TM/WII/1997
502.72
GHO

ECOLOGICAL IMPACTS OF PRESCRIBED BURNING IN CORBETT TIGER RESERVE, UTTAR PRADESH

DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT,
IN PARTIAL FULFILMENT OF THE MASTER'S DEGREE
IN WILDLIFE SCIENCE,
JULY 1997

By
SOHALI GHOSH

UNDER THE SUPERVISION OF
DR. VINOD B. MATHUR

TM/WII/1997
502.72
GHO

WILDLIFE INSTITUTE OF INDIA
DEHRA DUN

ECOLOGICAL IMPACTS OF PRESCRIBED BURNING IN CORBETT TIGER RESERVE, UTTAR PRADESH

DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT,
IN PARTIAL FULFILMENT OF THE MASTER'S DEGREE
IN WILDLIFE SCIENCE,
JULY 1997

By
SONALI GHOSH

UNDER THE SUPERVISION OF
DR. VINOD B. MATHUR

WILDLIFE INSTITUTE OF INDIA
DEHRADUN

"In considering the whole question of fire use and its effects, it might be well to .. remind ourselves of the natural prejudice introduced by the rightful recognition of the need for a more extensive and more effective protection from indiscriminate and destructive fires, and approach the entire question in the scientific spirit so aptly described by Francis Bacon 'A mind eager in search ,patient of doubt, fond of meditation, slow to assert, ready to reconsider.. and hating every kind of imposture on it, therefore especially framed for the study and pursuit of the truth .' (Haig, 1938)."

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that Ms Sonali Ghosh of the Wildlife Institute of India has carried out an original piece of research work entitled "**Ecological Impacts of Prescribed Burning in Corbett Tiger Reserve**" in partial fulfillment of the M.Sc. (Wildlife Science) degree of Saurashtra University. These investigations were carried out under my supervision from November 1996 to June 1997. I also certify that this research work has not been submitted for any other degree of any University.

Date: 30th June 1997

Place: Dehra Dun

(Dr. Vinod B. Mathur)
Faculty of Wildlife Management

Post Box No. 18, Chandrabani, Dehradun - 248 001. India
EPABX 640112 to 640115 Fax 0135-640117; Gram WILDLIFE
E-Mail wii.ndle@axcess.net.in

TABLE OF CONTENTS

	Page No.
List of tables, figures and plates.	i-ii
Acknowledgements	iii
Summary	iv-v
CHAPTER 1.0 INTRODUCTION	1
1.1 Prescribed burning in Indian grasslands	2
1.2 Grassland fire characteristics	3
1.3 Rationale for the present study	3
1.4 Study objectives	4
CHAPTER 2.0 STUDY AREA	6
2.1 General description	6
2.1.1 Location	6
2.1.2 History	6
2.1.3 Topography	6
2.1.4 Climate	8
2.1.5 Vegetation	8
2.1.6 Fauna	8
2.2 Intensive study area	9
2.2.1 Location	10
2.2.2 History	10
2.2.3 Topography	10
2.2.4 Climate	10
2.2.5 Fauna	
2.2.6 Landcover stratification of Dhikala Chaurs	11
CHAPTER 3.0 METHODOLOGY	16
3.1 Field work	16
3.2 Laboratory analysis	22
3.2 GIS-RS analysis	23
3.4 Data analysis	23
CHAPTER 4.0 IMPACT ON VEGETATION AND SOIL CHARACTERISTICS.	24
4.1.Soil properties	24
4.1.1 Results	24

4.1.2 Discussion 27
4.2.Above ground biomass 28
4.2.1 Results 28
4.2.2 Discussion 30
4.3.Below ground biomass 31
4.3.1 Results 31
4.3.2 Discussion 33
4.4.Grass nutrients 34
4.4.1 Results 34
4.4.2 Discussion 42
4.5. Fire impact on woody species 42
CHAPTER 5.0 IMPACT ON HERBIVORES AND BIRDS 45
5.1 Results 45
5.2 Discussion 47
CHAPTER 6.0 SPATIAL STRATEGIES FOR THE MANAGEMENT OF HOG DEER POPULATIONS. 51
6.1 Methodology 52
6.2 Discussion 59
CHAPTER 7.0 MANAGEMENT IMPLICATIONS. 60
Literature cited 62
Appendix I Grasses and dicots as recorded in Dhikala chaur
Appendix II Certain grass genera and their habit with respect to burning sources
Appendix III Succession in certain grassland types
Appendix IV Hog deer populations at CTR
Appendix V Lists of birds seen at Dhikala (during bird transects)

LIST OF PLATES

		Page No.
Plate 1:	Grasslands harbour a wide variety of wildlife species.	11
Plate 2a:	Major grassland types delineated in Dhikala chaurs.	11
Plate 2b:	Major grassland types delineated in Dhikala chaurs.	11
Plate 3:	Prescribed burning being carried out in Dhikala chaurs.	16
Plate 4:	Roads serve as fire breaks.	16
Plate 5:	Tall grasslands are invariably not completely burnt.	31
Plate 6:	Appearance of new flush after one week of prescribed burning.	49
Plate 7:	Emergence of non-graminoid species immediately after burning.	43

LIST OF TABLES.

Table1:	Nested plot technique for determining the optimal plot size for vegetation studies.	18
Table 2:	Soil nutrients in short grasslands for burnt and unburnt areas.	25
Table 3:	Soil nutrients in tall grasslands for burnt and unburnt areas.	26
Table 4:	Above ground biomass in different treatments of short and tall grasslands.	29
Table 5:	Below ground production in short and tall grasslands.	32
Table 6:	Crude protein values in burnt and unburnt areas of short and tall grasslands.	35
Table 7:	ADF in burnt and unburnt areas in short and tall grasslands.	36
Table 8:	Lignin in burnt and unburnt areas in short and tall grasslands.	37
Table 9:	Ash content in burnt and unburnt areas of short and tall grasslands.	39
Table10.	Mineral content of grass samples from burnt and unburnt areas of short grasslands.	40
Table 11:	Mineral content of grass samples from burnt and unburnt areas.	41
Table 12:	Chital pellet groups over the months from the burnt and unburnt plots.	45
Table 13:	Hog deer and chital densities and mean group size for the months of Jan-Apr'97.	46

LIST OF FIGURES

		Page No.
Fig 1:	Map of Corbett Tiger Reserve.	7
Fig 2:	Satellite imagery of Dhikala Chaurs.	12
Fig 3:	Landcover stratification of Dhikala chaurs.	13
Fig. 4:	Cluster analysis for similarity between the grass species in the sample plots.	17
Fig 5:	Species area curve for Plot size estimation.	18
Fig 6:	Experimental design for studying the impacts of prescribed fire.	20
Fig 7:	Sampling points as located in the Dhikala chaurs.	21
Fig 8:	Monthly variation in above ground biomass in short grasslands.	30
Fig 9:	Monthly variation in above ground biomass in tall grasslands.	30
Fig 10:	Plot wise variation in below ground biomass in short grasslands.	33
Fig 11:	Plotwise variation in below ground biomass in tall grasslands.	33
Fig 12:	Variation in undigestible matters in tall grasslands.	38
Fig 13:	Variation in Undigestible matters in short grasslands.	38
Fig 14:	Bird species richness as observed from January to April 1997.	47
Fig 15:	Flow diagram for spatial analysis.	53
Fig 16:	Flow diagram for devising burning strategies for management of Hog deer populations	54
Fig 17:	Creation of Thiessen polygon coverages.	57
Fig 18:	Habitat suitability map for Hog deer.	58

ACKNOWLEDGEMENTS

Behind this report lies the encouragement and guidance of numerous people who saw to it that I made it through (phew !).

At Corbett-

Sincere thanks to Mr. R. C. Gautam, Field Director Corbett Tiger Reserve,

Mr. R. Bhartari, Deputy Director Corbett Tiger Reserve, for taking care of all the requirements in the field (notwithstanding the extreme tolerance showed towards my experiments with fire !).

My field assistants, Mahesh, Shakeel and Feroz for doing all the hard work.

Manisha for all the wonderful time spent with her.

WWF-India and Corbett foundation for providing the extra funds for the project.

At Dehradun-

Sincere thanks to Mr. S.K. Mukherji, Director, Wildlife Institute of India for enrolling me for the course. Dr.A.J.T.Johnsingh for the idea itself. Dr.V.B.Mathur , my supervisor, for all the encouragement , support and advice . Dr. Ravi Chellam for providing the necessary 'growl' from time to time, Dr.Y.V.Jhala and Mr. Qamar for the 'vital' statisticsl. Dr. G.S.Rawat and Dr. S.P.Goyal for the timely discussions,. Dr.K.Shankar at WII, Dr. M.N.Jha at F.R.I. and Dr. P.P.Khanna at Wadia for giving the necessary support during the laboratory work.

Dr. P.S.Roy and Dr. Sarnam Singh from IIRS for the Remote sensing and GIS applications.

C.P., Ajay sharma and Rakesh at the Lab, Rajesh Thapa and Pannalal at the GIS and Vineet at the Database.

Nima, Shomita, Prachi, Advait, Madhu, Annan ,Amrendra, KK, Chandu and Jatinder for rushing things at the 11th hour.

Sukumar, Manoj , Mukesh and Dinesh with the formatting. Narender for the plates.

Maheshda and Ismail for the photocopying.

My classmates (scarecrows) for the wonderful time we all spent together .

Lastly, my parents who made all my wishes come true.

SUMMARY

This study was aimed at studying the ecological impacts of prescribed burning by evaluating the current practices of burning being carried out in a typical grassland habitat in Corbett Tiger Reserve . The study extended from November 1996 to April 1997. Twenty four experimental plots were laid to study the differences in soil and vegetation characteristics, with respect to burnt and unburnt areas in short (*Arundinella* and *Vetiveria* type) grasslands and tall (*Saccharum-Themeda* type) grasslands.

The main objectives were to determine the impacts of prescribed burning on soil and vegetation characteristics, distribution of animal and birds and to evolve spatial strategies for the management of Hog deer(*Cervus porcinus*) populations using Remote Sensing and Geographic Information systems.

T-tests and ANOVA (analysis of variance) were applied on the various soil and vegetation parameters to test the differences between the burnt and unburnt areas.

Short grasslands showed significant differences in soil available phosphorus, above ground biomass, crude protein, percentage fibre, ash, elemental potassium and sodium. The general increase in the soil available phosphorus, above ground biomass, crude protein and the decrease in the levels of percentage fibre, ash , elemental potassium and sodium in the short grassland burnt areas can be generally attributed to the removal of litter and the addition of ash which recycles the minerals back into the system.

Tall grasslands showed significant differences in case of soil available potassium and grass percentage fibre. Both the parameters decreased in case of the burnt

areas. The tall grasslands are tussock- forming perennial species which do not get burnt completely. There is not much removal of litter which perhaps hampers the growth of the new sprouts. Samples collected from **burnt and repeatedly clipped** areas were tested for crude protein, percentage fibre, ash and lignin. They showed significant differences in case of percentage fibre. The fibre being the maximum in case of these areas.

Below ground biomass did not show any difference between the burnt and unburnt areas in short and tall grasslands . The area has had a long fire history and the below ground biomass has perhaps stabilised over the years and hence cannot be detected in such a short term study.

Direct (road transects) and indirect (pellets) evidences were used to determine the **animal and bird distribution** with respect to the burning regime. Programme DISTANCE was used to estimate the animal densities while Menhinick's Index was used to calculate the bird species richness , before and after the date of prescribed burning. The animal densities and birds species richness increased after burning, but this could not be fully attributed to the burning regime. Other parameters such as change of seasons, also need to be taken into consideration .

Finally, **hog deer suitability map** was generated using ground data for various ecological parameters and remote sensing data which were overlaid with the help of Geographic Information system .

A burning regime separated on a temporal and spatial scale is required for sustaining hog deer populations in Corbett Tiger Reserve.

CHAPTER ONE

INTRODUCTION

The importance of disturbance in the dynamics of plants and animals has been widely recognised in the past decade (Sousa 1984, Pickett and White 1985). Disturbance has been defined as 'any relatively discrete event in time that removes organisms and opens up space which can be colonised by individuals of the same or different species' (Begon *et al* ,1990). Fire is one such discrete event which 'opens up space' at scales ranging from less than one ha to one million ha at an interval from one to one thousand years depending on the nature of the fuels and the occurrence of conditions conducive to fire (Goldammer, 1990).

Fire, therefore has become a subject of great interest among biologists, foresters and conservationists (Komarek 1969, Kayll 1974, Kozlowski and Ahlgren 1974, Kilgore 1981, Lewis and Ferguson 1988, Huston 1994, Bond 1996)

The fire climax vegetation and fire shaped mosaics are of great biological interest but maintaining them requires regular burning. For this reason prescribed burning has been recognised as a valuable management practice and it can be referred to as 'the skilful application of fire to natural fuels under conditions of weather, fuel moisture, soil moisture etc that will allow confinement of the fire to a pre-determined area and at the same time will produce the

intensity of heat and rate of spread required to accomplish certain planned benefits to one or more objectives, wildlife management , grazing, hazard reduction etc' (Biswell, 1989).

1.1 Prescribed burning in grasslands

Indian grasslands (an ecosystem chiefly dominated by graminaceous species) do not occur naturally by themselves and are maintained by fire, frost, floods or edaphic characters (Dabadhgao and Shankarnarayanan, 1973).

Prescribed burning of grasslands is generally undertaken to achieve any / all of the following management objectives (Rodgers 1986, Sawarkar 1986, Crutzen 1989) :

a) Destroy coarse, unpalatable and nutritionally deficient grasses so as to stimulate growth of new grass with higher protein content and increase fodder availability for the ungulates.

b) To maintain the scarce grasslands habitat in its present condition for the benefit of the characteristic grasslands species such as the Hog deer (*Cervus porcinus*) and check the encroachment of the grasslands by woody vegetation.

c) To reduce combustible material and fuel within the grasslands and thereby prevent serious wildfire at the peak of summer.

1.2 Grasslands Fire Characteristics

Grasslands fires are characterised by a rather narrow zone of flames advancing across a more or less homogeneously dispersed fuel. The fine texture of such fuel makes it more sensitive to weather change than is true of woody aerial stems. The amount and rate of heat released as vegetation burns depends on weather conditions, topography and amount of fuel (Kozlowski and Ahlgren 1974, Mall and Mehta, 1975). Most of the herbs are adapted to survive the fire and since the material consumed is mostly already dead, burning becomes an effective tool in arresting the grasslands at that successional stage (Daubenmire,1968).

1.3 Rationale for the present study

The use of fire as a management tool has not been very extensive in protected areas of India mainly because of inadequate understanding of the habitat requirements of various species. Therefore, the application of fire to fauna management , particularly rare and endangered species is a problem for wildlife managers. There is need to assess effects of present fire management practices on fauna and flora and to incorporate ecological burning practices into fire management plans (Good, 1994).

Although the principles of prescribed burning are well founded but unfortunately the application of such burning has been and is poorly planned and executed. This has led to many prescribed burns not meeting the desired results in terms of prescribed levels of fuel reduction, percentage of burnt area and unacceptable impacts on native flora and fauna.

levels of fuel reduction, percentage of burnt area and unacceptable impacts on native flora and fauna.

Further a number of investigations and reviews of the effects of fire on grasslands (Garren, 1943, Ahlgren and Ahlgren, 1965, Daubenmire, 1968) have presented contrasting differences that are sometimes completely contradictory, even though they pertain to the same area. Many studies have been affected by a conscious or unconscious bias, with investigations setting out to demonstrate that fire produce ill effects, or inherently assuming that fires are always detrimental (Stewart, 1963). Hence while interpreting results one must treat with caution the variable nature of fires and the environments in which they occur . No two fires, or the condition under which they occur, are alike (Vogl, 1974). The present study is an attempt to understand the fire-grasslands-animal interactions in one of the premier protected areas in India.

1.4 Study objectives

a) **To determine the impacts of prescribed burning on vegetation and soil characteristics.**

b) **To determine the impacts of prescribed burning on animal and bird distribution.**

c) **To evolve spatial strategies for the management of Hog deer population using Remote Sensing and Geographic Information System (GIS) Technology.**

Based on the Objective No.1 the following null hypotheses (Ho) have been framed for the present study:

Ho1 There is no difference between the burnt and unburnt soil properties.

Ho2. There is no difference in the above ground biomass in the burnt and unburnt areas.

Ho 3 There is no difference in the below ground biomass in the burnt and unburnt areas.

Ho 4 There is no difference in the grass nurtrients in the burnt , unburnt and repeatedly clipped areas.

Ho5 There is no difference in the mineral content of grasses in the burnt and unburnt areas.

