications during the present study so as to understand the relationships between land use and its effect on the spatio-temporal variations in species diversity in the forest-grassland-wetland complex, while its implications for resource use by human and biodiversity conservation. Additionally, an experimental study was also carried out so as to examine the effects of different burning practices on grasslands, a featured component of the landscape.

7.3.1 Land, Land Use and the People

The landscape mainly included the four type of lands: (i) forestland (protected areas and managed forests) owned by the State Forest Department, (ii) state owned revenue land (other than forest department), (iii) community owned '*Panchayat*' land, and (iv) private lands. The landscape is a vast alluvium plain.

A large proportion of the population in TCA, particularly 'Tharus', locals and migrant laborers inhabiting villages in proximity to forests and their livestock depend upon forest resources. Thus, they try to meet their sustenance requirements of food, fiber, fuel wood, grazing, thatch (grass), medicinal plants, small timber, gums and resins. Thus, traditionally the economy of the people inhabiting the landscape was primarily forest based. However, agriculture is now the mainstay of the local economy. The favourable conditions in terms of plain land, fertile soils, high water table, cheaper labor and improved agricultural practices have led to the rapid expansion of agriculture and its increased productivity. Currently, little over 60% of the land is being ploughed or net sown. Burgeoning human population and its increasing demands have resulted into the need of more and more land for cultivation. Rampant encroachment of forestland, reclamation of swamps, changed policies and resultant land use pattern have greatly reduced wildlife refuge in TCA and also the loss of vital linkages for movement and dispersal of wildlife from one area to the other. These ultimately manifest current challenges faced by the local communities, and field practitioners. People inhabiting the TCA have observed an unexpected transformation of the landscape within their living memory. In the first stance, a greater expanse of wilderness got either occupied by the outsiders those were settled here by the Government or immigrants those moved in to avail employment opportunities. The enterprising migrant farming community from Punjab and favourable policy facilitating green revolution ultimately turned the vast extent of natural areas (forests, grasslands and swamps) into crop fields.

During the past 2-3 decades, nearly more than half of the available forest area in TCA has been designated as wildlife protected areas (PAs) in view of the priority conservation need. Thus, the era of commercial exploitation of forests in TCA has almost seized by 1970s.

The history of forests in TCA dates back to 1860. Basically forests in TCA can be divided into two broad types: (a) Reserved Forests, and (b) the erstwhile private Vested forests. Former have been under the control and management of U.P. Forest Department from the beginning while later were vested in the state under the U.P. Zamindari Abolition and Land Reforms Act, 1952 or the Land Ceiling Act, 1960. Furthermore, in 1976 strips along roads, canals and railways have also been transferred to the Forest Department for management. These strips have now the legal status of Protected Forests.

The systematic forest working of Reserved Forests in TCA commenced in 1886 with the first Working Plan by Brown during the year 1886. Since then, there has been regular succession of Working Plans. Till 1970s, the old Reserved Forests and Vested forests were managed separately and they came to be managed jointly afterwards. Comparatively, the vested forests were heavily exploited in past by erstwhile Zamindars, whereas the old Reserved Forests were commercially exploited. Local people have continued to enjoy various rights and concessions in different Reserved, Protected, Vested forests and later two PAs. Despite rights and concessions have been extinguished in the case of National Park area and greatly reduced in the case of Sanctuary, local people illegally collect various forest resources and graze their livestock.

The present study (**Chapter 2**) on the assessment of landscape and forest spatial heterogeneity revealed that the landscape chiefly included the forestland (25.8%) comprising protected areas and managed forests and matrix (74.2%). Either a few, larger compact blocks or several smaller, isolated fragments represented the forestland. The matrix included extensive private agricultural lands, community lands, and scattered government lands. Once, extensively interspersed grasslands and swamps covered just 2.8% and 0.5% area of the landscape, respectively. Detailed landscape level assessment using remotely sensed data delineated 17 categories of land use/land cover types including nine forest types, two grassland types, forest plantations, and five other non-forest categories.

Forests covered nearly three-fourth (73%) of the forestland. Sal (*Shorea robusta*) dominated five forest types occupied 44.5% of the forested tract. Four other important forest types together covered 19.3% area of the forestland. This included Moist Mixed Deciduous, Khair and Sissoo, Tropical Seasonal Swamp, and Tropical Semi-Evergreen forests covering 9.3%, 6.9%, 2.5%, and 0.6% area of the forestland, respectively. Nearly 6% of the forestland was found encroached and under illegal cultivation. Interspersed grasslands, plantations, rivers and swamps covered 12.8%, 7.7%, 2.9%, and 0.7% area of the forestland. *Tamarix* scrub represented only 1.5% area of the forestland.

Interestingly, a few of the forest types either remained unrepresented in some of the constituent areas (DNP, KWLS, NKFD, SKFD) or represented just one or two such areas as a characteristic type. For example, the national park (DNP) area harboured all major forest and grassland types, except *Chandar* Sal forest and *Tamarix* scrub. On the contrary, dense Sal and Tropical Semi-Evergreen forest types occurred in DNP only. Nearly three-fourth extent of the Upland grasslands and almost half of the Lowland grasslands were confined to DNP only. Further, the other protected area i.e. KWLS had the maximum extent of *Chandar* Sal forests. In contrast to DNP, the Sanctuary (KWLS) lacked representation of dense Sal, Tropical Semi-Evergreen and Khair and Sissoo forest types. More than 90% area of Khair and Sissoo forests and almost 50% extent of Moist Mixed Deciduous forests were recorded in the managed forests of North Kheri Forest Division (NKFD). The actual area and percentage proportion of Swamps, Rivers and Sandy banks were highest in NKFD. Forests in the managed forests of South Kheri Forest Division (SKFD) were mainly characterized by moderately dense, open Sal forests and extensive plantations. Dense Sal, Sal Mixed, and Tropical Semi-Evergreen forest types were absent in SKFD. The maximum area and percentage proportion of *Tamarix* scrub were recorded in SKFD. Nearly two-third (63.1%) area under plantations recorded in TCA occurred in SKFD alone.

Beside above, a comparison of two management options i.e. PAs and MFs also allowed several noteworthy findings. Accordingly, three prominent forest types *viz.,* Dense Sal, Sal Mixed, and Tropical Semi-Evergreen forests remained unrepresented in MFs. The actual extent of five Sal forest types in PAs was as high as 61.3% while various Sal dominated forests covered just 37.9% area of MFs. Instead, managed forests possessed the much higher proportion of Moist Mixed Deciduous and Khair and Sissoo forest types. PAs had larger chunk (>60%) of Tropical Seasonal Swamp forests than MFs. PAs also had 17.6% of their actual area covered by two type of grasslands while MFs had only 7.7% of its area represented by grasslands.

Further, the detailed landscape level analysis on the number of patches, patch characteristics (size, shape, and quality), spatial arrangement (configuration), and proximity of different patches using various metrics amply indicated that the landscape under consideration has high forest spatial heterogeneity due to greater forest diversity as well as forest fragmentation. Four constituent areas of the landscape and different vegetation types were not only diverse, but also unique in several cases. This was obviously due to highly variable, irregular and scattered forest fragments having long history of management and also experiencing high biotic pressure.

7.3.2 Species Diversity

Detailed vegetation assessment undertaken in the four constituent areas, different vegetation types, and a comparison made between PAs and MFs revealed that the forests and grasslands in TCA also exhibit rich and unique plant species diversity. This is mainly due to the complex, dynamic nature of the *Terai* ecosystem, long history of forest and grassland management guided by successive Working Plans, and biotic pressure. Thus, a floral diversity of 259 plant species belonging to 199 genera and 76 families was recorded through an extensive sampling. The number of plant species in the four constituent areas ranged from 143 to 249. The DNP was the most diverse while NKFD was the least diverse among the four constituent areas. This difference was due to the non-representation of some of the vegetation types in one or more constituent areas. The DNP obtained representation of maximum vegetation types and also highest species richness of trees, and herbs while SKFD had the highest shrub species richness. PAs were more rich in species diversity than MFs. Importantly, much of the species richness in forests and grasslands of TCA resulted from a large number of low abundance and low frequency species. Out of 96 recorded tree species, 47 species occurred in less than 1% sampled plots. Only 10 species obtained values >10% frequency of occurrence.

The open Sal forests favoured more number of miscellaneous tree species than dense Sal forests. Sal was the prominent tree species in two PAs (DNP and KWLS) based on its IVI. In contrast, *Acacia catechu, Dalbergia sissoo, Terminalia alata, Barringtonia acutangula,* and *Haldina cordifolia* obtained much higher values of Importance Index in two managed forests than their corresponding values in two PAs. This revelation highlighted a distinction in the structure and composition of vegetation in PAs and MFs. *Tectona grandis* and *Eucalyptus citriodora,* two exotics to TCA together constituted 16.4% of the total trees (n = 31,467) enumerated. It reflects that the past management has thus resulted into replacement of native vegetation in extent as well as diversity. Nearly one-fourth of the standing trees in TCA were of Sal alone. Two other prominent and widespread species were *Mallotus phillippensis* and *Syzygium cumini.* These two species together constituted yet another one-fourth of the standing trees.

Sal distinctly characterized the DNP area. The KWLS was characterized by *Bauhinia racemosa, B. squamosa* and *Lagerstroemia parviflora* due to the occurrence of extensive *Chandar* Sal and Sal Mixed forests. Whilst *Barringtonia acutangula, Ficus benghalensis, Milliusa velutina* and *Terminalia alata* dominated forests in SKFD due to the fact that this managed forest harboured a greater chunk of Tropical Seasonal Swamp, moderately dense Sal, and open Sal forests. *Acacia catechu* and *Dalbergia sissoo* characterized NKFD due to the occurrence of maximum extent of Khair and Sissoo forests.

Dipterocarpaceae was the most important family in TCA based on the highest value of Family Importance (FIV). Fifty-two tree species out of 96 tree species recorded in TCA contributed for more than three-fourth tree diversity, density, and dominance as they belonged to just 10 plant families. More than 86% tree species were represented by a small number (~250) of individuals despite extensive sampling in the present study. This also indicated that such species were either highly localized or were in low abundance. Nevertheless, these species are of utmost ecological importance and calls for a priority attention.

A comparative assessment of shrub and herb layers in the four constituent areas and different vegetation types also allowed several important revelations. *Tiliacora acuminata* occurred in as many as 52.3% plots sampled in DNP. In contrast, its frequency values in two MFs i.e. SKFD and NKFD were much lower. Likewise, the density values of *Tiliacora acuminata* were highest in DNP, being 6,293.4 shrub/ha while corresponding values in NKFD and SKFD were drastically reduced, being 829.0 shrubs/ha and 234.1 shrubs/ha, respectively. This amply indicated that relatively open canopy forests and other habitat conditions/factors in MFs were not favourable to *Tiliacora acuminata* while this species gregariously occurred in majority of the forest types in DNP. *Lantana camara,* an exotic woody shrub occurred only in 5.7% plots sampled in TCA. This species was almost absent in dense Sal while Khair and Sissoo forests in NKFD favoured this weed. The density of *Helicteres isora* was significantly influenced by density of Sal forests. Thus, density of *Helicteres isora* increased considerably from dense to open Sal forests. In general, herb species were much widely distributed in MFs than PAs. *Dioscorea belophylla* was the most prominent herb in different forests of TCA. *Cassia tora* was the densest herb, followed by *Ageratum conyzoides*.

A comparative habitat use assessment by select faunal species revealed that nearly 50% of the sampled vegetation plots showed some formal use. Only 8.1% sampled vegetation plots in MFs had the presence of chital sign against 41.6% sampled plots in PAs those had the presence of chital sign. There was conspicuous absence of chital sign in sampled grasslands located in two MFs while grasslands in PAs harboured abundant chital population. This observation can be attributed to the fact that grasslands in MFs were relatively small, isolated and experienced much more biotic pressure. In contrast, nilgai sign were absent in grasslands occurred in PAs while 11% grasslands plots sampled in MFs had the presence of nilgai sign.

7.3.3 Grassland Management Practices

The tall grasslands in TCA form an integral part of the forestland. Biological values and ecological functions of grasslands in TCA have been ignored for a long time because of earlier policies. Mainly, cutting and burning are being in practice to maintain grassland diversity, productivity and meet subsistence needs of dependent people. The complexities of various management practices and their effects on grassland values and functions have been poorly understood. Therefore, the present study included an experimental trial so as to understand the effect of different burning regimes in combination with treatments *viz.,* grass cut, grass cut – removed, grass harrowed, simple burned, and no burn (control). The study specifically aimed to test two hypotheses: (i) whether treatments would increase dry season forage for ungulates; and (ii) harrowing and burning would simulate processes formerly kept tall grasses down when people were allowded to graze livestock and cut in the park, thus providing more forage and maintain composition in favourable forage species.

Prominently, *Imperata, Desmostachya,* and *Vetiveria* contributed to grass cover and biomass in the Upland grasslands while *Sclerostachya, Saccharum,* and *Themeda* spp. were main contributors in the Lowland grasslands. The dominance of these species was maintained under all the treatments despite repeated treatments for three consecutive years. All treatments except the harrowed–burned treatment yielded more or less same aboveground biomass (ABG) at the time of termination of experiment. Nevertheless, the effect of different burning treatments was prominent on the species composition and standing biomass of major grass species in both the type of grasslands. *Imperata cylindrica*, the main contributor to the biomass in the Upland grasslands registered a considerable decline (40-53%) in AGB under different treatments. In contrast, *Desmostachya bipinnata* showed considerable gain in its AGB ranging from 1% to 37% in cut–

burned treatment and the control. The maximum gain was in the harrowed–burned treatment indicating that *Desmostachya bipinnata* was distinctly favoured by this treatment that too at the cost of major desirable species i.e. *Imperata cylindrica*. Likewise, *Desmostachya bipinnata* which was otherwise absent in the Lowland grassland prior to the initiation of experiment, abruptly emerged and established in the harrowed–burned treatment. In opposite, major constituent species *viz., Sclerostachya fusca* and *Saccharum narenga* suffered in the harrowed–burned treatment as both these species registered a substantially reduced AGB i.e. almost half at the end of three years.