CHAPTER TWO

STUDY AREA

2.1 General description

2.1.1 Location

The study was carried out in Corbett Tiger Reserve (CTR), which is situated at the foothills of the Western Himalayas along Delhi - Ranikhet National Highway between $29^0$13'- $29^0$35' West and $78^0$46' - $79^0$33' East .The area falls in the 'Bhabar' tract of the country which is characterised by 'deep dry boulder deposits at the base of the outermost Himalayan hills '(Champion and Seth 1968). **(Fig. 1).**

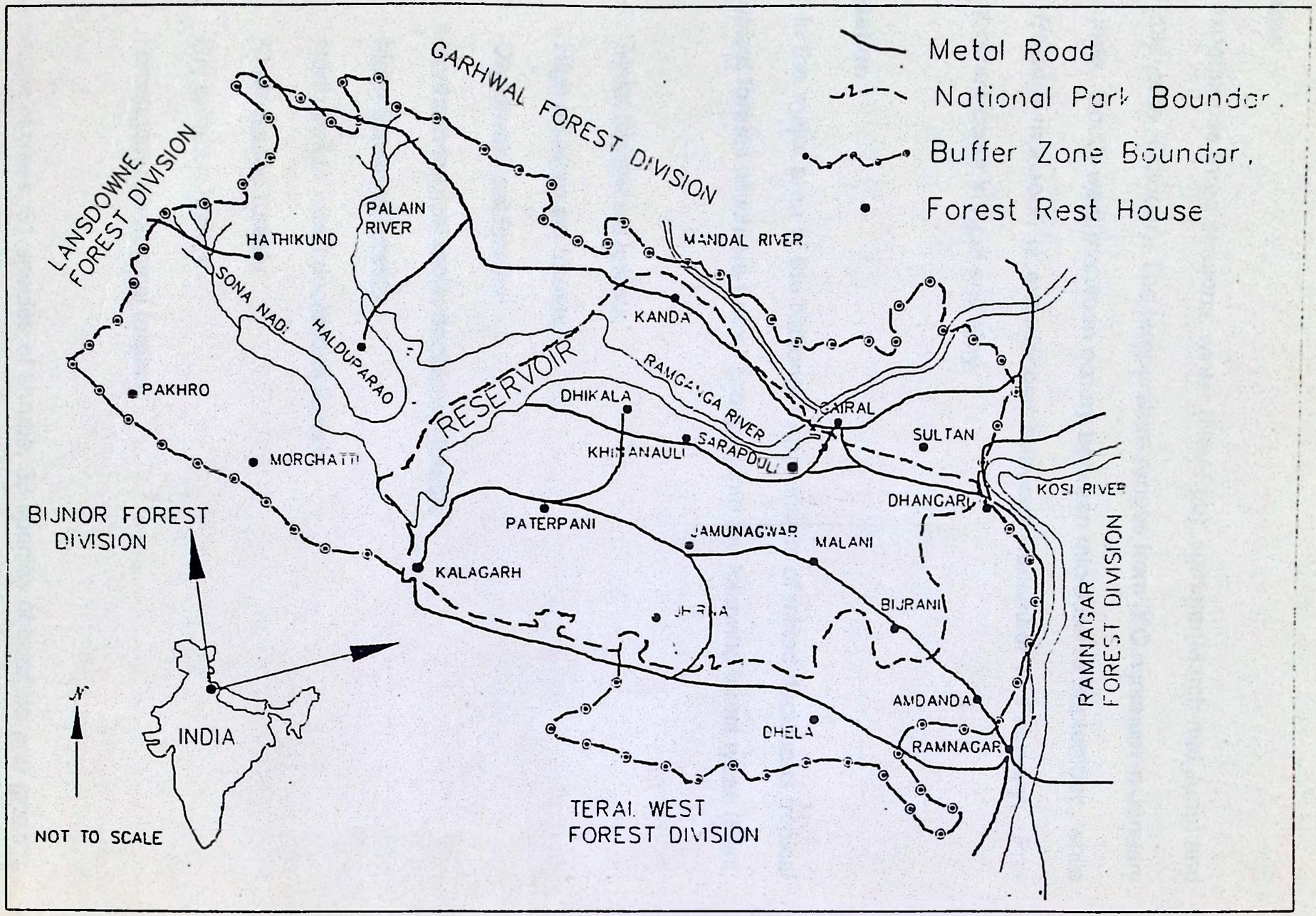
2.1.2 History

Corbett National Park was established on 8th August 1936 with an area of 323.75 km². Today, it forms a part of the Corbett Tiger Reserve which is spread over 1318.54 km² and includes apart from the National Park (520.82 km²), additional areas of Sonanadi Wildlife Sanctuary (301.18 km²) and Reserve Forest Buffer zone (496.54 km²) (Negi, 1994).

2.1.3 Topography

Geologically, the park belongs to Shiwalik formations which are composed of conglomerates, sand, rocks and stones and boulders. The altitude varies from 350 - 1200 m with undulating topography of many temporary marshy depressions, ravines and plateau-like land. The soil is alluvial.

CORBETT TIGER RESERVE



:: Map of Corbett Tiger Reserve.

2.1.4 Climate

The park experiences three seasons; winter (Nov-Feb), summer(March-mid June) and monsoon (mid-June -October). The temperature ranges from 3°C minimum in January to 46°C in June. South-west monsoon occurs between mid-June to September , while the North Eastern monsoon is experienced between December to February. Pre-monsoon showers occur in April and May.

2.1.5 Vegetation

Vegetation in the major area of the National Park consists of mixed deciduous tropical and sub tropical forests which are further grouped into the following forest types (Pant, 1986)

(i) Moist Siwalik sal forests.

(ii) High alluvium sal forests

(iii) Dry Siwalik sal forests

(iv) Northern tropical moist deciduous forests

(v) Moist Savanna forests

(vi) North Indian moist deciduous forests

(vii) Khair-Sissoo forests

(viii) Dry bamboo brakes

(ix) Himalayan sub-tropical forests

About 110 species of trees, 51 species of shrubs, 33 species of bamboo and grasses and 27 species of climbers have been recorded (Pant, 1986).

2.1.6 Fauna

About 50 species of mammals, 570 species of birds, 26 of reptiles, 7 amphibians besides many arthropods and other lower animal groups have been recorded. (Negi, 1994) . From the park area of particular significance are the elephant (*Elephas maximus*), tiger (*Panthera tigris)*, and leopard (*Panthera pardus*). Ungulates like sambar (*Cervus unicolor*), chital (*Cervus axis),* hog deer (*Cervus porcinus*) , barking deer (*Muntiacus muntjack*) and goral (*Nemorhaedus goral*) are also found. Birds of conservation interest are the 49 species of diurnal raptor species such as the red-thighed falconet (*Microhierax caerulescens),* Pallas's fishing eagle (*Haliaeetus leucoryphus)*, crested hawk eagle (*Spizaetus cirrhatus)* and the migratory winterbirds of the Family Ciconoiidae (storks) and Anatidae (ducks and geese) .Three species of endangered reptiles - King-cobra (*Ophiophagus- hannah*), gharial (*Gavialis gangeticus*) and the mugger (*Crocodylus palustris*) are present (Johnsingh and Joshua, 1994). The Ramganga river also harbours the endangered golden mahseer (*Tor putitora).*

2.2 Intensive study area

Since the present study was undertaken to understand the dynamics of fire-grasslands-animal interactions, the grassland at Dhikala was selected as the intensive study area. It is the largest grassland of the CTR.

2.2.1 Location.

Located in south Patlidoon (a river valley), it forms the western boundary of the park along with the Ramganga to its north and the dense sal forest to the south. The reservoir forms the western boundary of the grasslands. The altitude is 385.5 msl and it occupies an area of about 6-7 km^2 and was in continuation with the Boxar grasslands which now remains inundated by the reservoir waters .

2.2.2 History

The Dhikala grasslands or 'chaurs' as they are known locally were earlier inhabited by people of the 'Boxa' tribe who cultivated the lands near the Ramganga river. Once evacuated by the British, their fields gave way to grasslands which were then maintained in that successional stage by annual prescribed burning carried out by the forest department. The practice dates back as far as 1881 (Corbett Management Plan 1926-1936).

2.2.3 Topography

The grassland is a broad plateau, of which every year the river erodes away several tons of alluvial soil to make it even flatter.

2.2.4 Climate

The Dhikala grassland experiences the same overall climate as in other parts of the reserve, however the moisture level of the soil is greatly affected by the level of water in the reservoir. Cool misty mornings with heavy fog is a characteristic of the winters.

The summer temperatures shoot up due to lack of cover, however intermittent pre-monsoon showers in the month of May and June bring the temperatures down.

2.2.5 Fauna

The grasslands harbour typical grasslands fauna **(Plate 1)** such as hog deer and provides important food resources for elephant and chital .The grasslands forest edges also support a good number of sambar and barking deer among the herbivores. Tiger, jungle cat (*Felis chaus)* and other small carnivores also use the grasslands . Grasslands also support a good number of omnivores such as jackal (*Canis aureus*) and wild pig (*Sus scrofa*).

Among birds a number of migratory winter birds such as the, common teals (*Anas crecca*), marsh harriers (*Circus aeruginosus*), river chat (*Phoenicurus sp*), collared bushchats (*Saxicola torquata*), and certain leaf warblers (*Phylloscopus* spp) come down from the higher altitudes of the Himalayas during winter and inhabit the areas near the reservoir edge and the forest grasslands ecotones.

2.2.6 Landcover Stratification of the Dhikala Chaurs

The soil moisture seems to have an effect on the distribution of the various grass species. The landcover stratification for Dhikala chaurs and the surrounding areas was done into the following categories (based on the tone and texture and other features on the satellite imagery and the subsequent ground truthing) **(Fig 2 & 3, Plate 2a & 2b, Appendix - I) .**

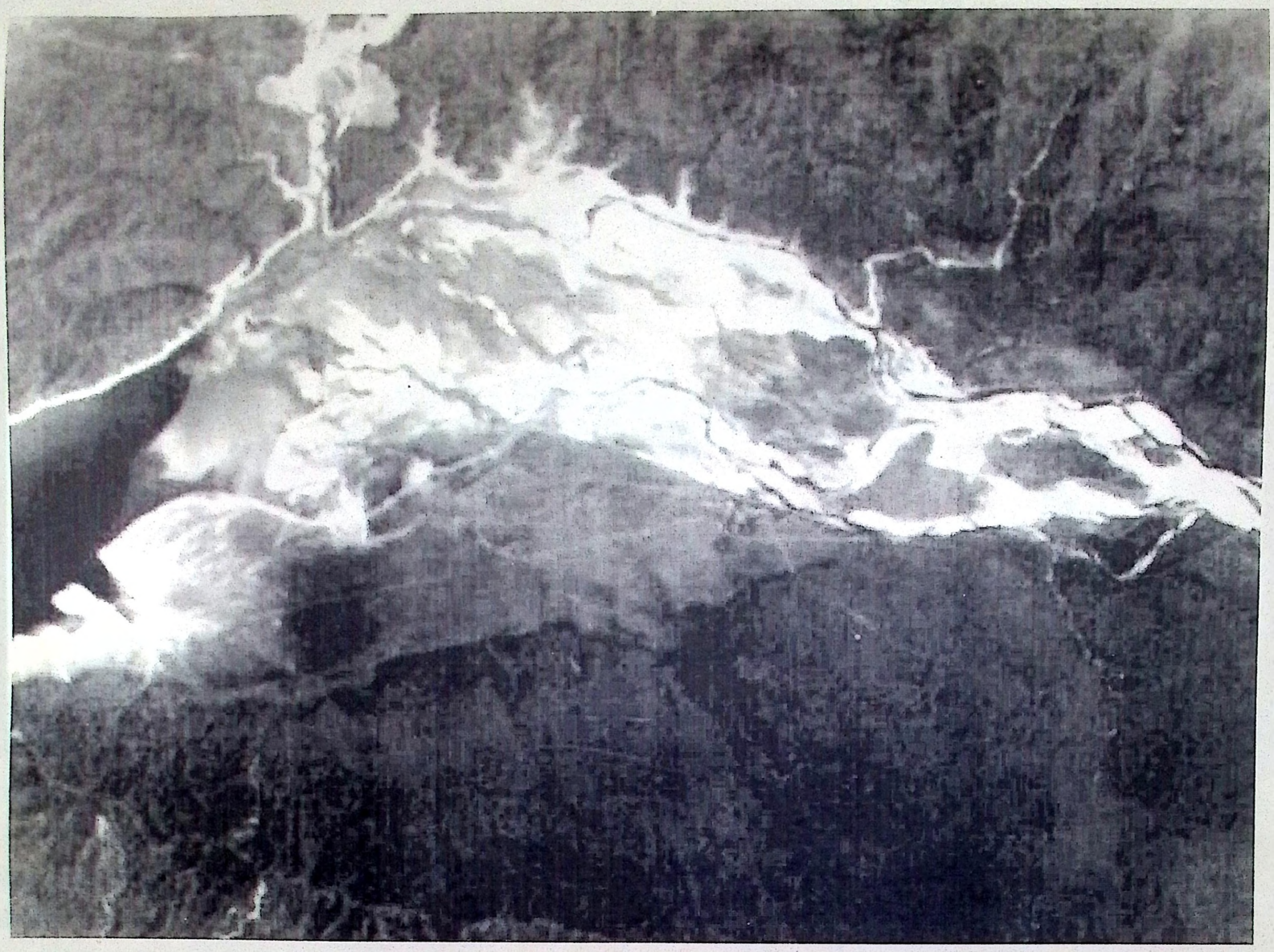
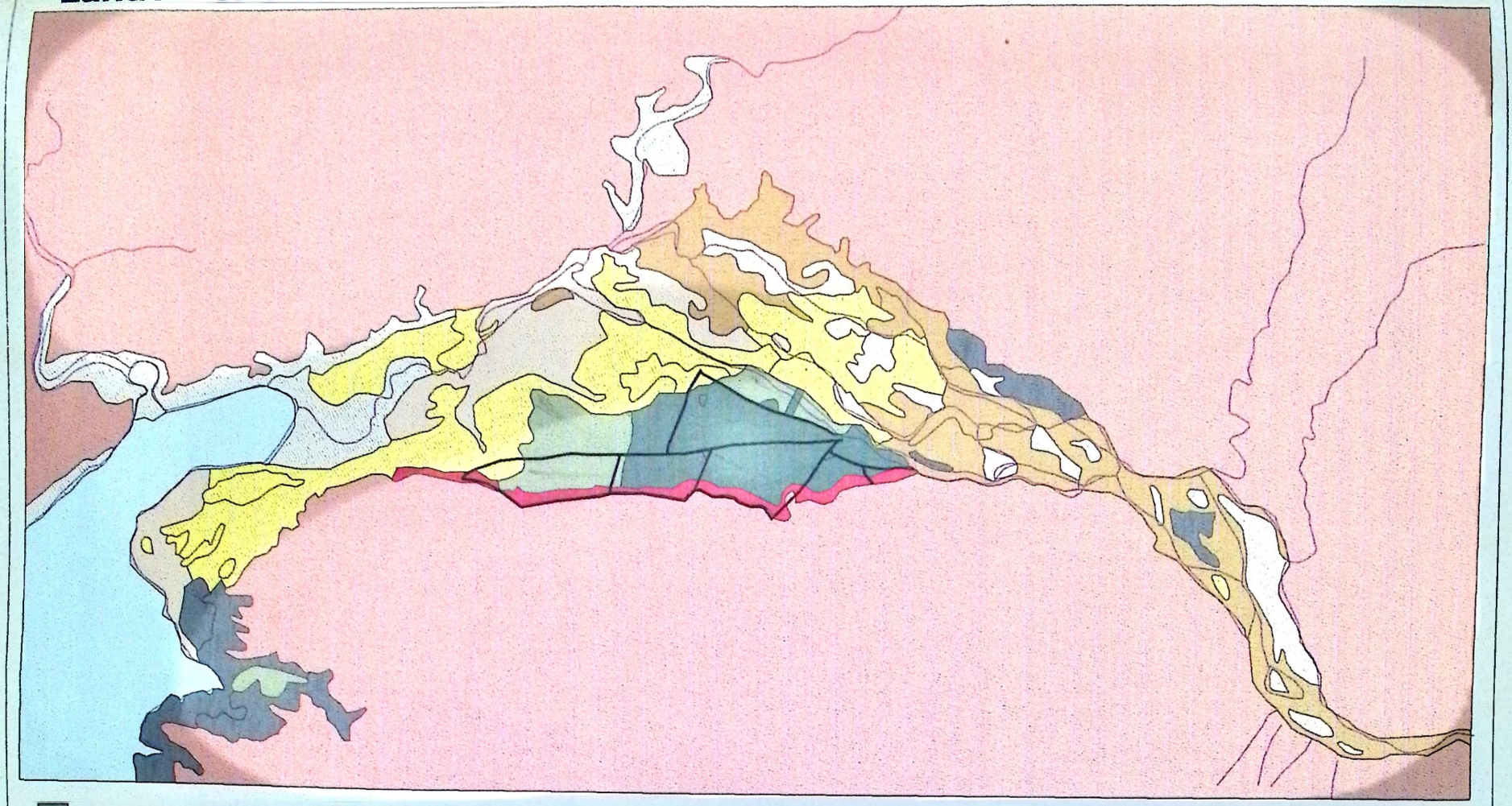


Fig. 2: Satellite Imagery of Dhikala Chaurs

Landcover Stratification of Dhikala Chaurs, Corbett Tiger Reserve



Tall Grasslands
Short Grasslands
River Bed:Low Biomass
River Bed:Medium Biomass
River Bed:High Biomass
Woodland
Sandy Bed
Water Bodies
Forest
Forest Edge-Weeds
Road

N

0 1 2 3
Kilometers

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

GIS Cell June, 1997

Plate 1 **Grasslands harbour a wide variety of wildlife species**

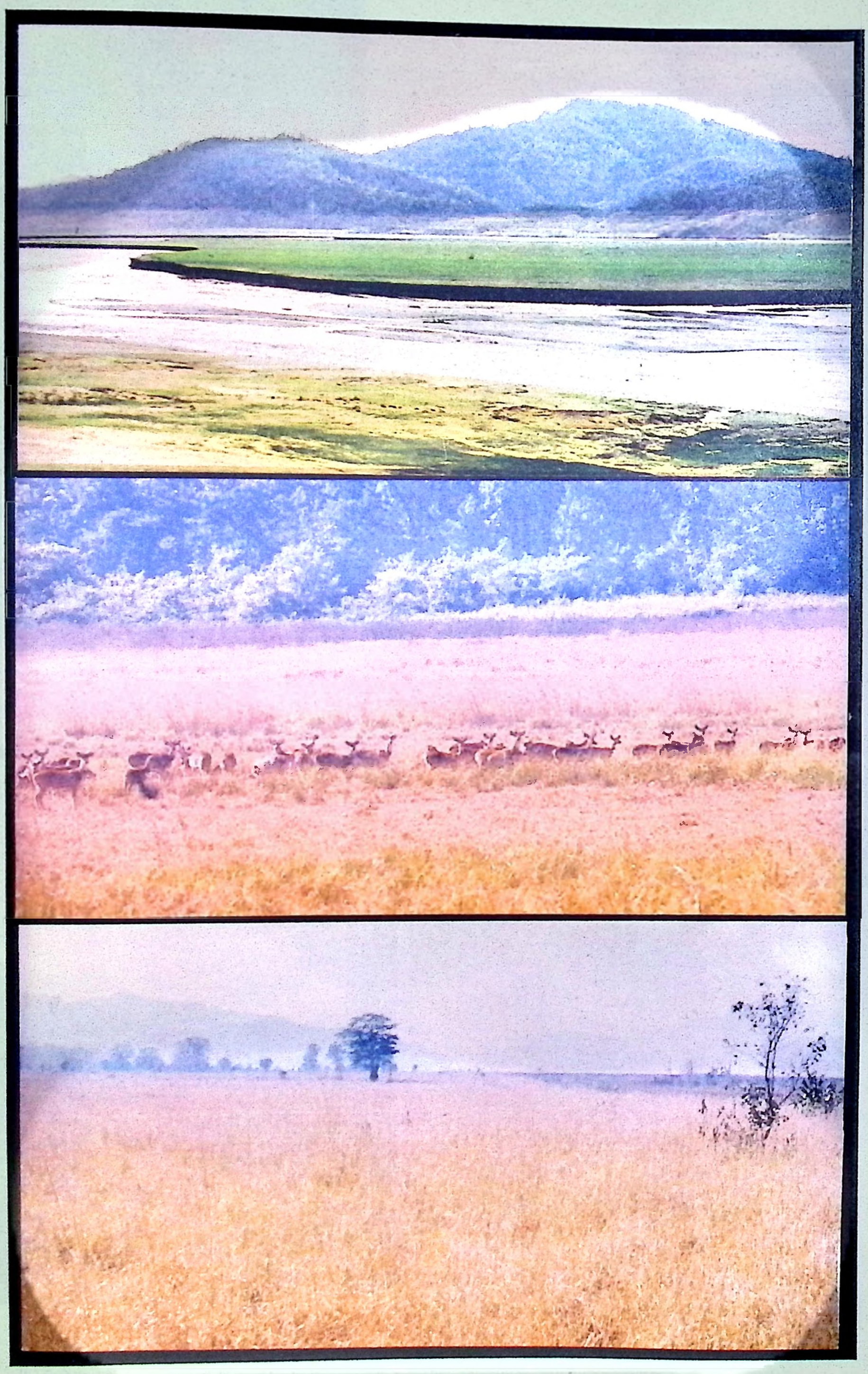
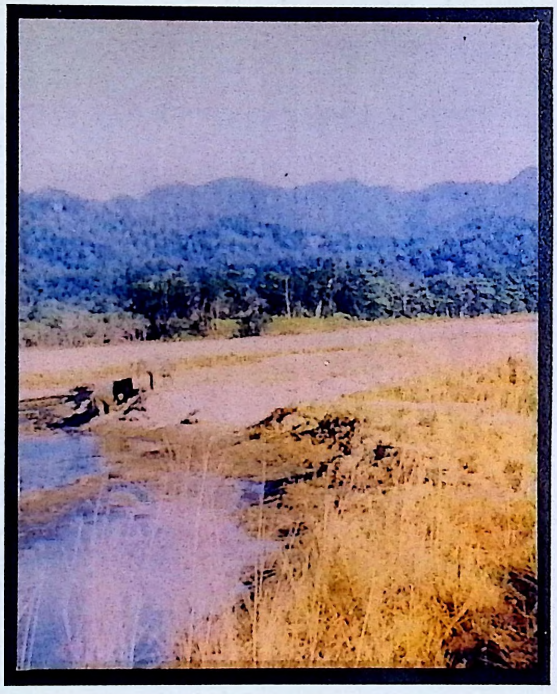


Plate 2a Major grassland types delineated in Dhikala Chaurs



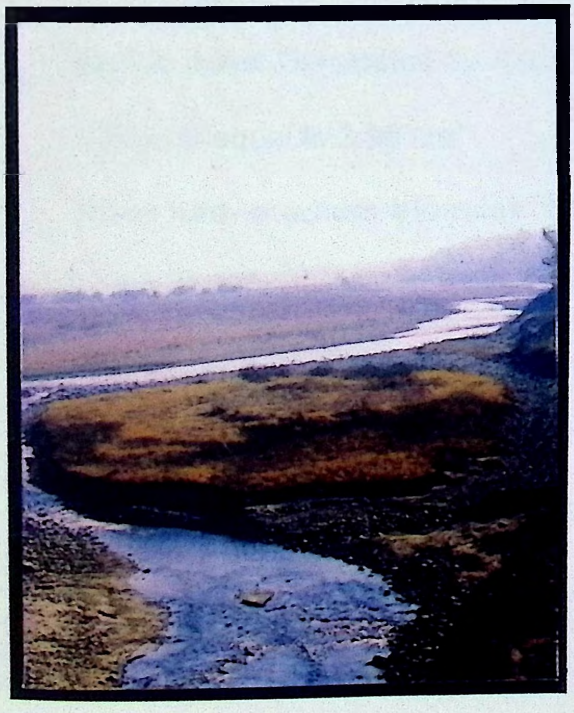


Plate 2b Major grassland types delineated in Dhikala Chaurs

1. **Tall grasslands** Moisture level less than 20 % (as recorded by a soil moisture meter in December 1996). Found in areas at the edges of forests and roads. Dominated by *Themeda arundinacea, Saccharum benghalensis, Cymbopogon flexuosus, Apluda mutica, Heteropogon contortus* etc. Among dicot herbs *Artimisia nilagirica, Tridax procumbens, Vernonia cinerea, Vicoa indica* are found . Area is equal to 2.81 km^2.

2 **Short grasslands** They occur mostly in areas with a moisture level of 20-40 %. Most palatable during the dry period. Dominated by *Vetiveria zizaniodes, Imperata cylindrica, Arundinella benghalensis, Heteropogon contortus, Desmostachya bipinnata, Chinoachne koenghii*, etc. Area is equal to 1.81 km^2.

3. **River bed-low biomass** Moisture level more than 40 % and above. Remains completely inundated by the reservoir water except for the drier seasons of April to June. Dominated by *Axonopus* species, *Poa* species, *Cynodon* species . Area is equal to 3.98 km^2.

4 **River bed- medium biomass** Moisture level is 40% and above and thrives in the seasonally dried areas of the Ramganga river and the reservoir. This type is dominated by *Cynodon dactylon* and other species such as *Axonopus* sps and *Poa* sps. Certain dicotyledonous species such as *Alysicarpus rugosus* (in the inundated areas), *Crotolaria medicaginea, Desmodium microphyllum, Cassia pumilla* etc.also can be found here(Jain *et al*, 1983). Area is equal to 7.87 km^2.

5. **River bed-high biomass** *Arundo donax, Phragmites karka, Saccharum sponataneum and Aristida cynantha* seem to grow exclusively in these areas of high moisture and sandy soil(Bor, 1960). In certain areas almost exclusively pure stands of *Dalbergia sissoo* and *Syzigium cumini* forests can be found. The area is equal to 7.03 km^2.

6. **Woodland** Certain tree species such as *Butea monosperma, Emblica officinalis, Bombax ceiba, Adina cordifolia* and *Cordia dichotoma* are also interspersed in the grasslands, giving it a savanna-like appearance.

7. **Sandy bed** The river bed areas where a lot of sand and silt accumulates every year due to erosion in the upper reaches of the river.

8. **Water bodies** comprises a part of the Ramganga and the reservoir waters.

9. **Forest** Almost exclusively dominated by sal (*Shorea robusta*) on one side of the river. Other sal associates found are *Mallotus philipinensis, Cordia dichotoma, and Litsea chinessis. Clerodendron viscosum* forms the understorey.

10. **Forest edge weeds** Dominated by *Cannabis sativa*, it thrives well near the roads at high moisture areas. *Lantana camara* and *Ageratum conyzoides* are also found but to a lower extent.

CHAPTER THREE

METHODOLOGY

3.1 Field work

Started on 1st Dec'96 and ended on 2nd May'97. Initial three days were spent in a reconnaissance and devising a suitable sampling strategy. The entire study area was about 4-5 km², and the grasslands were broadly classified as short and tall grasslands, each having a distinct species composition and height.

All the experiments were carried out in the short and tall grasslands as these were the areas regularly burnt by the park authorities. Burning is carried out in the month of January and February depending on the suitable weather conditions, maturity of the grass and the availability of manpower. Strips of about 10 metres width are cut in such a fashion that it encircles an area of about 1500 m^2. These circular patches (about 2-3 in total in the grasslands) are left unburnt while the rest of the grasslands is burnt. Fire is initiated along side the roads as it serves as a firebreak. In case of a fire escaping the fire workers try to beat the fire with *Helicteres isora* sticks **(Plate 3 & 4).**

A Hierarchical cluster analysis was further done to see the similarities between the two grasslands based on the percentage dominance of the grasses in the plot . The analysis clearly showed that there were mainly two types of grassland namely :

1. *Themeda-Saccharum , Cymbopogon , Arundinella*: dominated (tall)grasslands.
2. *Vetiveria-Desmostachya, Arundinella, Chrysopogon*; dominated (short) grasslands.

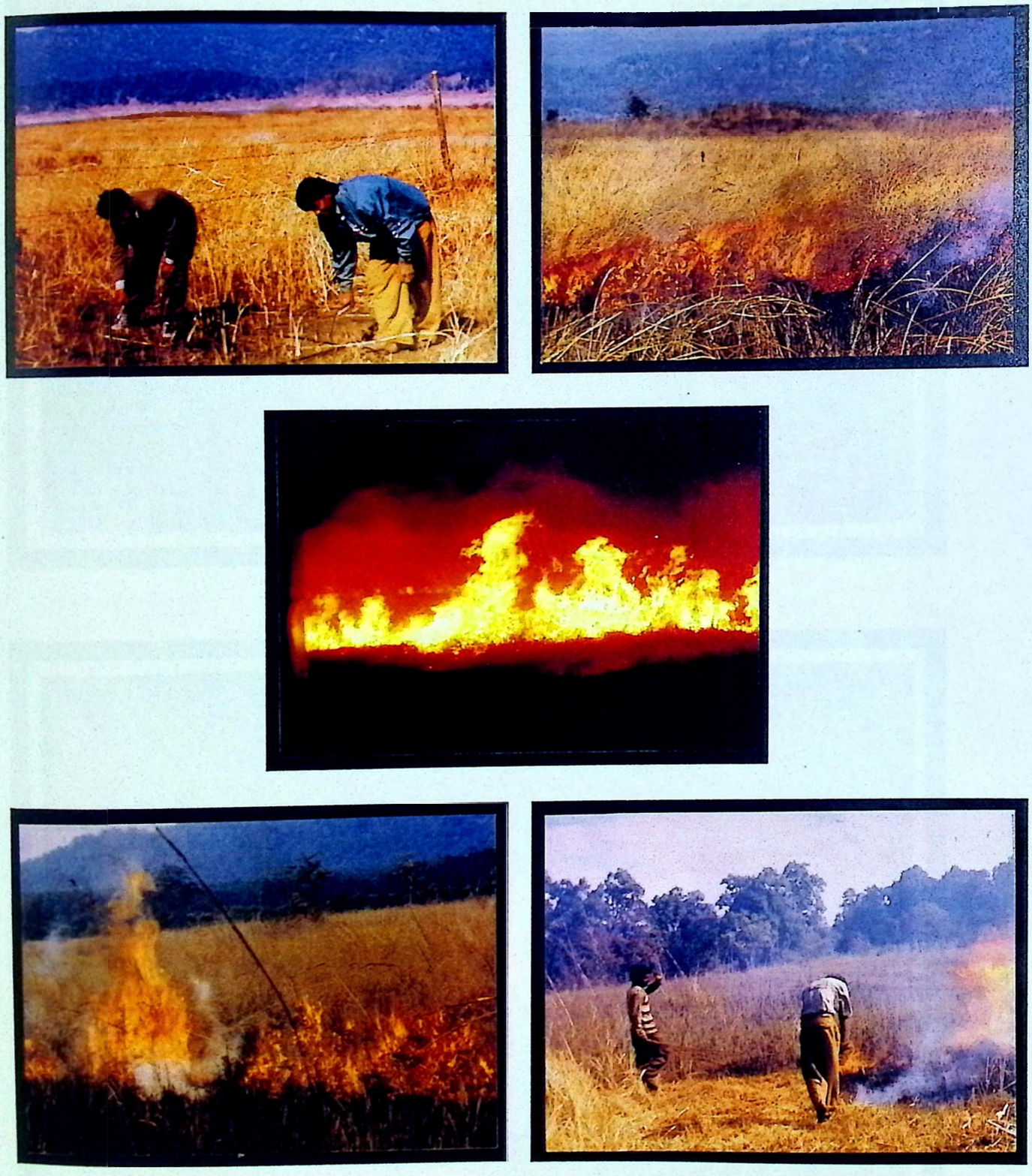


Plate 3 **Prescribed burning being carried out in Dhikala Chaurs**

Plate 4 Roads serve as fire breaks

The tall grassland types can be further divided into three types: *Themeda-Saccharum type* , *Cymbopogon-Arundinella* type and the *Heteropogon-Apluda* type. **(Fig. 4)**

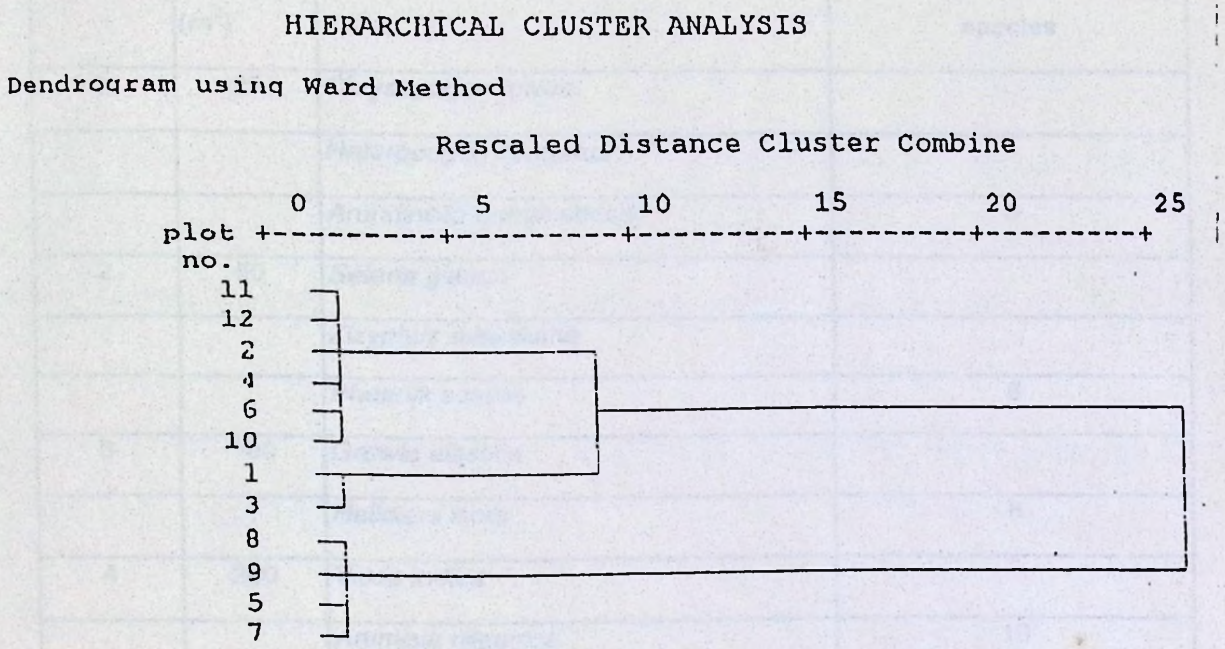


Fig 4: Cluster analysis for similarity between the grass species in the sample plots.

Species area curve (Mueller-Dombois and Ellenberg 1974, Kent and Coker 1992) was used to find out the suitable plot size which came to 400 m² **(Table 1, Fig 5).**

Table 1. Nested plot technique for determining the optimal plot size for vegetation studies.