The managed Upland and Lowland grassland plots distinctly favoured wild ungulates, particularly swamp deer and hog deer after the treatments were given and during the summer season. Thus, the management objective of promoting new growth and palatable grass during the lean season was achieved. Based on the relative pellet occurrence, swamp deer and hog deer used more the harrowed–burned and burned alone treatments in the Upland grassland. Similarly, the harrowed–burned treatment in the Lowland grassland remained favourable to both the deer species. However, the burned alone treatment was relatively avoided. Nonetheless, the treatment plots were small, and there might be effects of the neighbourhood. It is possible that both deer species simply show high use of particular treatment because they were there to forage something else and either used treated plots for rest or just to move across. Thus, in view of these findings harrowing in TCA is to be either avoided or judiciously used on atleast 2-3 years interval.

It is also clear that ending the current practices of cutting and burning would remove the benefit of new and palatable grass to ungulates during the lean period. Two earlier studies on *Terai* grasslands (Lehmkuhl, 1989; Peet *et al.,* 1997) and the present one have amply demonstrated that the short term variation between different treatments in studied grasslands were insignificant. Lehmkuhl (1989) has earlier highlighted that grazing was short-lived on early burns compared to late burns while grazing removed the greatest biomass from the late burned plots.

The present study could assess the effect of burning regimes on the habitat use by two wild ungulates only. None of the earlier studies has been able to study concurrently the effect of burning practices on different faunal species including the mega herbivores, small mammals, birds, herpetofauna, etc. However, the current knowledge based on several short term, scattered studies on different faunal species strongly advocate for a mosaic of habitats by cut, uncut, burned and unburned patches which would provide suitable habitat for the persistence of diverse faunal species of *Terai*. Staggered cutting and burning would also create different patches providing varying forage and cover conditions.

It is perceptible that in the absence of an appropriate long term comprehensive experimental research on *Terai* grasslands the basic premise about their management largely remains unanswered and debatable.

7.3.4 Landscape Management Units

The management of the entire TCA requires a broader perspective that integrates the PAs with MFs and the human dominated matrix from which emanates many of the stressors identified earlier. Differing goals and objectives for forest allocations (PAs and MFs), as well as the human dominated matrix, hinder landscape management for biodiversity conservation, which requires coordination of forest management activities among allocations. The TCA landscape has five distinct Landscape Management Units (LMU) that could form the basis for integrating disparate forest allocations for landscape management focused on biodiversity conservation. These units are: (1) a DNP core area; (2) a KWLS-South Kheri MF core area; (3) MF fragments in the North and South Kheri Division; (4) linear riverine habitats and connective corridors; and (5) the matrix of agricultural lands made up of community, private, and scattered government lands.

The DNP and KWLS-South Kheri MF core LMUs form two high-value, but isolated "sources" of relatively high biodiversity. DNP is important for its relatively large area in a compact block that minimizes edge effects with the agricultural matrix. It has highly diverse and productive forests and grasslands. The current strong conservation management focus with core and buffer zones provides good protection from human disturbance. It has national recognition and support as an important center of biodiversity and ecotourism. A small block of North Kheri MF contiguous with the southeast corner of DNP that is not currently part of buffer zone has potential to contribute to integrity of the DNP core area.

The KWLS-South Kheri MF core LMU has the next highest conservation value. KWLS forms the core of this conservation complex, with a focus of conservation that is high, but less than DNP. The contiguous South Kheri MF area has been managed for economic value, but has great conservation potential similar to the buffer zone of DNP, i.e., as a buffer zone to KWLS. An effective TCA landscape management plan would need to recognize the importance of managing KWLS and adjacent managed forests as a single conservation unit, perhaps in a core-buffer zone concept.

Isolated MF fragments, the third LMU, can have value for biodiversity conservation even without connecting corridors, if the integrity of the forests can be maintained or restored. Usually, the field managers and conservationists tend to think of the large species (e.g. tigers, elephants) that operate at large scales and need large protected areas. Hence, small fragments with insufficient or isolated habitat and large negative edge effects (e.g., human disturbance) are often considered expendable. Small fragments, however, can be important elements of a biodiversity conservation plan, especially where natural areas are extremely limited as in the *Terai*. They can be "core areas" for the persistence of small species and fine-scale processes (e.g., insects, bryophytes, and small mammals), and centers for the dispersal of those species if connectivity is re-established. They might also be stepping stones or temporary/additional, refugia (sink) for larger core species. Such small patches might also be managed to relieve resource pressure on larger core areas by providing forest produces, but using new management practices that both generate forest products and maintain or restore ecological values will have to be designed, implemented, and tested. Managing small fragments, however, is challenging because of the large amount of edge exposed to human disturbance in the matrix.

The fourth LMU of linear patches of riverine habitat along small and large streams or rivers are critical special habitats that also might function as connecting corridors. The floodplains of the major Sharda and Ghagra rivers could be important habitats if current intense human pressures for agricultural development and grazing could be ameliorated. Corridors on smaller rivers could connect smaller patches of MF. Maintaining or restoring the ecological integrity, or at least the proper functioning condition, if not complete restoration, will be as challenging, or more so, than with isolated MF fragments because to the high amount of edge exposed to human disturbance and their importance as water sources.

The fifth matrix LMU as a source of human disturbance has been recognized in conventional management plans as an important element of forest management. Ecodevelopment plans try to redirect resource dependency from protected areas to special development areas within the matrix. Where that need can not be met in the short to long term by ecodevelopment of the matrix, some resource needs might be met from within forested or protected areas, if extraction is consistent with wildlife management goals. Less easily managed, except through compensation payments, is the crop depredation and sometimes human deaths that occur when animals interact with the matrix. The solution to that problem is providing for more or better habitat within the forested areas.

Matrix lands are themselves highly fragmented into community lands, private parcels of generally small (1-2 ha) size, and scattered government lands. Thus, consistent or uniform management options for the matrix are difficult to develop. Revenue generation and subsistence agriculture are the dominant uses. Most of the area does not provide habitat for wildlife, although some species such as the sarus crane (*Sarus antigone*) can adapt to human landscapes, although these habitats may in fact be population sinks because of high human-caused mortality. Some crops, such as sugarcane, form semi-natural habitats with good and bad aspects. Sugarcane may have some temporary value as refuge or dispersal habitat; but that value may be negated by the elevated risk of mortality from poaching.

7.4 Linking LMUs with Corridors

Linking LMUs to create a interconnected TCA network of PAs and MFs is difficult in the current landscape. The five LMUs are isolated in the agricultural matrix and connectivity will be very difficult to establish because of private ownership and the pressures of resource dependency. Some parts of the linear riverine LMU might serve to connect patches of fragmented MF, but maintaining the integrity of those riverine corridors will be difficult under intense human pressure.

The primary connectivity objective within the TCA should be the 12-15 km between the two cores DNP and KWLS-South Kheri LMUs. Making that link would have several benefits. It would include some of the remnant and critical Ghola and Gajrola monsoon swamp deer habitat outside DNP, increase the area of important alluvial grassland spanning the Sharda river, link swamp deer populations in the two core areas, and link tiger and other species in the core areas as well.

Several options with varying degrees of practicality and effectiveness can be considered to create that core LMU connectivity. Land could be purchased to create a corridor. Conservation easements could be purchased wherein ownership of the land remains in private hands but concessions are made by the owner to create or maintain habitat. A "community reserve", might be formed that enlists the support of private landowners by providing incentives to maintain cover or other habitat elements during all or part of the year, or to protect animals while in the area similar to the Tiger Watch Programme. Those solutions would not only include the funds and personnel of government agencies, but also the participation of private landowners and non-governmental organizations (e.g. World Wildlife Fund for Nature, World Bank and charitable foundations) interested in conservation and development.