Plot no.	Size (m^2)	Species	Cumulative total number of species
1	25	*Chrysopogon fulvus*	
		Heteropogon contortus	
		Arundinella benghalensis	3
2	50	*Setaria glauca*	
		Zizyphus mauritiana	
		Phoenix acaulis	6
3	100	*Grewia elastica*	
		Helicters isora	8
4	200	*Vicoa indica*	
		Artimisia nilagirica	10
5	400	*Apluda mutica*	11
	800	*Butea monosperma*	12

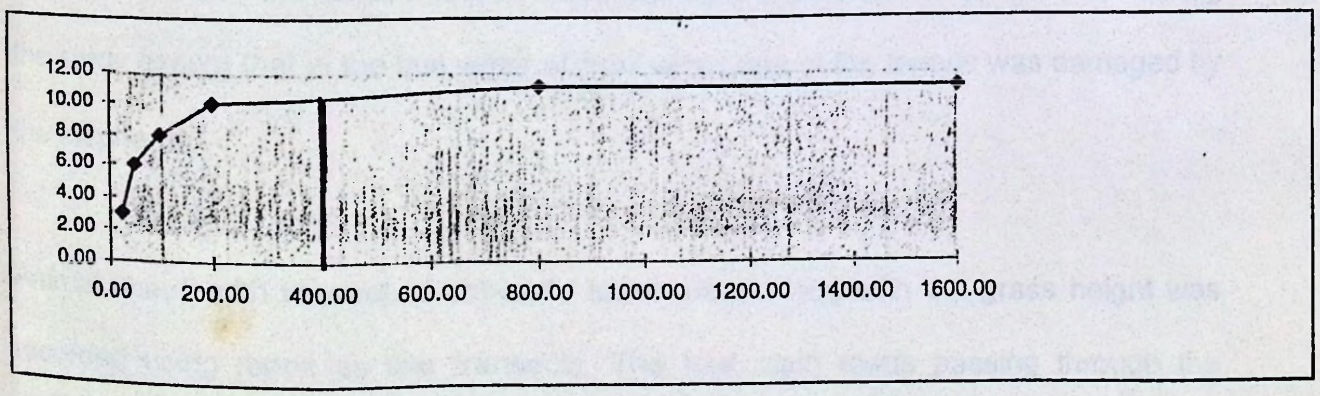


Fig. 5 Species area curve for plot size estimation for vegetation studies.

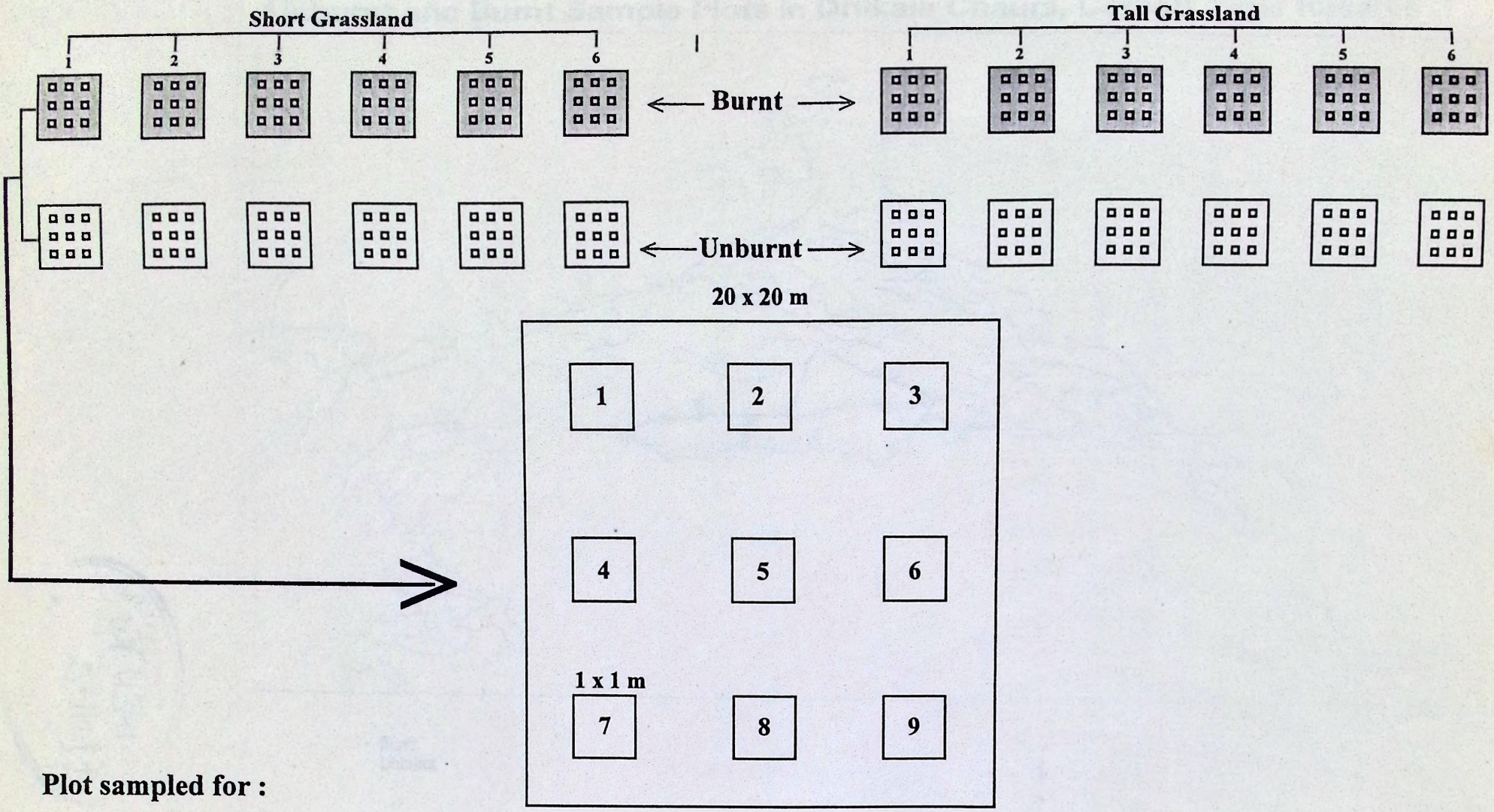
Two plots with similar species composition were subjected to the different treatments. One was burnt, the other left unburnt .Twelve such plot pairs (twenty four plots in total) were laid in the area; six in short grass and six in tall grass areas (Fig 6 & 7). These plots were laid randomly in the stratum of homogenous vegetation composition.

Within each plot nine 1*1 metre quadrates were clipped monthly to estimate the total above ground biomass. The dry weight is measured by keeping the samples in the oven at 80 degree Celsius , or till the dry weight is observed to be constant.

Below ground biomass (in a 25*25*15 cm monolith) was also taken once for 3 quadrates in each plot (72 samples in total).

Two of the plots one each in short and tall grasslands type was fenced using poles and barbed wires. The area fenced was 10*20 metres and similar observations were carried out within the fenced areas. They served the purpose of control plots during the study except that in the last week of April when one of the fences was damaged by the elephants.

Animal usage with respect to unburnt / burnt areas along with the grass height was recorded using roads as line transects. The four main roads passing through the Dhikala chaurs were taken as the baseline for transects and the animal and bird distribution with respect to the area was recorded.



Plot sampled for :

1. Soil pH
2. Soil moisture
3. Soil organic matter
4. Available phosphorus
5. Available potassium
6. Above ground biomass
7. Below ground biomass
8. Crude protein
9. Lignin
10. ADF
11. Ash
12. Elemental phosphorus
13. Elemental sodium
14. Elemental potassium
15. Animal evidence (pellets)

EXPERIMENTAL DESIGN FOR STUDYING THE IMPACTS OF PRESCRIBED FIRE

Unburnt and Burnt Sample Plots in Dhikala Chaurs, Corbett Tiger Reserve

• Burnt
Unburnt

N

0 1 2 3

Kilometers

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

GIS Cell June, 1997

Wildlife Institute of India
WII/1361
5-11-97

Pellet groups were also periodically removed from the plots to serve as an indirect evidence for animal usage of the burnt and unburnt areas.

3.2 Laboratory analysis

Soil and grass samples were taken from the plots (for treatments-burnt, unburnt and repeatedly clipped) and subjected to analysis. Samples from repeatedly clipped areas were also taken to see if cutting would have any effect on the plant constituents. Cutting effect, to an extent can be generalised to the grazing effect. Soil samples were taken till the depth of 10-15 cm while for the grass samples only the fresh sprout was taken .The samples were taken twice in the entire study period.

The grass samples (N= 64) were analyzed for crude protein (micro-kjeldahl technique) and fibre(Acid detergent fibre (ADF), lignin and ash), (Van Soest 1963, Goering and Van Soest 1970, Allen 1989) . Elemental potassium, phosphorus and sodium were analysed using an Inductively coupled plasma-atomic absorption spectrophotometer (ICP-AES, Thompson and Walls1989, Potts 1989). Calorific value of the grass samples was determined using the Bomb calorimeter.

Soil samples were analysed for organic carbon (Walkley- Black method, Jackson 1967), available phosphorus (using a Spectro- colorimeter 103) and available potassium (using a Systronics digital ppm 125 Flame Photometer Model No. 12) (Morgan-reagent method, Jackson 1967).

3.3 GIS-RS data:

Geocoded Panchromatic data and IRS-IC LISSIII FCC data (May 1996)on a scale of 1:50,000 was visually interpreted for preparing the land cover stratification map for Dhikala chaurs. ARC/INFO software was used for developing suitability classes for Hog deer.

3.4 Data analysis

Data was analysed using Microsoft-Excel and SPSS packages. Raw data was subjected to normality using KS-runs test and suitable parametric tests as given under (Sokal and Rohlf, 1995). The Confidence Interval was fixed at 95% and the type one error α was fixed at 0.05 level.

The various statistical tests done, were used to test the differences in treatments namely burnt and unburnt areas and in few cases in repeatedly clipped areas. Density estimates for Chital and Sambar were estimated using programme DISTANCE ver 2.1 (Buckland *et al* 1993, Laake *et al* 1994).

Bird species richness (number of species in an area) was calculated using the Menhinick's Index (Magurran, 1988).

$$R = S / \sqrt{N}$$

where

R = species richness, S = number of species, N = no of individuals of all species in a community or a vegetation plot.

CHAPTER FOUR

IMPACTS OF PRESCRIBED BURNING ON VEGETATION AND SOIL CHARACTERISTICS

4.1 Soil properties

Ho_1: There are no differences between the burnt and unburnt soil properties.

4.1.1 Results

In order to study differences in soil parameters from burnt and unburnt areas they were subjected to T-test for independent samples . The parameters were soil organic matter, available potassium and available phosphorus. Short grass showed significant differences in case of available phosphorus while tall grasslands showed significant differences in case of available potassium. **(Table 2 & 3).**

Table 2 . Soil nutrients in Short grasslands for burnt and unburnt areas.

Sl.no	Variable	Type	No. of samples	Mean (%)	S.E. of Mean	Test performed	p-value
1	Organic matter (SG)	UB	9	2.7312	0.394	Independant samples'T-Test	0.38
		B	10	3.1368	0.208		
2	Available phosphorus (SG)	UB	8	0.0021	0.001	Independant samples'T-Test	**0.041***
		B	7	0.0044	0.001		
3	Available potassium (SG)	UB	8	0.0211	0.011	Independent samples'T-Test	0.656
		B	7	0.0159	0.003		

SG = Short Grasslands; UB =unburnt ; B = Burnt * Significant

Table 3 . Soil nutrients in tall grasslands for burnt and unburnt areas.

S.no	Variable	Type	No. of Sample	Mean (%)	S.E. of Mean	Test performed	p-value
1	Organic matter (TG)	UB	9	2.9074	0.242	Independent samples'T-Test	0.587
		B	9	3.103	0.256		
2	Available phosphorus (TG)	UB	8	0.0034	0.001	Independent samples'T-Test	0.417
		B	9	0.0075	0.005		
3	Available potassium (TG)	UB	9	0.0257	0.002	Independent samples'T-Test	**0.024***
		B	8	0.018	0.002		

TG= Tall Grasslands; UB =unburnt; B = Burnt * Significant

4.1.2 Discussion

Low intensity fires generated during prescribed burning are unable to change the soil chemical structure in a major way. The repeatability of fire over the years must have brought a permanent change in the soil composition which is difficult to detect in a short term study. Grasslands fires tend to be cooler than forest fires with soil temperatures reaching a maximum of 120° Celsius for less than one minute. Some soil nutrients and organic matter may be lost, water holding capacity and soil wettability are changed and populations of soil microbes altered. However all the organic matter at the soil surface, Nitrogen, Calcium, Sodium and Magnesium is released and deposited on the soil even at moderate temperatures and rapidly recycled into the system (Vogl 1974, Singh *et al* 1991).

The input of base-rich ashes after fire increases the soil pH by .05 pH unit for a few weeks, independent of the fire regime. Such low variations in soil pH are unlikely to affect greatly the nutrient status of the soil (amount or form), but microsite / trace gas effects could still be significant (Coutinho, 1982). Burning or protection has very little short term effects if any, on the soil organic nitrogen and soil organic matter. Late burning is more detrimental ; the repeated burning of Nitrogen rich leaves growing at the onset of the wet season leads to higher losses in Nitrogen and the abnormal growth which follows, contribute to the impoverishment of the soil.

In case of Dhikala grasslands, significant differences in the available phosphorus in short grasslands and available potassium in case of tall grasslands can be perhaps

due to change in soil pH, or due to differences in the microsite conditions . Overall, most effects of the fire on the soil result from the removal of the above ground cover and from the addition of ashes to the upper horizons. In the long term, nutrient concentrations tends to increase with protection but it is often highest in early burnt plots and lowest in later burnt ones, intermediate values being found in protected plots (Viro, 1969).

4.2 Above ground biomass

Ho_2 There is no difference in the above ground biomass in the burnt and unburnt areas.

4.2.1 Results

The above ground grass biomass samples were subjected to a simple factorial ANOVA using a hierarchical method for the burnt and unburnt areas for each grasslands type. This statistical design was necessary to take the pseudoreplication of the sampling points into account (Hurlbert, 1984). Short grasslands showed significant differences while the tall grasses did not show any difference at all (**Table 4, Fig 8 & 9).**

Table 4. Above ground Biomass In different treatments of short and tall grasslands.

s.no	Variable	Type	No. of Sample	Mean ($gm/m^{3)}$	Test performed	p-value
1	above ground biomass(SG)	UB	146	40.10	Simple-factorial ANOVA (month as covariate)	.0001*
		B	146	59.28		
2	above ground biomass(TG)	UB	138	44.09	Simple-factorial ANOVA (month as covariate)	.362
		B	138	46.74		

SG= Short grasslands ;TG= Tall Grasslands; UB = unburnt ; B = Burnt * Significant

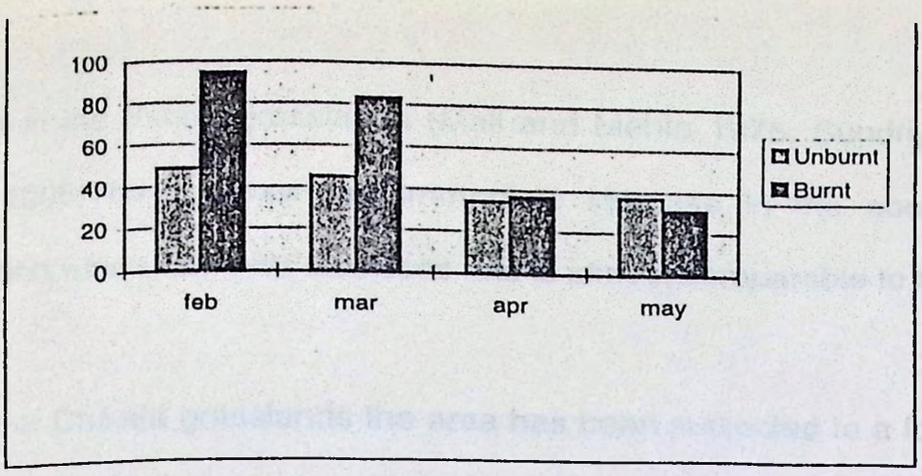


Figure 8. Monthly variation in above ground biomass in short grasslands

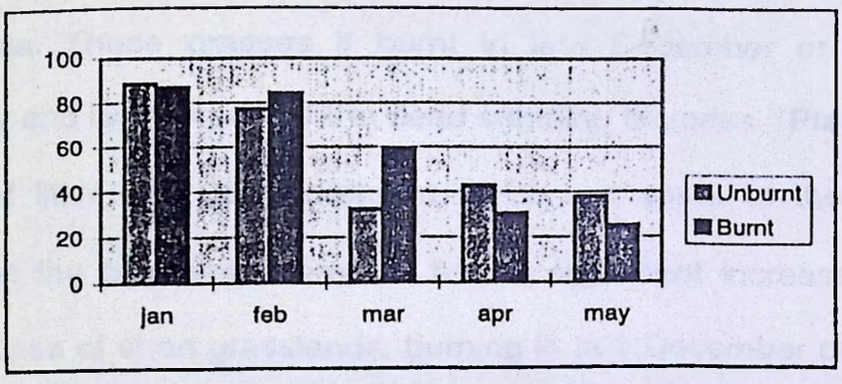


Figure 9. Monthly variation in above ground biomass in tall grasslands

4.2.2 Discussion

Burning has been found generally to increase the production of most grasslands vegetation. However it hardly effects the strong perennial grasses whose root systems survive (Mott, 1982). Frequent burning tends to decrease production (by 30% -50 %) and the rate of nutrient cycling through the grass layer (Vogl, 1967, Afolayan and Fujitso 1978, Ojima *et al*, 1990, Redmann, 1992, Daubenmire, 1968).