Regional linking of the TCA with PAs in the Indian and Nepalese Terai is another priority to ensure the viability of large or wide-ranging species like elephant and tiger. If successful, the TCA would be an important link in between the Bardia and Suklaphanta PAs in Nepal.

7.5 Establishing Habitat Management Objectives

Management within individual LMUs below the landscape level (e.g., compartments, circles), also will need to change. Forest areas have a long history of intensive management for economic values, primarily timber harvest for railway sleepers and other wood products, grazing, grass collection, and other subsistence uses. Management for Sal to the exclusion of "miscellaneous" species has altered and shaped the composition and structure, hence potential biodiversity of TCA forests in unknown ways. Hence, TCA forests and grasslands are not by any means pristine, i.e., formed by natural processes alone. That creates some difficulty in describing the desired future conditions for forest and grassland vegetation in the TCA from a biodiversity conservation perspective.

Management goals or desired future conditions (DFC), for vegetation management are often developed using natural conditions (i.e., without a significant history of human disturbance) as the baseline or management target. The assumption is that "natural" stand conditions and their pattern across the landscape will maintain the full range of biodiversity, e.g., species and their interactions with each other and the environment. If those conditions are unknown, or if there is high variation in the composition and structure of a vegetation community or landscape as a result of the environment or disturbance processes, then a range of conditions, or states, is used to bracket acceptable conditions. In the case of the TCA, those "natural" conditions, thus management targets consistent with biodiversity management are difficult to know because of the long history of human activity.

Given extensive past management it is difficult to determine a DFC for Sal forests, and methods to achieve it, that is consistent with the objectives of biodiversity conservation. For example, how do the manager will know that the increasing dominance of *Tiliacora* with the closure of the Sal canopy is "bad" and needs to be reversed? If the DFC is based on the habitat needs of the important ungulates and tiger, then it might be safe to assume the reduction of *Tiliacora* is necessary. However, from an ecosystem or biodiversity perspective *Tiliacora* might be recovering its previous dominance in the relatively undisturbed Sal forest, and it might have great value for species other than ungulates. What is the role of *Tiliacora* in the ecosystem and what are the consequences for biodiversity, if it is removed to increase ungulate forage? Likewise, one can ask what is the proper role of fire in forest ecology and management?

Grasslands in TCA also have a long history of human disturbance that has shaped their current composition and structure and the animal communities that are associated with them. What is the DFC for grasslands? Natural processes might be leading to the dominance of tall coarse grasses that are less favored by ungulates; but, tall grasses might be critical for other species such as hispid hare or grassland birds. Removal of those tall grasses with fire or mechanical treatments will impact the viability of those species. In a large undisturbed grassland ecosystem, the balance of Upland and Lowland grasslands as well as short and tall grassland patches might be kept over large areas. However, in the confines of the TCA, some balance of management and natural processes needs to be made to ensure the viability of all grassland species. Some form of alternate year burning or mechanical treatment would ensure the persistence of tall grass species.

These questions point to the need for a fuller understanding of forest and grassland successional and disturbance dynamics, vegetation-animal interactions, and the implications for biodiversity conservation or restoration. Only through a good understanding of the relationships between forest and grassland pattern and processes one can know what and how to restore, or determine the DFC of forests and grasslands.

That understanding also is necessary to modernize silvicultural systems by moving them from a focus simply on the production of wood and other human goods and services to the production of both human and ecological goods and services and viable and diverse forest ecosystems. That transition from old to "new forestry" will be critical for integrating PAs and MFs to meet the ecological goals of the LMUs in the TCA. It will require a period of adjustment of attitudes and experimentation with new methods in an adaptive management process in which managers can team with scientists to learn while actively managing.

7.6 Managing Specific Habitats

Managers currently recognize the need to manage key wetland and grassland habitats. In forests, fruit-bearing trees traditionally have been recognized in management plans and operations as important wildlife trees. Managers are beginning to recognize the ecosystem and wildlife value of defective and dead wood (snags and down logs), instead of their value for salvage. Defective trees and snags provide key cover and foraging habitats for cavity excavating birds and secondary cavity nesters that use woodpecker holes, for example. Down logs are key habitats for invertebrates, reptiles, and small mammals, which are prey to many birds and other small mammals.

Forest types that represent relatively small areas of the forested landscape, such as the Moist Mixed Deciduous forest, are important elements of biodiversity. Manipulative management practices needs to be carefully considered in light of the ecology and wildlife values of these relatively rare and important vegetation types. For example, studies in Chitwan, Nepal have shown a strong link between rhinoceros, the regeneration of *Trewia nudiflora*, and the establishment of mixed riverine forest patches (Lehmkuhl, pers. comm.). Rhinos eat the fallen fruit of *Trewia*, then defecate the scarified seeds into manure-rich dung piles in grasslands. *Trewia* seeds germinate profusely amidst in dung piles, along with other herbs, and form the nucleus of forest patches if such dung piles escapes burning. The mosaic of grassland and riverine forest provides the key habitat mix for abundant chital population, which is the primary prey for tiger. Rhinos, deer, and other herbivores are key dispersers of other plant seeds as well. Along with the tall-short grass issue discussed above, this example presents another reason to carefully consider biodiversity issues in grassland and forest fire management plans.

7.7 Conclusion

In conclusion, management of the TCA for biodiversity and forest productivity will be challenging. The TCA remains a vital element of global and regional biodiversity, but current and future challenges for management are great. Past management that focussed on social and economic uses was pervasive and has set forest and grassland ecosystems on a trajectory of change with poorly understood implications for biodiversity. Field managers need to develop new field methods that focus on biodiversity and human-oriented goals, then test them in an adaptive management framework that allows them to constantly learn and adjust while actively managing. Specifically, management needs to invest in research and develop the administrative and scientific frameworks for adaptive management projects to learn how to maintain or restore wildlife habitats or populations to levels that might ensure long-term viability. Research also needs to investigate the status, ecology, habitat needs, and population and habitat management strategies for the other less conspicuous species that makes up the bulk of TCA biodiversity. Direct human demands for forest resources and indirect influences from the matrix (e.g. ground water pumping) and beyond (e.g. deforestation in the mountains) are intense and will increase. The current model of forest management will have a difficult time succeeding in integrating biodiversity and human use of forests at the landscape scale. A new multi-scale model of forest ecosystem management that integrates ecologically and administratively fragmented forest units needs to be developed. A second higher and more effective level of landscape management will integrate the dynamics and administration of the agricultural and urban matrix of the TCA. There are a dedicated cadre of professional forest managers and scientists, and interested public in the TCA that can make this new approach work.

Summary

Introduction: The decline of forests is a global concern due to the pace and magnitude of its conversion to other uses. In managed forest landscapes, logging patterns often result in changes in the structure and composition. Forest landscapes are, thus rich in spatial heterogeneity from a variety of causes, including the environment, biotic interactions, disturbance and succession. Spatial patterns can have a strong influence on the distribution, abundance, population dynamics and ecosystem processes including the spread of disturbance. Understanding the heterogeneity and dynamics of natural forest landscapes has therefore, become very important as management objective for forests increasingly emphasize the maintenance of biological diversity. Using natural or semi-natural ecosystems as a template for management is quite challenging, require understanding not only of the patterns of forest change, but also the processes that underlie them.