Studies in the Indian grasslands (Mall and Mehta 1975, Sundriyal 1995, Gupta and Singh 1995) have shown an immediate increase in the above ground biomass production which however stabilises and is almost comparable to the protected plots.

In case of Dhikala grasslands the area has been subjected to a long history of annual prescribed burning and there has been a more or less stabilisation in the vegetational composition with a preponderance of fire-resistant, tussock forming perennial species such as *Themeda arundinacea, Saccharum benghalensis and Cymbopogon martini* in the area. These grasses if burnt in late December or January do not burn completely and leave much of the dead standing biomass (**Plate 5**) .Since there is no removal of litter and ash increment which are some of the possible reasons for increase in the biomass, there will be no significant increase in the new biomass either. In case of short grasslands, burning in late December or January results in full removal of the mature grass and the remaining litter. There is a significant ash increment which perhaps results in the greater production of above ground biomass.

4.3 Below ground biomass

Ho_3 There is no difference in the below ground biomass in the burnt and unburnt areas.

4.3.1 Results

Below ground biomass samples were subjected to t-test for independent samples. They did not show any significant differences between the treatments in the short and tall grasslands (**Table 5, Fig 10 & 11)**

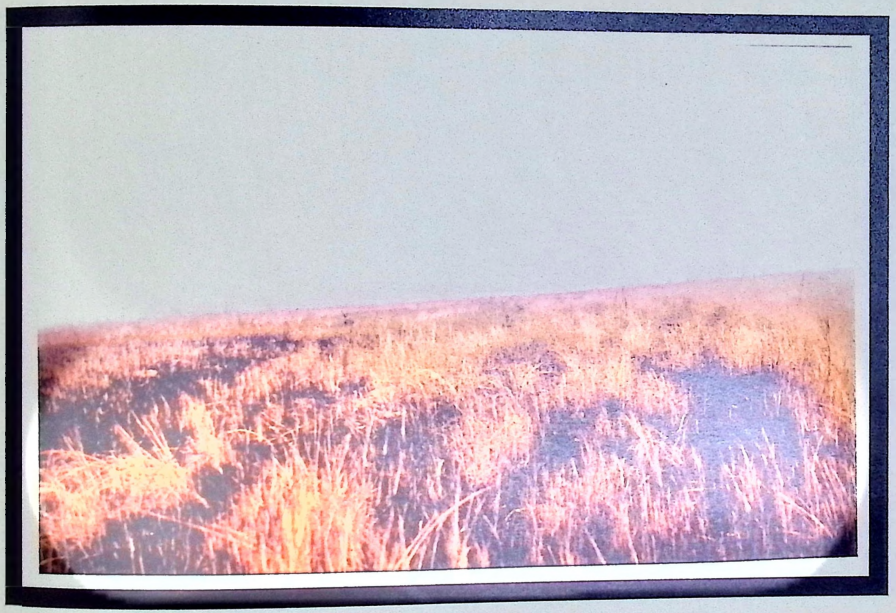


Plate 5 **Tall grasslands are invariably not completely burnt**

Table 5.Below ground production in short and tall grasslands.

s.no	Variable	Type	No. of Sample	Mean (gms/m ^{3})	Test performed	p-value
1	Below ground biomass(SG)	UB	12	3091.397	T-test for independent samples	0.09
		B	12	4927.956		
2	Below ground biomass(TG)	UB	12	5376.344	T-test for independent samples	0.139
		B	12	3763.440		

SG= Short grasslands ;TG= Tall Grasslands; UB =unburnt; B = Burnt * Significant

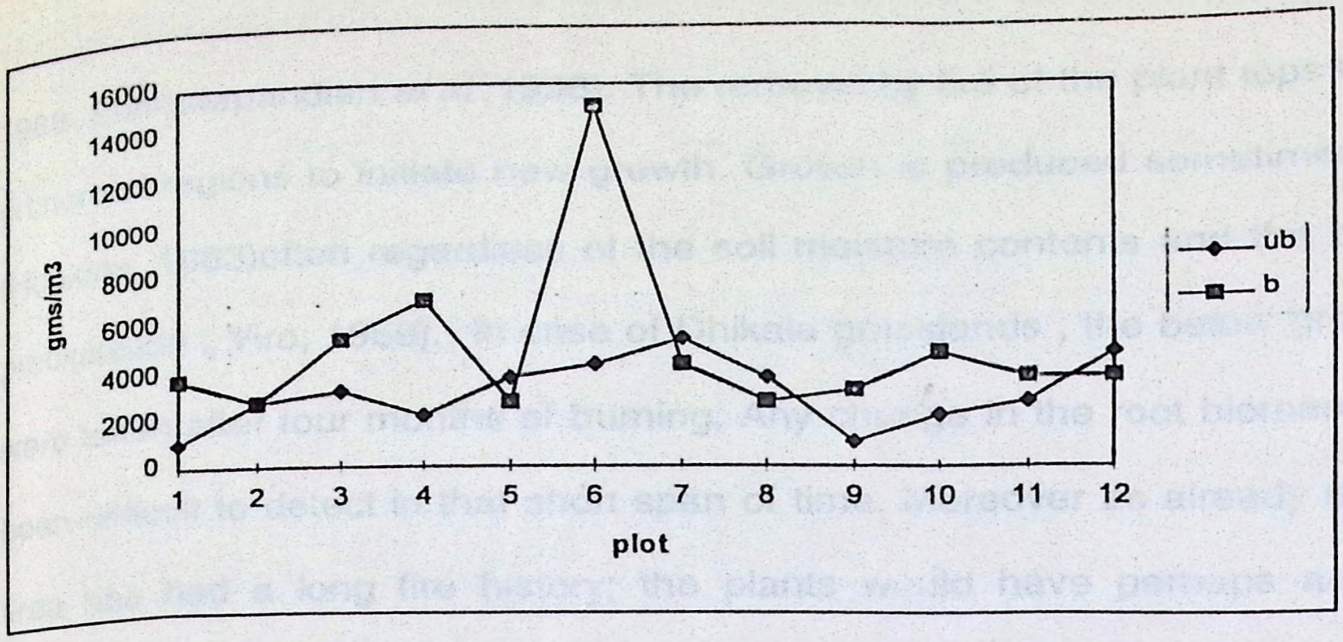


Figure 10. Plotwise variation in below ground biomass in short grasslands

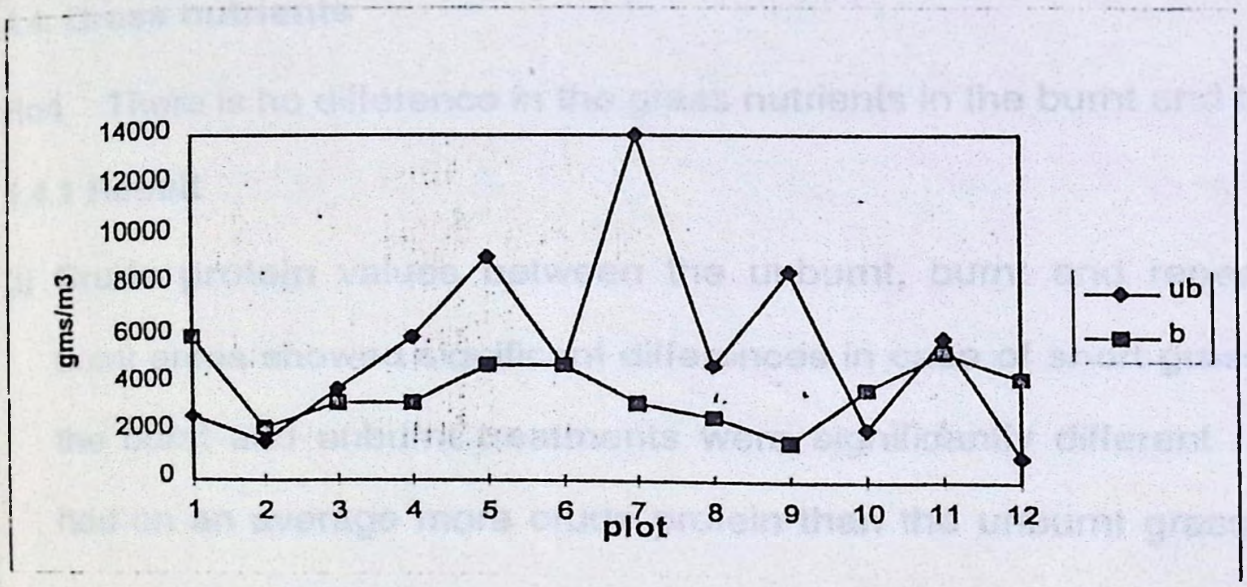


Figure 11. Plotwise variation in below ground biomass in tall grasslands

4.3.2 Discussion

The higher yields of the above ground portion of plants are related to corresponding increases in the root systems (Kucera and Koelling 1970, Daubenmire, 1968, Stanton,

1988, Sundarapandian *et al* ,1996). The removal by fire of the plant tops triggers latent primordial regions to initiate new growth. Growth is produced sometimes very rapidly (Hopkins ,1963)often regardless of the soil moisture contents and the occurrence of precipitation (Viro, 1969). In case of Dhikala grasslands , the below ground samples were taken after four months of burning. Any change in the root biomass would have been difficult to detect in that short span of time. Moreover as already mentioned the area has had a long fire history; the plants would have perhaps adapted to the continous fire regime and hence the stabilization in the below ground biomass has been observed.

4.4. Grass nutrients

Ho4 There is no difference in the grass nutrients in the burnt and the unburnt areas.

4.4.1 Result

(i) **Crude protein** values between the unburnt, burnt and repeatedly clipped and burnt areas showed significant differences in case of short grasslands though only the burnt and unburnt treatments were significantly different .The burnt grasses had on an average more crude protein than the unburnt grasses . In case of tall grasses fire again did not seem to effect the crude protein values as it did not show any significant differences (**Table 6).**

Table6. Crude protein values in burnt and unburnt areas of short and tall grasslands

Sl. No	Variable	Type	No. of Sample	Mean (%)	S.E. of Mean	Test performed	p-value
1	Crude Protein (SG)	UB	12	7.5574.	0.451	One-Way	**0.0148***
		B	12	10.952 8	0.54	ANOVA	
		RC	8	9.0885	1.787	TUKEY's HSD	ub*b
1	Crude Protein (TG)	UB	12	8.0382	0.451	One-Way	0.1524
		B	12	9.4466	0.54	ANOVA	
		RC	8	8.9417	1.787	TUKEY's HSD	

SG= Short grasslands ;TG= Tall Grasslands; UB = rnt ; B = Burnt ; RC= repeatedly clipped;* Significant

ADF (Acid detergent fibre) which determines the unpalatibility of the forage showed significant differences between burnt and repeatedly clipped areas in the short grass areas; the mean fibre content being more in repeatedly clipped and burnt areas as compared to the unburnt and burnt areas. The burnt areas had the the least fibre

among them. In case of tall grasses all the treatments showed significant differences with the mean fibre content being highest in repeatedly cut and burnt areas and the lowest in the burnt areas **(Table 7).**

Table 7 Acid detergent fibre in burnt and unburnt areas in short and tall grasslands.

Sl. no	Variable	Type	No. of Sample	Mean (%)	S.E. of Mean	Test performed	p-value
1	ADF(SG)	UB	12	41.1791	.974	One-Way	**.0338***
		B	12	39.1102	1.297	ANOVA	UB*B
		RC	8	43.5942	0.625	TUKEY's HSD	
2	ADF (TG)	UB	12	40.9953	.526	One-Way	**.0008***
		B	12	38.0409	.652	ANOVA	UB*B
		RC	8	42.1331	.985	TUKEY's HSD	B*RC

SG= Short grasslands ;TG= Tall Grasslands; UB = unburnt ; B = Burnt * Significant, RC= Repeatedly clipped

Percentage lignin which also determines the unpalatability of the grasses was not significantly different in the short grasses and the tall grasses**(Table 8).**

Table 8. Lignin in burnt and unburnt areas in short and tall grasslands.

Sl. no	Variable	Type	No. of Sample	Mean (%)	S.E. of Mean	Test performed	p-value
1	Lignin(SG)	UB	12	10.9557	1.928	One-Way	0.1088
		B	12	7.2302	0.481	ANOVA	
		RC	8	7.6681	1.004	TUKEY's HSD	
2	Lignin(TG)	UB	12	10.5125	1.627	One-Way	0.2286
		B	12	7.192	.597	ANOVA	
		RC	8	8.6504	.482	TUKEY's HSD	

SG= Short grasslands ;TG= Tall Grasslands; UB = unburnt ; B = Burnt * Significant

Percentage ash showed significant differences in the unburnt and repeatedly clipped short grass areas. The average ash content being highest in unburnt areas and the lowest in the repeatedly clipped and burnt areas. Tall grasses did not show any difference between the treatment **(Table 9, Fig 11 & 12).**

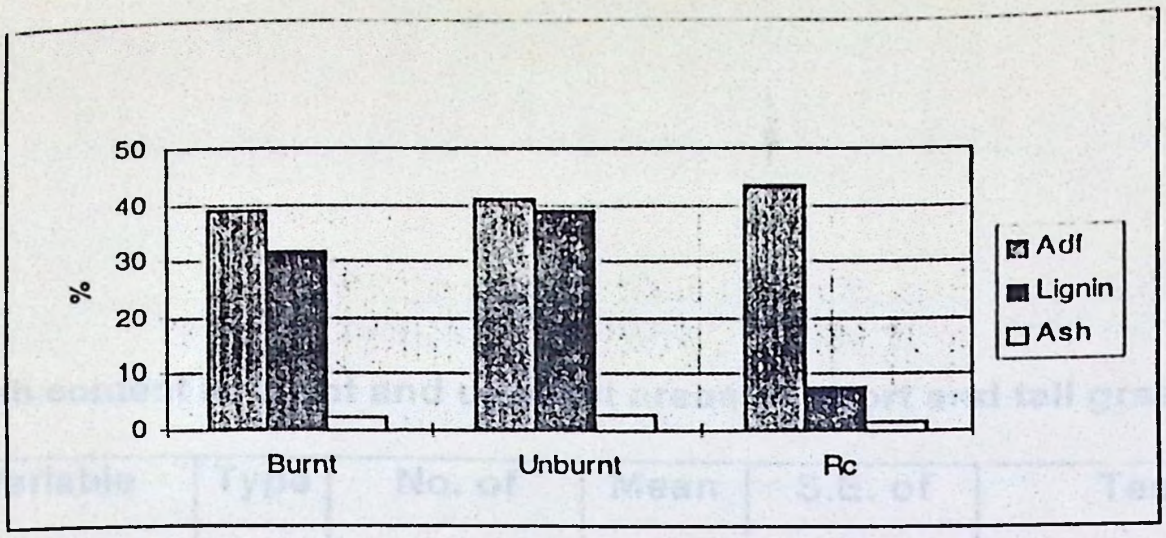


Fig.12 Variation in undigestible matters in tall grasslands

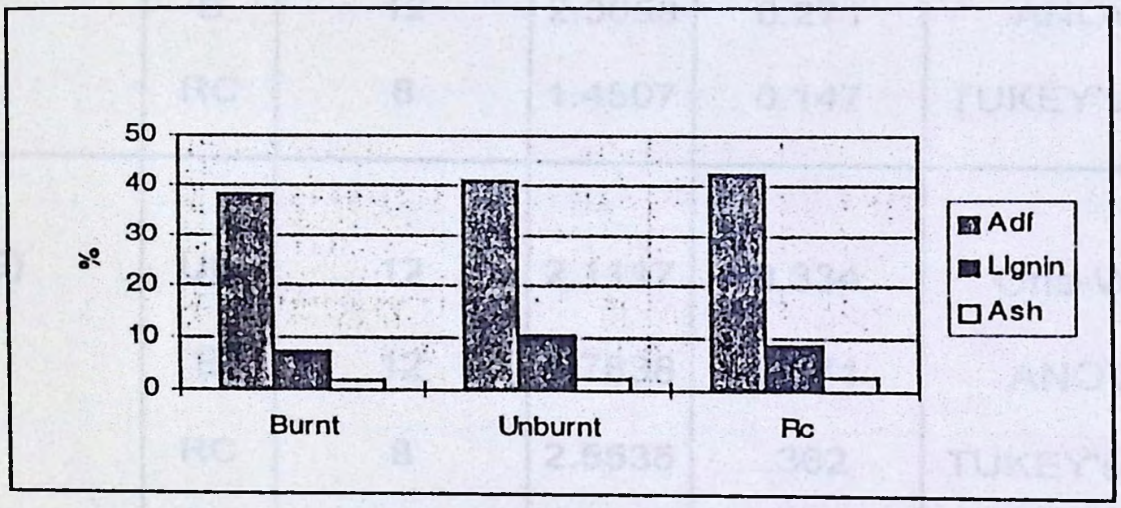


Fig.13 Variation in undigestible matters in short grasslands

Table 9 .Ash content in burnt and unburnt areas of short and tall grasslands.

Sl. no	Variable	Type	No. of Sample	Mean (%)	S.E. of Mean	Test performed	p-value
1	Ash(SG)	UB	12	3.0084	0.334	One-Way ANOVA TUKEY's HSD	**0.0043***
		B	12	2.3058	0.271		
		RC	8	1.4507	0.147		
2	Ash(TG)	UB	12	2.1117	0.334	One-Way ANOVA TUKEY's HSD	.1312
		B	12	1.7838	0.271		
		RC	8	2.5535	.362		

SG= Short grasslands ;TG= Tall Grasslands; UB = unburnt ; B = Burnt * Significant,

(v). **Elemental sodium** showed significant differences in case of short grasslands. Elemental potassium and elemental phosphorus did not show any significant differences in any of the grasslands types. **(Table 10 & 11).**

Table 10 Mineral content of grass samples from burnt and unburnt areas of short grasslands.

Sl. no	Variable	Type	No. of Sample	Mean (ppm)	S.E. of Mean	Test performed	p-value
1	Potassium	UB	6	7583.33	1410.77	T-test for Independent Sample	0.622
		B	6	8333.33	247.207		
2	Sodium	UB	6	455	58.55	T-test for Independent Sample	0.068*
		B	6	319.166	6.376		
3	Phosphorus	UB	6	2101.167	272.631	T-test for Independent Sample	0.318
		B	6	1797.167	96.74		

Table 11 Mineral content of grass samples from burnt and unburnt areas of tall grasslands.

S.no	Variable	Type	No. of Sample	Mean (ppm)	S.E. of Mean	Test performed	p-value
1	Potassium	UB B	6 6	9416.666 8500	472.875 500	T-test for Independent Sample	0.213
2	Sodium	UB B	6 6	383.33 321.667	23.688 21.396	T-test for Independent Sample	0.82
3	Phosphorus	UB B	6 6	1988.667 2006.166	89.078 149.851	T-test for Independent Sample	0.922

4.4.2 Discussion

Studies have shown that except for minimal losses in nitrogen, sulphur and potassium there is no direct loss in nutrients from the system, but rather an abrupt release of elements which normally would have become available gradually due to the slow decay of plant litter is observed in burnt areas (Daubenmire 1968, Khare *et al* 1985, Gupta and Singh 1995, Sundarapandian *et al* 1996). However, all this fertility is made available at once in the form of ash at the soil surface, where it is subjected to horizontal displacement by wind or water or perhaps to loss by leaching through the soil profile too quickly for it to be absorbed as colloids or taken up by soil organisms which fix it back into the system. Repeated fires thus make the soil mineral deficient and thus the plants which grow on them.

At Dhikala fire directly effects the crude protein value of the short grasses such as *Imperata cylindrica, Vetiveria zizaniodes, Arundinella benghalensis and Desmostachya bipinnata*, hence making them more palatable to the wild animals. This may be attributed to the removal of litter and the addition of ash which releases the free elements into the system.

4.5 Fire impact on woody species

Studies have shown that repeated fires generally promote grasses at the expense of woody species (Robertson and Lords 1957, Hare, 1961, Scott, 1971,Trollope;1971, Glover 1971) although a number of woody plants are extremely fire tolerant and even fire dependant. Increased number of grass and forb, flowers and seeds are usually

stimulated by burning (Curtis and Patch 1950 , Ehrenreich and Ackman 1963, Lemon 1967, Parnott 1967).

The reduction in the number of woody species present is usually offset by a corresponding increase in herbs (Collins,1992, Kiane and Arno 1990) Repeated burning in native grasslands communities generally does not reduce the species diversity and may even increase it by promoting growth of additional grasses, legumes and other forbs including annual plants. Dense stands of grass particularly sod-forming and rhizomatous tall grasses in wet habitats and species belonging to such monocotyledonous families as the Cyperaceae, Typhaceae and Juncaceae may be added in pure stands by burning (Chadokar, 1977) **(Appendix - II).**

Fires sometimes also create disturbed sites or pioneer conditions that permit invasion by certain opportunistic species such as annuals, or short-lived perennial and weedy natural or aggressive alien species (Stewart 1963, Antonio and Vitousek 1992).

In case of Dhikala chaurs it was observed that soon after the grasslands was burnt in late January , a dicot herb species *Artimisia nilagirica* was the first one to sprout in the tall grass areas **(Plate7).** Gradually more annual dicots started sprouting such as *Trichodesmium indicum, Helecteris isora, Leucas cephalos, Premna herbacea, Peucedamum dhana, Grewia elastica, Leucas cephalos, Evolvulus alsinoides, Vicoa indica and Curcuma augustifolia.* Certain xerophytic species such as *Zizyphus mauritiana* seems to benefit as the fire removes the necessary cover required for other

Plate 6 **Appearance of new flush after one week of prescribed burning**

shade loving species. *Cannabis sativa* , a weed has encroached upon almost all of the river bed islands and is gradually spreading from the forest-grasslands edges **(Appendix - III).**

There is a possibility that fire actually promotes the propagation of these species by preparing an optimum seed bed for the fire-resistant seeds. A further investigation in this matter is required.

CHAPTER FIVE

IMPACT OF PRESCRIBED FIRE ON ANIMALS AND BIRDS

5.1 Results

Chital pellet densities over the months for burnt and unburnt areas were compared using a t-test. They showed significant differences for the months of April and May. The average pellet groups being more in case of burnt areas (**Table 12**).

Table 12 Chital pellet groups over the months from the burnt and unburnt plots.

Month	Type	Sample size	Mean No. of Pellet groups	Standard Error	Test performed	p-value
DEC	UB	6	3.54	1.303	T-test For	0.3010
	B	6	2.75	0.664		
JAN	UB	6	4.51	1.893	Independent	0.104
	B	6	8.87	2.664		
FEB	UB	7	8.85	3.278	Samples	0.335
	B	7	10.90	3.379		
MAR	UB	10	6.55	0.245		**0.0159***
	B	10	14.29	0.167		
APR	UB	10	5.16	0.245		**0.0139***
	B	10	11.40	0.167		

UB = unburnt; B= burnt, *= significant

Animal densities for species such as chital and hog deer, were calculated using the transect data from January to April' 97. The grasslands was burnt on 22 February'97 (Table 13).

Table 13. Hog deer and chital densities and mean group size for the months of Jan- Apr'97

Species	Month	Density	CV	Group size	CV
Hog deer	Jan	20.657	52.41	5.29	42.36
	Feb	37.287	57.46	6.78	48.45
	Mar	60.31	49.48	10.09	37.25
	Apr	124.07	46.25	12.69	6.65
Chital	Jan	93.42	45.41	9.62	35.31
	Feb	271.36	25.26	44.52	20.64
	Mar	319.05	67.88	20.8	63.32
	Apr	266.64	34.9	14.21	30.22

CV = Coefficient of Variation

(iii) In case of birds the Menhinick's Index gave the bird species richness before and after the fire. There was an increase in the species number from 1.218 before the fire to 1.717 just after the fire to 2.074 after about ten days of fire. **(Fig 14)**

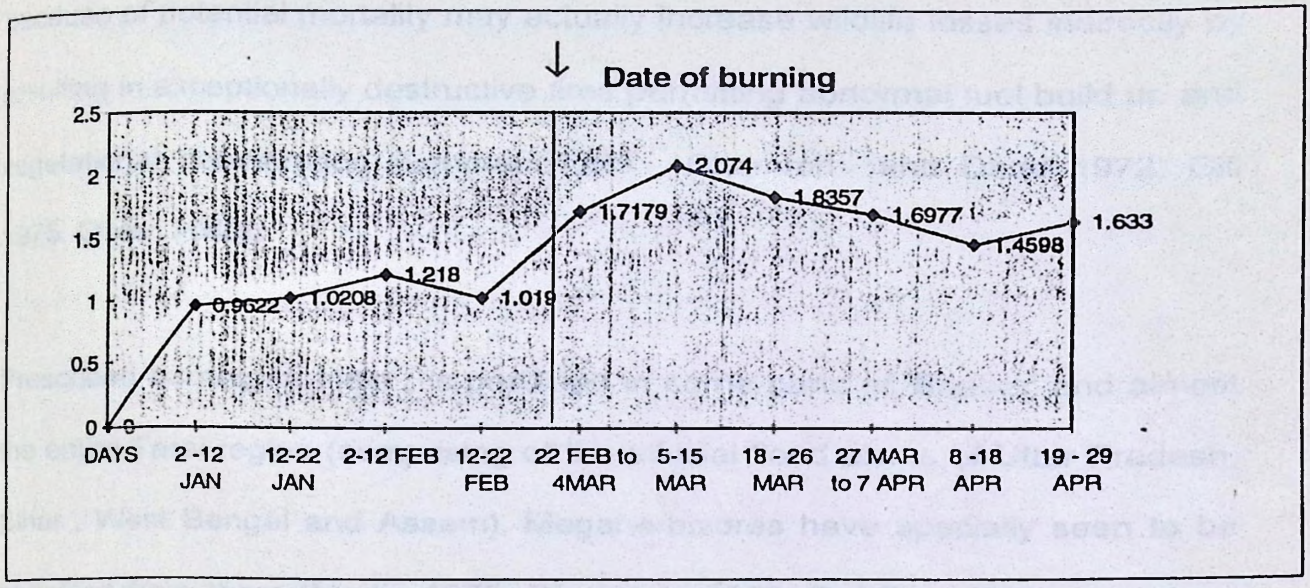


Fig.14 Bird species richness as observed from Jan.-Apr.97

5.2 Discussion

Majority of grasslands mammals and birds respond favourably to the changes created by the judicial use of controlled fire (Komarek 1969, Beck and Vogl 1972, Vogl 1974, Dodge 1972, Friend 1993, Moe 1994,)and the general benefits derived from improved habitats, increased productivity and growth stimulation (Leopold 1933, Vogl 1967, Cancelado and Yonke 1970, Hurst 1970, Riechert and Reeder 1972, Peek 1980). Instances of animal mortality however

specially in the case of reptiles and slow moving amphibians and ground nesting birds have been reported from uncontrolled grasslands fires (Vogl 1967, Brynard 1971, Moore 1977, Rahmani 1988).

But it is important to note that decision to exclude fires from grasslands because of potential mortality may actually increase wildlife losses indirectly by resulting in exceptionally destructive fires permitting abnormal fuel build up and vegetational deterioration (Lehmann1965 , Chamrod and Dodd 1972, Gill 1975, Oliver 1980).

Prescribed burning in India , is practised in some parts of 'Bhabar' and almost the entire Terai region (comprising of the alluvial flood plains of Uttar Pradesh, Bihar , West Bengal and Assam). Megaherbivores have specially seen to be benefited from them (Martin 1975, Dinerstein 1979, DebRoy 1986, Johnsingh 1986, Qureshi unpublished data). Animals are also known to selectively graze on the more palatable /nutritious species compared to the more coarse and unpalatable species.

Late burning has been proved detrimental specially in the case of ground nesting birds (Braithwaite and Estbergs, 1987). Studies have shown that prescribed burning has adversely affected the populations of the Bengal florican (*Eupodotis bengalensis*) ,the lesser florican (*Sypheotides indica*) and the Swamp partridge (*Francolinus gularis*) (Rahmani, 1988).

In Dhikala, the grass sprouts within 5-7 days of burning and the animals such as Chital immediately start feeding on it (**Plate 6**). Since rutting had not yet taken place completely (till April 1997), most of the male chital (pers.obs. during study) were in big bachelor herds sometimes comprising of as many as hundred animals. Similar observations were made by Schaller in February 1968 when he observed about 500 chital divided into 4 population units congregated on the Dhikala meadow (Schaller, 1968) The composition of the chital herds changes frequently and the herd size was to some extent influenced by the availability of food. Males seem to be using the grasslands more compared to the females who preferred to remain at the forest-grasslands edges.

Wild pigs are the first one to utilise the burnt grasslands, digging up for the tuberous roots. They seem to prefer burnt areas initially in the months of December to late February and as the season progresses from the winter to summer, areas with higher moisture are preferred.

Hog deer also seem to prefer burnt areas, but they remained confined to an area of about 2 km ^{2} characterised by partially burnt tall grasses. However, the fact that a fawn was born on one of the experimental grass plots also suggest that cover is very important for these grasslands specialists.

Sambar and barking deer preferred to remain at the forest-grasslands edges. Only twice were sambar encountered in the open grasslands which can be due

Plate 7 **Emergence of non-graminoid species immediately after burning**

to their movement towards the water. Elephants seldom used the grasslands in the first month after burning, however when the new grass was about 40 cm high, they fed on the chaurs in big herds during evening and retreated back in the forest by morning. By first week of May they were spending most of their time in the grasslands.

Post burn colonisation by birds was marked by seasonal as well as burnt and unburnt differences. Crow Pheasants(*Centropus sinensis)* which were seen in December in unburnt areas were never seen afterwards in the burnt grasslands (pers. obs.). Burning attracted a number of common swallows (*Hirundo rustica*) and black drongos (*Dicrurus adsimilis)* who continuously hovered above the fire trying to catch all the escaping insects. Crested bunting (*Melophus lathami*) were the first to colonise the charred areas. Collared bush chats (*Saxicola torquata*), Pied bush chats(*Saxicola caprata*), shrikes, munias, rollers, chats, pipits, larks, plovers, lapwings, warblers were some of the birds seen in the area **(Appendix - V).**

CHAPTER SIX

SPATIAL STRATEGIES FOR THE MANAGEMENT OF HOG DEER POPULATIONS

Wildfires are complex phenomena which are affected by several environmental and human factors that interact through complicated spatial processes(Burrough 1986, Roy *et al* 1991, Chou 1992, Baird *et al* 1994, Chuvieco and Salas 1996, Jain *et al, 1996*). Therefore many endangered or vulnerable species such as the Hog deer which are also habitat specialists require much attention when a prescribed burn is planned. Hog deer is listed as an endangered animal throughout much of its range in southern Asia (Dhungel *et al* 1992). Hog deer are presently listed in Schedule II of the Indian Wildlife Protection(Act) 1972. However , in view of the rapid loss of grasslands habitat there is a need to shift them into Schedule I of the Wildlife Protection(Act) (Pers. Comm. V.B.Sawarkar, 1997).

Hog deer have small home ranges (60-80 ha) and are sedentary preferring grasslands where food, cover and water are available (McCarthy and Dissanayake, 1994). *Saccharum* species, *Imperata cylindrica*, and C*ynodon dactylon* are preferred grass species for food and cover.

According to Blandford (1888-91), Lydekker (1898) and Prater (1985), the rut of the hog deer occur during September and October while Schaller (1968) observed the rut of the hog deer from June to January with a peak in September and October . After a gestation period of eight months the fawns are born in April and May. Although hog

deer are essentially solitary, they apparently congregate at the time of the rut at certain feeding sites.

Hog deer populations in CTR have fluctuated over the years **(Appendix - IV).**

An attempt has been made in this study to correlate various ecological parameters on which the data has been gathered with the hog deer abundance in order to determine suitability classes and to devise an appropriate spatial strategy for managing its populations.

To accomplish the above task help of Geographical Information System (GIS) technology has been taken. A GIS is a computer system which is capable of combining several layers of geographic data to produce outputs in the form of summary statistics and maps. Geographic data are data which can be related to specific locations on the Earth's surface. Roads, rivers, soils, vegetation and topography are examples of Geographic data that are now capable of being analysed and integrated to produce value added information sets. The utility of GIS lies in its ability to compress and integrate a number of varied and perhaps complex data sets such that the yields are understandable to a larger audience then would be the case if they were dealing with the raw data and mathematics (Garvey, 1994).