The Aim: The present study formed a part of the major collaborative project entitled "Management of Forests for Biological Diversity and Forest Productivity – A New Perspective", jointly implemented by the Wildlife Institute of India and the US Forest Service. The project aimed to address the primary requirement of forests of sustaining biodiversity. It is being realized that the traditional forest management approach had to undergo a major shift in emphasis and strategies. The project expected to demonstrate the integration of science and management in a planning process that establishes the complimentary roles of wildlife protected areas and the large surrounding landscape of managed forests in maintaining forest based biological diversity. The project was field based at four Conservation Areas (CAs) that covered large landscapes of forested and non-forested matrix areas representing a variety of biogeographic patterns, forestry practices, ethnic human societies and their forest based culture, economies and tradition, and the range of administrative realities. Each of the CAs included select protected areas (PAs) – National Parks or Wildlife Sanctuaries; Managed Forests (MFs) and the intervening matrix of the Government, community or private lands so as to constitute a larger delineated landscape.

The Study Area: The present study specifically focussed on the *Terai* Conservation Area (TCA), one of the four CAs. Once, the *Terai* forests in the foothills of the Himalayas constituted a lush belt of green vegetation in the extensive tract of alluvial Gangetic flood plains. The forest is mainly moist deciduous, dominated by the most valuable Sal (Shorea robusta) forests of India. A significant attribute of the Sal forest ecosystem is the interspersed swamps and wet, tall grasslands. The TCA is an important regional, national, and international centre of biodiversity. The diverse and productive *Terai* ecosystem has witnessed a sea change in the past several decades due to changes in land use policies, long history of forest management, settlement of refugees, uncontrolled expansion of agriculture and the associated large scale reclamation/ conversion of grassland and swampy habitats, enhanced resource dependence and persistent factors like fire, livestock grazing and flash floods. These factors have greatly reduced the once extensive *Terai* ecosystem into smaller forest fragments. The TCA is the last and largest representative of the Indian *Terai* ecosystem.

The TCA covering 7,896.6 sq km constitutes a spatial heterogeneous landscape of PAs including Dudwa Natioal Park (DNP) and Kishanpur Wildlife Sanctuary (KWLS); and Managed Forests (MFs) of North Kheri and South Kheri Forest Divisions (NKFD and SKFD) within a matrix of private agricultural lands. The forestland in TCA covered 1,726.5 sq km which is equally split between PAs (883.7 sq km) and MFs (842.8 sq km). The TCA forests in DNP, KWLS, NKFD and SKFD are under different management objectives. The major portion (~97%) of the TCA comes under the Lakhimpur Kheri district of Uttar Pradesh. The Indo-Nepal border forms much of the northern boundary of the TCA, particularly the DNP.

The Objectives: Keeping in view the above, following basic questions were posed while formulating the present study:

- What are the current patterns of spatial heterogeneity at the landscape level? What are the factors (natural, biotic, and of management) responsible for such mosaic and diversity patterns?
- What are the current patterns of plant and animal diversity in TCA, their habitat associations and the status, trends and spatial distribution of habitats and species of particular interest?
- How the spatial mosaic has influenced the distribution of different vegetation communities, species diversity and abundance of species of concern?
- What are the species-specific positive, neutral or negative associations and factors responsible for them? What are the patterns of recruitment, growth and mortality of species of concern?
- How does the burning practices influence grassland diversity, productivity and wild ungulate use?

In a nutshell, the present study focussed on the landscape spatial patterns, their influence on species diversity and also the effect of various grassland burning practices in TCA. In order to achieve this, the following objectives were set forth for the present study:

- To assess, characterize and map the current land use and landscape patterns.
- To identify, classify and describe vegetation communities, assess their extent and geographic distribution in the landscape.
- To assess the influence of landscape spatial patterns on habitat and species of particular management interest.
- To assess grassland burning practices *vis-à-vis* plant diversity, productivity, ungulate use and make appropriate recommendations for the management.

The Approach: In the above context, it was imperative to use a holistic landscape assessment approach for the various types of field quantification. The field reconnaissance and the preliminary assessment in TCA were carried out during 1996-97. Extensive consultations and review of literature were carried out prior to the reconnaissance. A combination of well tested field assessment methods and modern techniques *viz.,* Remote Sensing and GIS were used in the present study. The false colour composites of IRS of 1B LISS 2 Sensor of January, 1997 were used to assess the landscape heterogeneity and characterization. An interpretation key and the field knowledge was used for extending the interpretation and to prepare the land use/ vegetation type map of the CA in GIS domain using ARC/INFO 8.0.2 software. Software FRAGSTATS* ARC Version 3.2 was used for quantifying landscape structure and spatial pattern analysis. A detailed vegetation assessment was carried out to compare patterns among various vegetation types deciphered using remote sensing data, evaluate the effect of two broad forest management options (PAs and MFs), and compare vegetation diversity in the four constituent areas of TCA. Vegetation samples were distributed on the basis of vegetation types, management units, and patch size. Altogether, 1,748 plots (20m x 20m) for tree, 1,674 plots (10m x 10m) for shrub and 1,674 (1m x 1m) for herb diversity were sampled in different forest types, the Upland grassland, Tamarix scrub and plantations. In addition, 159 plots (10m x 10m) were sampled in the Lowland grasslands for the assessment of shrub, herb and grass diversity. The vegetation data was analyzed for frequency, density, abundance, Importance Value Index (IVI), Family Importance Value (FIV) using standard methods for vegetation assessment. Cluster Analysis (SPSS), TWINSPAN and STATECOL programmes were used for the forest classification, grassland classification and diversity indices, respectively.

In order to have an understanding of wildlife use of different habitats in TCA, field data on the presence/absence of indirect signs (dung/ scat) in delineated vegetation types were collected during vegetation sampling for select species of conservation concern. Percentage frequency of occurrence was computed vegetation type-wise for each species.

Additionally, an experimental study was carried out so as to examine the effects of different burning practices on grasslands, a featured component of the landscape. Split plots of 100m x 260m were used to assess the effect of different burning treatments in the Upland and Lowland grasslands. Three replicates of split plots were taken in each of the grassland. Each experimental plot was split into five equal blocks (100m x 50m) so as to provide four treatments viz., grass cut and burned; grass cut, removed, and burned; grass harrowed and burned; and grass burned as standing. The fifth block separated by a strip of 10m buffer was provided no treatment, thus remained unburned. This block served as control for the experimental trial. The baseline information on plant species composition, phenology, grass height, aboveground biomass (AGB) and pellet count (wild ungulates-swamp deer and hog deer) were made in each of the split plot in the first week of January, 1998 prior to the four treatments were given. The experimental treatments provided in February every year were continued for three consecutive years (1998-2000). The experiment was terminated in January, 2001. In all, four sets of measurements were repeated every year i.e. in January, April, July, and October for each of the studied parameters.

The demographic information for the region was obtained from the Census data and village micro plans. Information on the past forest management was collected from the successive forest working plans and wildlife management plans for MFs and PAs, respectively.

The Landscape: Forest and grasslands in TCA, especially within PAs, remain relatively strong and vital reservoirs of *Terai* biodiversity, and are important social and economic assets. However, stressors to the TCA ecosystem are numerous. Despite intense human pressure, the persistence or reintroduction of most species indicates management generally has been a success. However, continued success is uncertain. The whole range of biodiversity, or the 'little things that run the world' are known poorly – including many species and the functions that link them and their habitats. Large flagship species have been the focus of research and management. Populations are small for some important species viz., swamp deer, rhinoceros, tiger and elephant. Habitats are changing in ways that may not be beneficial. Vital habitats are threatened by the spread of weeds and unpalatable species. Changes in river hydrology, associated siltation, and excessive ground water exploitation are causing changes in forest and grassland composition and structure. Passive management of forests, particularly in PAs has resulted in increasing dominance of unpalatable Tiliacora acuminata. Encroachment of forestland for agricultural conversion is a serious threat. Livestock grazing, requirement of fodder and uncontrolled fires in forest are persistent issues.

Following is the gist of findings relevant to the landscape spatial heterogeneity, species diversity, habitat use, and the grassland burning practices.

Land, Land Use and the People: The landscape mainly included the four types of lands: (i) forestland (protected areas and managed forests) owned by the State Forest Department, (ii) state owned revenue land (other than forest department), (iii) community owned 'Panchayat' land, and (iv) private lands. The landscape is a vast alluvium plain.

A large proportion of the population in TCA, particularly 'Tharus', locals and migrant laborers inhabiting villages in proximity to forests and their livestock depend upon forest resources. Thus, they try to meet their sustenance requirements of food, fiber, fuel wood, grazing, thatch (grass), medicinal plants, small timber, gums and resins. Thus, traditionally the economy of the people inhabiting the landscape was primarily forest based. However, agriculture is now the mainstay of the local economy. The favourable conditions in terms of plain land, fertile soils, high water table, cheaper labor and improved agricultural practices have led to the rapid expansion of agriculture and its increased productivity. Currently, little over 60% of the land is being ploughed or net sown. Burgeoning human population and current land use have greatly reduced wildlife refuge in TCA and also the loss of vital linkages for movement and dispersal of wildlife from one area to the other. These ultimately manifest current challenges faced by the local communities, and field practitioners.

During the past 2-3 decades, nearly more than half of the available forest area in TCA has been designated as wildlife protected areas (PAs) in view of the priority conservation need. Thus, the era of commercial exploitation of forests in TCA has almost seized by 1970s. The history of forests in TCA dates back to 1860. Basically forests in TCA can be divided into two broad types: (a) Reserved Forests, and (b) the erstwhile private Vested forests.

The systematic forest working of Reserved Forests in TCA commenced in 1886 with the first Working Plan. Since then, there has been regular succession of Working Plans. Till 1970s, the old Reserved Forests and Vested forests were managed separately and they came to be managed jointly afterwards. Comparatively, the vested forests were heavily exploited in past by erstwhile Zamindars, whereas the old Reserved Forests were commercially exploited. Local people have continued to enjoy various rights and concessions in different Reserved, Protected, Vested forests and later two PAs. Despite rights and concessions have been extinguished in the case of National Park area and greatly reduced in the case of Sanctuary, local people illegally collect various forest resources and graze their livestock.

The present study on the assessment of landscape and forest spatial heterogeneity revealed that the landscape chiefly included the forestland (25.8%) comprising protected areas and managed forests and matrix (74.2%). Either a few, larger compact blocks or several smaller, isolated fragments represented the forestland. The matrix included extensive private agricultural lands, community lands, and scattered government lands. Once, extensively interspersed grasslands and swamps covered just 2.8% and 0.5% area of the landscape, respectively. Detailed landscape level assessment using remotely sensed data delineated 17 categories of land use/land cover types including nine forest types, two grassland types, forest plantations, and five other non-forest categories.

Forests covered nearly three-fourth (73%) of the forestland. Sal (Shorea robusta) dominated five forest types occupied 44.5% of the forested tract. Four other important forest types together covered 19.3% area of the forestland. This included Moist Mixed Deciduous, Khair and Sissoo, Tropical Seasonal Swamp, and Tropical

Semi-Evergreen forests covering 9.3%, 6.9%, 2.5%, and 0.6% area of the forestland, respectively. Nearly 6% of the forestland was found encroached and under illegal cultivation. Interspersed grasslands, plantations, rivers and swamps covered 12.8%, 7.7%, 2.9%, and 0.7% area of the forestland. Tamarix scrub represented only 1.5% area of the forestland.

Interestingly, a few of the forest types either remained unrepresented in some of the constituent areas (DNP, KWLS, NKFD, SKFD) or represented just one or two such areas as a characteristic type. For example, the national park (DNP) area harboured all major forest and grassland types, except Chandar Sal forest and Tamarix scrub. On the contrary, dense Sal and Tropical Semi-Evergreen forest types occurred in DNP only. Nearly three-fourth extent of the Upland grasslands and almost half of the Lowland grasslands were confined to DNP only. Further, the other protected area i.e. KWLS had the maximum extent of Chandar Sal forests. In contrast to DNP, the Sanctuary (KWLS) lacked representation of dense Sal, Tropical Semi-Evergreen and Khair and Sissoo forest types. More than >90% area of Khair and Sissoo forests and almost 50% extent of Moist Mixed Deciduous forests were recorded in the managed forests of North Kheri Forest Division (NKFD). The actual area and percentage proportion of Swamps, Rivers and Sandy banks were highest in NKFD. Forests in the managed forests of South Kheri Forest Division (SKFD) were mainly characterized by moderately dense Sal and open Sal forests and extensive plantations. Dense Sal, Sal Mixed, and Tropical Semi-Evergreen forest types were absent in SKFD. The maximum area and percentage proportion of Tamarix scrub were recorded in SKFD. Nearly two-third (63.1%) area under plantations recorded in TCA occurred in SKFD alone.

Beside above, a comparison of two management options i.e. PAs and MFs also allowed several noteworthy findings. Accordingly, three prominent forests types viz., Dense Sal, Sal Mixed, and Tropical Semi-Evergreen forests remained unrepresented in MFs. The actual extent of five Sal forest types in PAs was as high as 61.3% while various Sal dominated forests covered just 37.9% area of MFs. Instead, managed forests possessed the much higher proportion of Moist Mixed Deciduous and Khair and Sissoo forest types. PAs had larger chunk (>60%) of Tropical Seasonal Swamp forests than MFs. PAs also had 17.6% of their actual area covered by two type of grasslands while MFs had only 7.7% of its area represented by grasslands.

Further, the detailed landscape level analysis on the number of patches, patch characteristics (size, shape, and quality), spatial arrangement (configuration), and proximity of different patches using various metrics amply indicated that the landscape under consideration has high forest spatial heterogeneity due to greater forest diversity as well as forest fragmentation. Four constituent areas of the landscape and different vegetation types were not only diverse, but also unique in several cases. This was obviously due to highly variable, irregular and scattered forest fragments having long history of management and also experiencing high biotic pressure.