6.1 Methodology

The methodological steps for carrying out spatial analyses are given in Flow diagrams **(Fig 15, Fig 16).**

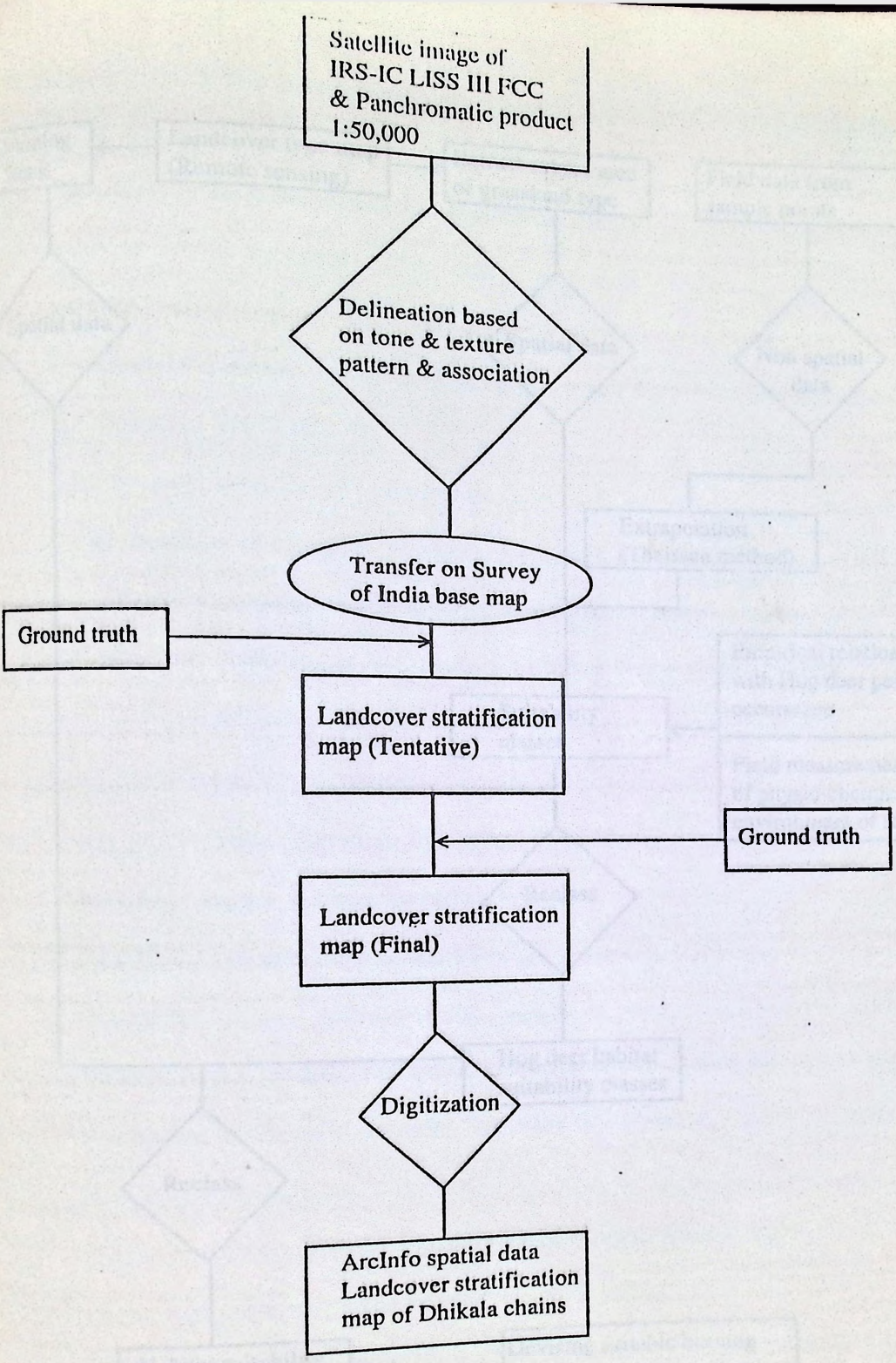


Fig 15 **Flow diagram for spatial analysis**

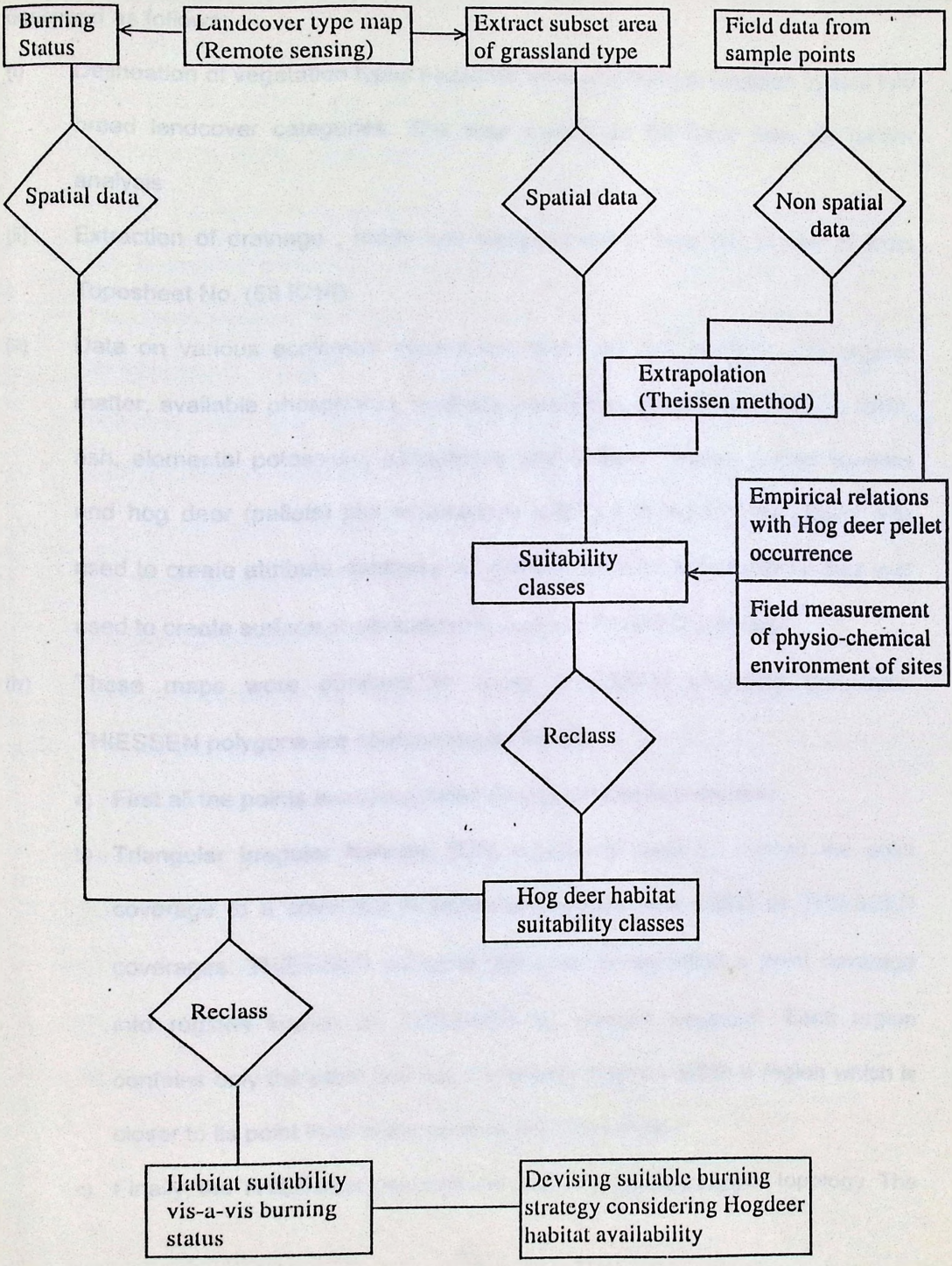


Fig. 16 Flow diagram for devising burning strategies for management of Hog deer population

The steps leading to the determination of suitability classes for hog deer can be described as follows:

(i) Delineation of vegetation types based on tonal and textural variation in data into broad landcover categories. This map served as the base map for further analysis .

(ii) Extraction of drainage , roads and sampling points from the Survey of India Toposheet No. (53 K/14).

(iii) Data on various ecological parameters (soil pH, soil moisture, soil organic matter, available phosphorus, available potassium, crude protein, ADF , lignin, ash, elemental potassium, phosphorus and sodium , above ground biomass and hog deer (pellets) plot occupance) collected in the Dhikala chaurs was used to create attribute database for different stratum. Subsequently data was used to create surface or attribute maps using ARC/INFO software.

(iv) These maps were obtained by using THEISSEN modelling procedure. THIESSEN polygons are constructed as follows:

a) First all the points are triangulated through a common identifier.

b) Triangular Irregular Network (TIN) module is used to convert the point coverage to a coverage of proximal polygons also called as THIESSEN coverages. THIESSEN polygons are used to apportion a point coverage into regions known as THIESSEN or Voronoi polygons. Each region contains only the point and has the unique location within a region which is closer to its point than to the point of any other region.

c) Finally, the THIESSEN polygons are built to generate polygon topology. The

location of the points are used as the label points for the THIESSEN polygons.

The above process can be diagrammatically represented as follows (ARC Commands, ESRI, 1994) **(Fig 17)**

v) Once the layers were generated , a coefficient correlation matrix between all the ecological parameters and hog deer pellet occupance was calculated . Parameters which were strongly positively / negatively correlated were selected for generating a hog deer habitat suitability class. It is to be noted however that only one parameter, (pH) was statistically significant, other parameters were also considered in model building as they are ecologically significant.

(vi) The layers were multiplied with their correlation coefficient to generate a hypothetical surface using the following equation:

Suitability Class = (0.56 pH + 0.27 Moisture) - (0.14 Crude Protein + 0.26 Available Potassium + 0.08 Fibre + 0.26 Elemental Potassium)

(vii) The suitability class so obtained reclassified using histograms to obtain five suitability classes as follows **(Fig 18).**

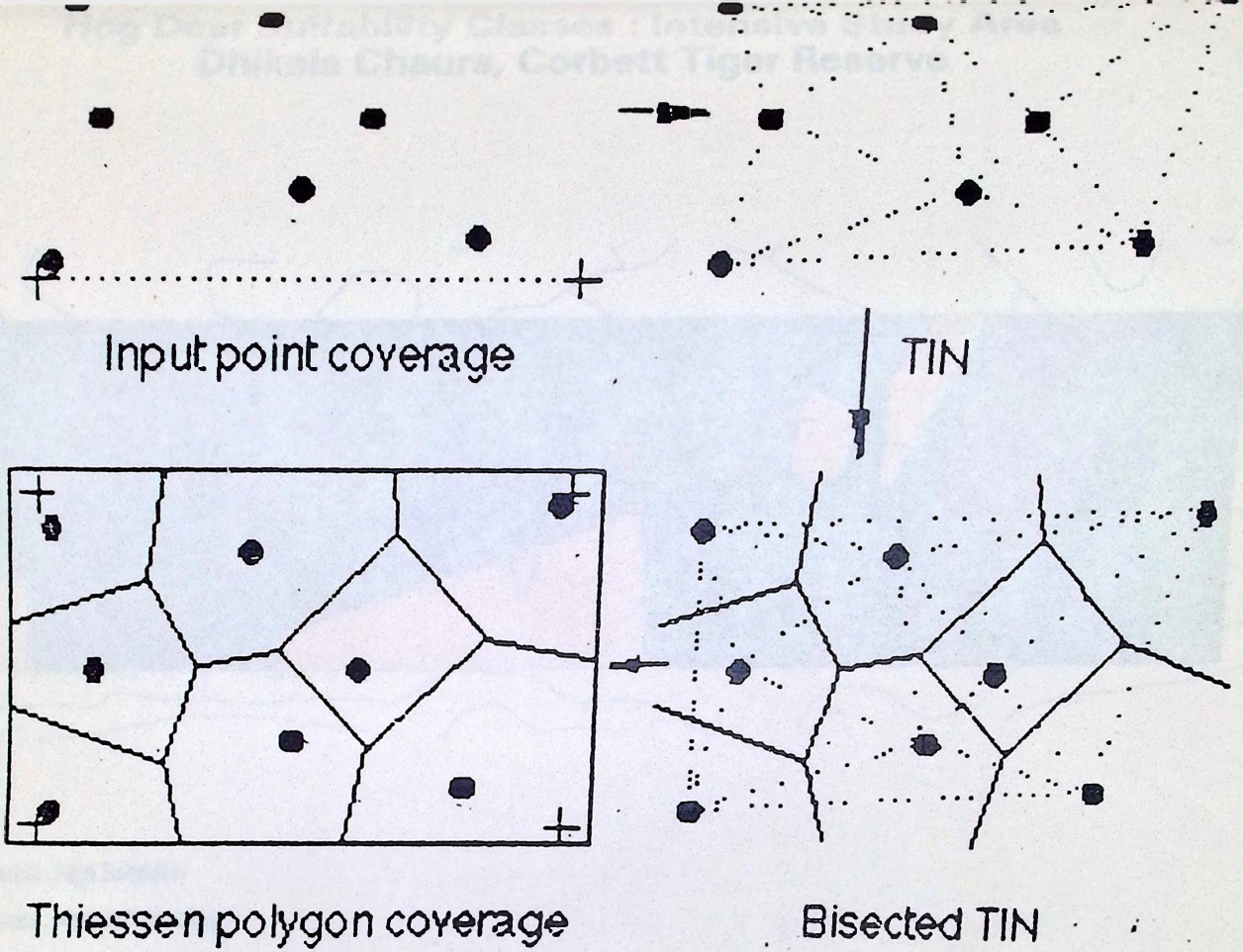
a. Unburnt - Highly suitable . Area equals 0. 5763 km^2

b. Unburnt - Medium suitable. Area equals 1.0326 km^2

c. Unburnt - Low suitable. Area equals 0. 3232 km^2

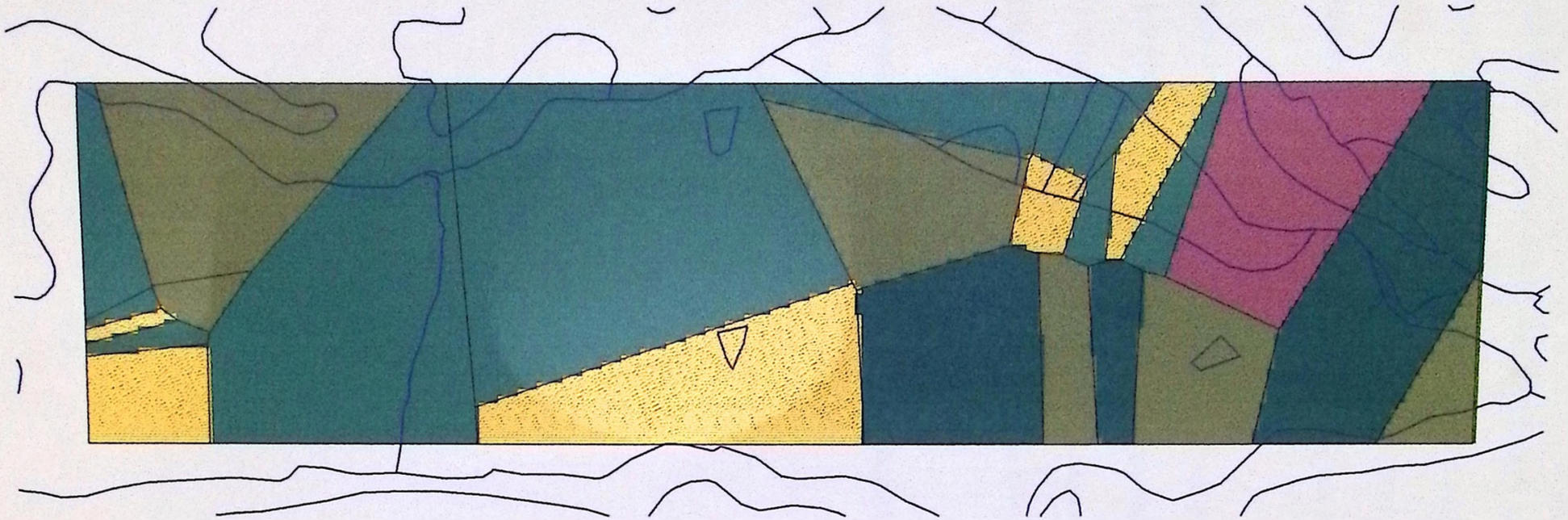
d. Burnt - Highly suitable. Area equals 0. 772 km^2

e. Burnt - Medium suitable. Area equals 1.7904 km^2



. Creation of THIESSEN polygon coverages.

Hog Deer Suitability Classes : Intensive Study Area
Dhikala Chaurs, Corbett Tiger Reserve



- Unburnt Grasslands : High Suitability
- Unburnt Grasslands : Medium Suitability
- Unburnt Grasslands : Low Suitability
- Burnt Grasslands : High Suitability
- Burnt Grasslands : Medium Suitability

N

0 0.4 0.8

Kilometers

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

GIS Cell June, 1997

6.2 Discussion

From the map generated it is clearly evident that highly suitable classes for hog deer occur both in burnt and unburnt patches. The unburnt patches meet the requirements for cover while the burnt patches provide palatable and nutritious forage. Thus it is critical to have a mosaic of burnt and unburnt patches on Dhikala chaurs.

The present burning practice at Dhikala is to leave small areas and burn the rest of the grasslands within a period of 5-6 days. A more appropriate strategy would be to burn the area in the two time periods with the first burn separated from the second by at least a month. Further areas of at least 1km^2 in size should be left unburnt .

There is a need to improve the above modelling by including all ecologically significant variables as well as enlarging the datasets.

CHAPTER SEVEN

MANAGEMENT IMPLICATIONS

The results of the present study and the experience gained in planning its methodology and implementing it in the field have several management implications. However it must be emphasized that this study is reporting results from a very short period of field work, spread over one winter season and partially covering a summer season,. Therefore , extrapolation of results should not be generally done and, if required must be done with abundant caution.

The results have indicated that soil nutrients are mobilized following a prescribed burn and a change in soil properties occurs. It is however more important to study the long term changes in soil organic matter levels, loss of substantial amounts of nutrients in smoke and the short circuiting of bio-geochemical pathways.

The effects of fire on fauna vary depending on the prescribed burning regime, including the intensity and frequency of burning as well as the season. In case of birds in the present study the bird species richness as measured but Menhinick's Index showed an increase in species number from 1.218 before the fire to 1.717 just after the fire to 2.074 after about ten days of fire. This could be due to arrival of species which are attracted to recently burnt sites because of increases in abundance or availability of food, such as the flushed out insects or seed fall. There is therefore a

need to assess effects of present prescribed burning management practices on all fauna and especially the rare and endangered ones and to incorporate ecological burning practices into fire management plans.

The study also highlights the need for conducting long term research on fire ecology and monitoring its impact as well as the integration of research findings into the management plans. Similarly , there is a need for improved communication between researchers and wildlife managers.

Professional fire management requires the continuing input of research data, but the transfer of these data and findings into meaningful and useable formats to management remains a challenge for both researchers and managers.