Species Diversity: Detailed vegetation assessment undertaken in the four constituent areas, different vegetation types, and a comparison made between PAs and MFs revealed that the forests and grasslands in TCA also exhibit rich and unique plant species diversity. This is mainly due to the complex, dynamic nature of the *Terai* ecosystem, long history of forest and grassland management guided by successive Working Plans, and biotic pressure. Thus, a floral diversity of 259 plant species belonging to 199 genera and 76 families was recorded through an extensive sampling. The number of plant species in the four constituent areas ranged from 143 to 249. The DNP was the most diverse while NKFD was the least diverse among the four constituent areas. This difference was due to the non-representation of some of the vegetation types in one or more constituent areas. The DNP obtained representation of maximum vegetation types and also highest species richness of trees, and herbs while SKFD had the highest shrub species richness. PAs were more rich in species diversity than MFs. Importantly, much of the species richness in forests and grasslands of TCA resulted from a large number of low abundance and low frequency species. Out of 96 recorded tree species, 47 tree species occurred in less than 1% sampled plots. Only 10 species obtained values >10% frequency of occurrence.

The open Sal forests favoured more number of miscellaneous tree species than dense Sal forests. Sal was the prominent tree species in two PAs (DNP and KWLS) based on its IVI. In contrast, *Acacia catechu, Dalbergia sissoo, Terminalia alata, Barringtonia acutangula,* and *Haldina cordifolia o*btained much higher values of Importance Index in two managed forests than their corresponding values in two PAs. This revelation highlighted a distinction in the structure and composition of vegetation in PAs and MFs. Tectona grandis and Eucalyptus citriodora, two exotics to TCA together constituted 16.4% of the total trees (n=31,467) enumerated. It reflects that the past management has thus resulted into replacement of native vegetation in extent as well as diversity. Nearly one-fourth of the standing trees in TCA were of Sal alone. Two other prominent and widespread species were *Mallotus phillippensis* and *Syzygium cumini.* These two species together constituted yet another one-fourth of the standing trees.

Sal distinctly characterized the DNP area. The KWLS was characterized by *Bauhinia racemosa, B. squamosa* and *Lagerstroemia parviflora* due to the occurrence of extensive Chandar Sal and Sal Mixed forests. *Barringtonia acutangula, Ficus benghalensis, Milliusa velutina* and *Terminalia alata* dominated forests in SKFD due to the fact that this managed forest harboured a greater chunk of Tropical Seasonal Swamp, moderately dense Sal, and open Sal forests. *Acacia catechu* and *Dalbergia sissoo* characterized NKFD due to the occurrence of maximum extent of Khair and Sissoo forests.

Dipterocarpaceae was the most important family in TCA based on the highest value of Family Importance (FIV). Fifty-two tree species out of 96 tree species recorded in TCA countributed for more than three-fourth tree diversity, density, and dominance as they belonged to just 10 plant families. More than 86% tree species were represented by a small number (~250) of individuals despite extensive sampling in the present study. This also indicated that such species were either highly localized or were in low abundance. Nevertheless, these species are of utmost ecological importance and calls for a priority attention.

A comparative assessment of shrub and herb layers in the four constituent areas and different vegetation types also allowed several important revelations. *Tiliacora acuminata* occurred in as many as 52.3% plots sampled in DNP. In contrast, its frequency values in two MFs *i.e.* SKFD and NKFD were much lower. Likewise, the density values of *Tiliacora acuminata* were highest in DNP, being 6,293.4 shrub/ha while corresponding values in NKFD and SKFD were drastically reduced, being 829.0 shrubs/ha and 234.1 shrubs/ha, respectively. This amply indicated that relatively open canopy forests and other habitat conditions/factors in MFs were not favourable to *Tiliacora acuminata* while this species gregariously occurred in majority of the forest types in DNP. Lantana camara, an exotic woody shrub occurred only in 5.7% plots sampled in TCA. This species was almost absent in dense Sal while Khair and Sissoo forests in NKFD favoured this weed. The density of Helicteres isora was significantly influenced by density of Sal forests. Thus, density of Helicteres isora increased considerably from dense to open Sal forests. In general, herb species were much widely distributed in MFs than PAs. Dioscorea belophylla was the most prominent herb in different forests of TCA. Cassia tora was the densest herb, followed by Ageratum conyzoides.

A comparative habitat use assessment by select faunal species revealed that nearly 50% of the sampled vegetation plots showed some formal use. Only 8.1% sampled vegetation plots in MFs had the presence of chital sign against 41.6% sampled plots in PAs those had the presence of chital sign. There was conspicuous absence of chital sign in sampled grasslands located in two MFs while grasslands in PAs harboured abundant chital population. This observation can be attributed to the fact that grasslands in MFs were relatively small, isolated and experienced much more biotic pressure. In contrast, nilgai sign were absent in grasslands occurred in PAs while 11% grasslands plots sampled in MFs had the presence of nilgai sign.

Grassland Management Practices: The tall grasslands in TCA form an integral part of the forestland. Biological values and ecological functions of grasslands in TCA have been ignored for a long time because of earlier policies. Mainly, cutting and burning are being in practice to maintain grassland diversity, productivity and meet subsistence needs of dependent people. The complexities of various management practices and their effects on grassland values and functions have been poorly understood. Therefore, the present study included an experimental trial so as to understand the effect of different burning regimes in combination with treatments viz., grass cut, grass cut–removed, grass harrowed, simple burned, and no burn (control). The study specifically aimed to test two hypotheses: (i) whether treatments would increase dry season forage for ungulates; and (ii) harrowing and burning would simulate processes formerly kept tall grasses down when people were allowded to graze livestock and cut in the park, thus providing more forage and maintain composition in favourable forage species.

Prominently, *Imperata, Desmostachya,* and *Vetiveria* contributed to grass cover and biomass in the Upland grasslands while *Sclerostachya, Saccharum*, and *Themeda* spp. were main contributors in the Lowland grasslands. The dominance of these species was maintained under all the treatments despite repeated treatments for three consecutive years. All treatments except the harrowed–burned treatment yielded more or less same aboveground biomass (ABG) at the time of termination of experiment. Nevertheless, the effect of different burning treatments was prominent on the species composition and standing biomass of major grass species in both the type of grasslands. *Imperata cylindrica,* the main contributor to the biomass in the Upland grasslands registered a considerable decline (40-53%) in AGB under different treatments. In contrast, *Desmostachya bipinnata* showed considerable gain in its AGB ranging from 1% to 37% in cut–burned treatments and the control. The maximum gain was in the harrowed–burned treatment indicating that *Desmostachya bipinnata* was distinctly favoured by this treatment that too at the cost of major desirable species i.e. Imp*erata cylindrica.* Likewise, *Desmostachya bipinnata* which was otherwise absent in the Lowland grasslands prior to the initiation of experiment, abruptly emerged and established in the harrowed–burned treatment. In opposite, major constituent species *viz., Sclerostachya fusca* and *Saccharum narenga* suffered in the harrowed–burned treatment as both these species registered a substantially reduced AGB i.e. by almost half at the end of three years.

The managed Upland and Lowland grassland plots distinctly favoured wild ungulates, particularly swamp deer and hog deer after the treatments were given and during the summer season. Thus, the management objective of promoting new growth and palatable grass during the lean season was achieved. Based on the relative pellet occurrence, swamp deer and hog deer used more the harrowed–burned and burned alone treatments in the Upland grassland. Similarly, the harrowed–burned treatment in the Lowland grassland remained favourable to both the deer species. However, the burned alone treatment was relatively avoided. Nonetheless, the treatment plots were small, and there might be effects of the neighbourhood. It is possible that both deer species simply show high use of particular treatment because they were there to forage something else and either used treated plots for rest or just to move across. Thus, in view of these harrowing findings in TCA is to be either avoided or judiciously used on atleast 2-3 years interval.

It is also clear that ending the current practices of cutting and burning would remove the benefit of new and palatable grass to ungulates during the lean period. Two earlier studies on *Terai* grasslands and the present one have amply demonstrated that the short term variation between different treatments in studied grasslands were insignificant. It has been earlier highlighted that grazing was short-lived on early burns compared to late burns while grazing removed the greatest biomass from the late burned plots.

The present study could assess the effect of burning regimes on the habitat use by two wild ungulates only. None of the earlier studies has been able to study concurrently the effect on burning practices on different faunal species including the mega herbivores, small mammals, birds, herpetofauna, etc. However, the current knowledge based on several short term, scattered studies on different faunal species strongly advocate for a mosaic of habitats by cut, uncut, burned and unburned patches which would provide suitable habitat for the persistence of diverse faunal species of *Terai*. Staggered cutting and burning would also create different patches providing varying forage and cover conditions.

It is perceptible that in the absence of an appropriate long-term comprehensive experimental research on *Terai* grasslands the basic premise about their management largely remains unanswered and debatable.

Landscape Perspective: The management of the entire TCA requires a broader perspective that integrates the PAs with MFs and the human dominated matrix from which emanates many of the stressors identified earlier. Differing goals and objectives for forest allocations (PAs and MFs), as well as the human dominated matrix, hinder landscape management for biodiversity conservation, which requires coordination of forest management activities among allocations. The TCA landscape has five distinct Landscape Management Units (LMU) that could form the basis for integrating disparate forest allocations for landscape management focused on biodiversity conservation. Linking LMUs to create a interconnected TCA network of PAs and MFs is difficult in the current landscape. The five LMUs are isolated in the agricultural matrix and connectivity will be very difficult to establish because of private ownership and the pressures of resource dependency. Some parts of the linear riverine LMU might serve to connect patches of fragmented MF, but maintaining the integrity of those riverine corridors will be difficult under intense human pressure. The primary connectivity objective within the TCA should be the 12-15 km between the two cores DNP and KWLS-South Kheri LMUs. Making that link would have several benefits. It would include some of the remnant and critical Ghola and Gajrola monsoon swamp deer habitat outside DNP, increase the area of important alluvial grassland spanning the Sharda river, link swamp deer populations in the two core areas, and link tiger and other species in the core areas as well.

Several options with varying degrees of practicality and effectiveness have been suggested to create that core LMU connectivity. Regional linking of the TCA with PAs in the Indian and Nepalese *Terai* is another priority to ensure the viability of large or wide-ranging species like elephant and tiger. If successful, the TCA would be an important link in between the Bardia and Suklaphanta PAs in Nepal.

Establishing Habitat Management Objectives: Management within individual LMUs below the landscape level (e.g., compartments, circles), also will need to change. Forest areas have a long history of intensive management for economic values. Management for Sal to the exclusion of "miscellaneous" species has altered and shaped the composition and structure, hence potential biodiversity, of TCA forests in unknown ways. Hence, TCA forests and grasslands are not by any means pristine, i.e., formed by natural processes alone. That creates some difficulty in describing the desired future conditions for forest and grassland vegetation in the TCA from a biodiversity conservation perspective. Management goals or desired future conditions (DFC), for vegetation management are often developed using natural conditions (i.e., without a significant history of human disturbance) as the baseline or management target. The assumption is that "natural" stand conditions and their pattern across the landscape will maintain the full range of biodiversity, e.g., species and their interactions with each other and the environment. Given extensive past management it is difficult to determine a DFC for Sal forests, and methods to achieve it, that is consistent with the objectives of biodiversity conservation.

Grasslands in TCA also have a long history of human disturbance that has shaped their current composition and structure and the animal communities that are associated with them. What is the DFC for grasslands? Natural processes might be leading to the dominance of tall coarse grasses that are less favored by ungulates; but, tall grasses might be critical for other species such as hispid hare or grassland birds. Removal of those tall grasses with fire or mechanical treatments will impact the viability of those species. In a large undisturbed grassland ecosystem, the balance of Upland and Lowland grasslands as well as short and tall grassland patches might be kept over large areas. However, in the confines of the TCA, some balance of management and natural processes needs to be made to ensure the viability of all grassland species. Some form of alternate year burning or mechanical treatment would ensure the persistence of tall grass species.

These questions point to the need for a fuller understanding of forest and grassland successional and disturbance dynamics, vegetation-animal interactions, and the implications for biodiversity conservation or restoration. Only through a good understanding of the relationships between forest and grassland pattern and processes one can know what and how to restore, or determine the DFC of forests and grasslands.

That understanding also is necessary to modernize silvicultural systems by moving them from a focus simply on the production of wood and other human goods and services to the production of both human and ecological goods and services and viable and diverse forest ecosystems. That transition from old to "new forestry" will be critical for integrating PAs and MFs to meet the ecological goals of the LMUs in the TCA. It will require a period of adjustment of attitudes and experimentation with new methods in an adaptive management process in which managers can team with scientists to learn while actively managing.

Managing Specific Habitats: Managers currently recognize the need to manage key wetland and grassland habitats. In forests, fruit-bearing trees traditionally have been recognized in management plans and operations as important wildlife trees. Managers are beginning to recognize the ecosystem and wildlife value of defective and dead wood (snags and down logs), instead of their value for salvage. Defective trees and snags provide key cover and foraging habitats for cavity excavating birds and secondary cavity nesters that use woodpecker holes, for example. Down logs are key habitats for invertebrates, reptiles, and small mammals, which are prey to many birds and other small mammals. Forest types that represent relatively small areas of the forested landscape, such as the Moist Mixed Deciduous forest, are important elements of biodiversity. Manipulative management practices needs to be carefully considered in light of the ecology and wildlife values of these relatively rare and important vegetation types.

Conclusion: In conclusion, management of the TCA for biodiversity and forest productivity will be challenging. The TCA remains a vital element of global and regional biodiversity, but current and future challenges for management are great. Past management that focussed on social and economic uses was pervasive and has set forest and grassland ecosystems on a trajectory of change with poorly understood implications for biodiversity. Field managers need to develop new field methods that focus on biodiversity and human-oriented goals, then test them in an adaptive management framework that allows them to constantly learn and adjust while actively managing. Specifically, management needs to invest in research and develop the administrative and scientific frameworks for adaptive management projects to learn how to maintain or restore wildlife habitats or populations to levels that might ensure long-term viability. Research also needs to investigate the status, ecology, habitat needs, and population and habitat management strategies for the other less conspicuous species that makes up the bulk of TCA biodiversity. Direct human demands for forest resources and indirect influences from the matrix and are intense and will increase. The current model of forest management will have a difficult time succeeding in integrating biodiversity and human use of forests at the landscape scale. A new multi-scale model of forest ecosystem management that integrates ecologically and administratively fragmented forest units needs to be developed. A second higher and more effective level of landscape management will integrate the dynamics and administration of the agricultural and urban matrix of the TCA. There are a dedicated cadre of professional forest managers and scientists, and interested public in the TCA that can make this new approach work.

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