Finally a renewed interest in fire and grasslands is needed . The implications of this short term study is to make a beginning towards the understanding of the complex phenomenon that is **Fire**. More long term studies are required which are able to experiment in natural conditions . Fire behavior can be very heterogeneous across small distances and in similar fuels burnt at different times. New analytical methods need to be developed to explore the implications.

LITERATURE CITED

*AFOLAYAN,T.A. and FUJITSO,M.(1978). Seasonal variation in the protein content and the grazing of some tropical savanna grasses. *East African Wildland Journal*(16); 97-104.

AHLGREN,I.F. and AHLGREN,C.E.(1965).Effects of prescribed burning on soil micro-organisms in a Minnesota Jack-Pine Forest *Ecology*.(46);304-310.

ALLEN ,E .S.(1989).(edt).*Chemical analysis of ecological materials*. Blackwell Scientific Publications, Oxford .

ANTONIO,C.M.D. AND VITOUSEK,P.M.(1992).Biological invasions by exotic grasses, the grass/fire cycle and global change. *Annual Review of Ecology and Systematics*.(23)63-87.

ARC COMMANDS(1994). GIS by *ESRI* Inc.U.S.A.

BAIRD,I.A., P.C,CARLING AND J.R,IVE (1994).Fire planning for wildlife management: A decision support system for Nadgee Nature reserve Australia. *International Journal of Wildland fire* 4(2):107-121.

*BECK,A.M. AND VOGL,R.T.(1972)The effect of spring burning on rodent populations in a brush praire Savanna. *Journal of Mammalogy*(53)336-346.

BEGON, M, HARPER, J. L. and TOWNSEND,C.R.(1990). *Ecology, individual, population and communities*. Blackwell, Oxford.

*BISWELL,H.H.(1956).Ecology of California grasslands. *Journal of Range Management*(9);19-27

BISWELL,H.H.(1989).*Prescribed burning in California wildlands management*. University of California press. Berkely.

*BLANFORD,W.(1888-1891). *The fauna of British India*, Mammalia.London.

BOND,W.J. AND WILGEN.B.(1996).*Fire and plants*. Chapman and Hall. London.

BOR,N.L.(1960).*The grasses of Burma, Ceylon, India and Pakistan*. London, Permagon Press.

BRAITHWAITE,R. AND J,ESTBERGS (1987).Fire birds of the top end .*Australian Natural History* 22(7) 299-301.

*BRYNARD,A.M.(1971)Controlled burning in the Kruger National Park- history and development of a veld burning policy. *Proceedings of the 11th annual Tall timbers Fire Ecology Conference*;219-231.

BUCKLAND, S.T. ,.ANDERSON,D.R., BURNHAM,K.P. and LAAKE,J.L.(1993). *Distance sampling; estimating abundances of biological populations* . Chapman and Hall. London.

BURROUGH,P.A.(1986).Principles of geographical information systems for Land Resources assessment. *Monographs on soil and resources.* Survey No.12.Oxford Science publications.

*BURROWS,N.D, W.L,MACAW AND K.G,MAISEY (1987). *Planning for fire management in dry Andhra forests In: Nature conservation ;the role of remnants of native vegetation.*

*CANCELADO,R. and YONKE,T.R.(1970).Effects of prairie burning on insect populations. *Journal Of Kans Entomological society*(43);274-281.

*CHADOKAR,P.A.(1977).Establishment of Stylo(*Stylosanthes guianensis*) In Kunai (*Imperata cylindrica*) pastures and its effect on dry matter yield and animal production in the Markham valley, Papua New Guinea. *Tropical Grasslands*(11);263-277.

CHAMPION,H.G. and SETH,S.K.(1968). *A revised survey of the forest types of India.* Manager of publications. Nasik.

CHAMROD,A.D. and DODD,J.D.(1972).Prescribed burning and grazing for prairie chicken habitat manipulation in the Texas coastal prairie. *Proceedings of the 12th Annual Tall Timbers Fire Ecology Conference*;257-276.

CHOU,Y.H.(1992).Management of wildfires with a geographical information systems. *International Journal Of Geographical Information Systems*(6)2,123-140.

CHUVIECO,E., SALAS,J.(1996).Mapping the spatial distribution of forest fire danger using GIS. *International Journal of Geographical Information Systems*(10)3;333-345.

COLLINS,L.S (1992). Fire frequency and common heterogeneity in tall grass prairie vegetation. *Ecology* 73(6) 2001-2006.

COUTINHO,L.M.(1982).Ecological effects of Fire in Brazilian cerrado: In *Ecology of Tropical savannas*. B.J.Huntley and B.J.WALKER (edt).Berlin.Springer Verlag.273-291.

CRUTZEN,G.(1989). *A guide for prescribed fire in southern forests*. Technical publication .U.S. Department of Agriculture and Forest service ;Southern region.

*CURTIS,J.T. and PATCH,M.L.(1950).Some factors affecting flower production in Andropogon Gerardi. *Ecology*(31);488-489.

DABADGHAO P.M. AND SHANKARNARAYANAN,K,A,(1973).*The grass cover of India*. New Delhi,ICAR.

DAUBENMIRE ,R. (1968).Ecology of fire in grasslands. *Advances in Ecology*.Vol 5:209-267

DEBANO, L.F AND C.E,CONRAD (1978). The effect of fire on nutrients in a Chaparral Ecosystem. *Ecology* 59(3):489-497.

DEBROY,S. (1986).Fire in wet grasslands habitats of Assam. *The Indian Forester.* Vol 112(10). 914-918.

DHUNGEL,S.K. and BART W.O'GARA.(199?). Ecology of the hog deer in royal Chitwan National Park, Nepal. *Wildlife Monographs*(119).1-40.

DINERSTEIN,E.(1979).An ecological survey of the Royal Karnali- Bardia Wildlife Reserve, Nepal II.Habitat animal interactions. *Ecosystem properties*. 56-59

*DODGE,M.(1972). Forest fuel accumulation; A growing problem. *Science*.77:139-142.

*EHRENREICH,J.H. and AKMAN,J.M.(1963).An ecological study of certain management practises on native prairie in Iowa. *Ecological monographs*(33);113-130.

FRIEND,G.R.(1993).Impact of fire on small vertebrates in mallee woodlands and Heathlands of temperate Australia; A review .*Biological Conservation* 65(3);99-114.

*GARREN,K.H.(1943).The effects of fire on vegetation of the south eastern united states. *Botanical review* (9);617-654.

GARVEY, M.(1994). The use of Geographic Information systems to analyse wildfire threat. In*: Proceedings of conference on fire and biodiversity. Biodiversity Series*: Paper No.8. Department of Environment and Sports and Territories. Australia.

GOOD, R (1994). Fuel dynamics, pre-plan and future research needs. In*: Proceedings of conference on fire and biodiversity. Biodiversity Series*: Paper No.8. Department of Environment and Sports and Territories. Australia.

*GILL,M.A. (1975).Fire and the Australian flora. *Australian Forestry*.38:4-25.

*GLOVER P.E.(1971).Wildlife with a discussion on fire and other influences. *Proceedings of the 11th annual Tall Timbers Fire Ecology Conference*;319-336.

GOLDAMMER,J.G.(ed) (1990). *Fire in the tropical biota* :Ecosystem processes and global challenges. Springer-Verlag Berlin: 447-475.

*GOERING,H.K. AND VAN SOEST,P.J.(1970).*Forage fibre analysis apparatus, reagents, procedures and some applications.* ARS-US department Agricultural handbook No.379,Superitendant of Documents.U.S.govt. printing office.Washington D.C.

GUPTA, B AND K.B,SINGH (1995). Effect of burning on biomass production, nutrient and behaviour of mid-hill grasslands in Himachal Pradesh. *Range management and Agroforestry* 16(1): 51-59.

*HARE,R.C.(1961).*Heat effect on living plants*, USFS S.Forest Exp. Sta; 132-83.

*HAIG,I.T.(1938).Fire in modern forest management. *Journal of Forestry* (36);1045-1051.

*HOPKINS,B.(1963).The role of fire in promoting the sprouting of some savanna species. *Journal of west African Sciences*(7);154-162.

HURLBERT,S.H., (1984).Pseudoreplication and the design of ecological field experiments. *Ecological monographs*.54(2);187-211.

*HURST,G.A.(1970).The effects of controlled burning on arthropod density and biomass in relation to Bobwhite quail(*Colinus virginianus*) brood habitat. *P.hD thesis* Missisippi state University.

HUSTON, M.A.(1994). *Biological diversity; the coexistence of species on changing landscapes*. Cambridge University Press.

JACKSON,M.L.(1967).*Soil chemical analysis*. Prentice hall of India Pvt Ltd.New Delhi.

JAIN,A, S.A,RAVAN, R.K,SINGH, K.K,DAS AND P.S,ROY (1996). Forest fire risk modelling using GIS and Remote Sensing. *Current science*. :928- 933.

JAIN,S.KAND A.R.K,SASTRY (1983). *Botany of some tiger habitats in India*. B.S.I. 81 pp.

JOHNSINGH,A.J.T (1986).Impact of fire on wildlife ecology in two dry decidous forests in south India. *The Indian Forester* Vol 112(10):933-938.

JOHNSINGH,A.J.T AND J.JOSHUA (1994).Conserving Rajaji and Corbett National Park;the elephant as a flagship species. *Oryx* 28(2):135-140.

KAYLL,A.J (1974).*Use of fire in land management. in Fire and Ecosystems* .(edited by) T.T.Kozlowski and C.E.Ahlgren. Academic press, NewYork 542 pp.

KENT,M. and COKER,P(1992). *Vegetation description and analysis; a practical approach*.CRC press and Belhaven press.

KHARE,D.K.,P.K.KHARE AND G.P.MISHRA (1985).Effects of forest fire on soil nutrient levels in a Tectona grandis forest stand. In: *Ecology and Resource management in Tropics*, (eds) K.C.Misra. Bhargava book depot. Varanasi.

KIANE,R.E, S.K,ARNO (1990). Simulating cumulative effects in ponderosa pine/Douglas fir forests. *Ecology* 71: 191-203.

*KILGORE,B.M(1981).Fire in Ecosystem distribution and structure: *Proceedings of the conference on fire regimes and ecosystems.*

KOMAREK,E.V.(1969).Fire and animal behaviour. *Proceedings of 9th Annual Tall Timbers Fire Ecology Conference*;47-96.

KOZLOWSKI,T.T AND C.E,AHLGREN(1974).*Fire and Ecosystems.* Academic press New York 542 pp.

*KUCERA,C.L. and KOELLING,M.(1970). The influence of fire on composition of central Missouri Prairie. *American Midland Naturalist.*(72),142-147.

LAAKE,J.L., BUCKLAND,S.T., ANDERSON,D.R.(1994).DISTANCE: User's guide; Ver 2.1.Colorado Coop. Fish and Wildlife Research unit. Colorado State University. Fort Collins. Colorado.

LAMONT,B.B AND H.V,RUNISMAN (1993).Fire may stimulate flowering , branching, seed production and seedling establishment in two Kangaroo Paws(Haemodoraceae). Journal of Applied *Ecology*(30):256-264.

*LEHMANN,V.W.(1965).Fire in the range of Attwater's prairie chicken. *Proceedings of the 4th Annual Tall Timber's Fire Ecology Conference*;127-143.

*LEMON,P.C.(1967).Effects of fire on herbs of the Southeastern United states and Central Africa. *Proceedings of the 6th Annual Tall Timbers Ecology Conference*;112-127.

*LEOPOLD,A.(1933).*Game management.*Scribner's.New York.

*LEWIS,H.T AND FERGUSON,T.A (1988).Yards, corridors and mosaics:how to burn a boreal forest. *Human Ecology.* 16(1).

KHARE,D.K.,P.K.KHARE AND G.P.MISHRA (1985).Effects of forest fire on soil nutrient levels in a Tectona grandis forest stand. In: *Ecology and Resource management in Tropics*, (eds) K.C.Misra. Bhargava book depot. Varanasi.

KIANE,R.E, S.K,ARNO (1990). Simulating cumulative effects in ponderosa pine/Douglas fir forests. *Ecology* 71: 191-203.

*KILGORE,B.M(1981).Fire in Ecosystem distribution and structure: *Proceedings of the conference on fire regimes and ecosystems.*

KOMAREK,E.V.(1969).Fire and animal behaviour. *Proceedings of 9th Annual Tall Timbers Fire Ecology Conference*;47-96.

KOZLOWSKI,T.T AND C.E,AHLGREN(1974).*Fire and Ecosystems*. Academic press New York 542 pp.

*KUCERA,C.L. and KOELLING,M.(1970). The influence of fire on composition of central Missouri Prairie. *American Midland Naturalist*.(72),142-147.

LAAKE,J.L., BUCKLAND,S.T., ANDERSON,D.R.(1994).DISTANCE: User's guide; Ver 2.1.Colorado Coop. Fish and Wildlife Research unit. Colorado State University. Fort Collins. Colorado.

LAMONT,B.B AND H.V,RUNISMAN (1993).Fire may stimulate flowering , branching, seed production and seedling establishment in two Kangaroo Paws(Haemodoraceae). Journal of Applied *Ecology*(30):256-264.

*LEHMANN,V.W.(1965).Fire in the range of Attwater's prairie chicken. *Proceedings of the 4th Annual Tall Timber's Fire Ecology Conference*;127-143.

*LEMON,P.C.(1967).Effects of fire on herbs of the Southeastern United states and Central Africa. *Proceedings of the 6th Annual Tall Timbers Ecology Conference*;112-127.

*LEOPOLD,A.(1933).*Game management*.Scribner's.New York.

*LEWIS,H.T AND FERGUSON,T.A (1988).Yards, corridors and mosaics:how to burn a boreal forest. *Human Ecology*. 16(1).

*LLOYD,R.S.(1972).Effects of fire on a Derbyshire grasslands community .*Ecology*(53);915-920.

*LYDEKKER(1898).*The deer of all lands.* London.

MAGURRAN,A.(1988).*Ecological diversity and its measurements.* Croom Helm, London.

MALL,L.P. AND MEHTA,S.C.(1975).*The grasslands Fire*; An ecological study.School of Studies in Botany. Vikram University. Ujjain.291-297.

MARTIN,C.(1975).Status and ecology of the Barasingha (*Cervus duaucelli branderi*) in Kanha National Park . *Journal of Bombay Natural History Society.* 74:60-131.

McCARTHY, A.J. and DISSANAYAKE, S.B.(1994). Status of the Hog deer in Sri lanka. ORYX. 28(1);62-85.

MORENO,J.M AND W.C,OECHEL (eds)(1994).*The role of fire in mediterranean type ecosystem.* Springer-Verlag New York.

MOE,S.R.(1994).Distribution and movement pattern of deer in response to food quality and manipulation of grassy habitat;a case study with emphasis on Axis deer(*Cervus axis*) in lowland Nepal. *Doctor Scientiarum thesis.* Agricultural University of Norway.

*MOORE,C.T.(1977).Man and fire in the Central Northern American Grasslands 1535-1890. A documentary historical geography. *PhD thesis,*University of California.Los Angeles.

*MOTT,J.J.(1982).Fire in improved pastures of Northern Australia. *Tropical grasslands* 16(3):97-100.

MUELLER-DOMBOIS,D. and ELLENBERG,H.(1974).*Aims and methods of vegetation ecology.* John wiley and sons. New York.

NEGI,A.S (1994). Reorganised Corbett Tiger Reserve. *Corbett* vol 1

OJIMA,S,DENNIS, PARTON,W.J., SCHIMEL,D.S. and OWENSBY, C.E. (1990). Simulated impacts of annual burning on Prairie ecosystems.?

OLIVER,W.L.R.(1980).The Pigmy hog. Special Scientific report 1. *The Jersey Wildlife Preservation Trust. Jersey*, Channel Islands.

PANT,P.C.(1986).Flora of Corbett National Park. *Botanical Survey of India.* Dehradun.

*PARNOTT,R.T.(1967).A study of wire grass (Aristida strica Mich) with particular reference to fire. *M.A.Thesis*, Duke University, Durnham. North Carolina.

PATIL ,B .D. and PATHAK ,P .S. (1978). *Grasslands development in the Himalayas.(?).*

*PEEK,J.M (1980). Natural regulation of ungulates. *Wildland Society Bulletin*.8(3):217-227.

PICKETT,S.T.A, and WHITE,P.S.(edt)(1985).*The ecology of Natural disturbance.* Academic press.New York.

*POTTS,P.J.(1989).A handbook of Sillicate rock analysis. Glasgow and London.Pant,P.C.(1986).Flora of Corbett National Park. *BSI Dehradun.*

PRATER,S.(1985).The book of Indian animals ,*BNHS*,Bombay.

RAHMANI,A.R.(1988).Grasslands birds of the Indian sub continent; A review in Ecology and Conservation of grasslands Birds. P.D.Goriup(edt).*ICBP Technical publication.*

REDMANN,R.E.(1992).Primary production in ecosystems of the world.(*Natural grasslands*). R.T.Coupland (edt). Elsivier. Netherlands;75-93.

*RIECHERT,S.E. and REEDER,W.G.(1972).Effects of fire on spider distribution in southwestern wisconsin Prairie. *Midwest Prairie conference*;73-90.

*ROBERTSON,J.H. AND LORDS,H.P.(1957).Survival of rabbit brush species following chemical burning and mechanical treatments. *Journal of Range Management*(10)83-89.

RODGERS,W.A (1986).The role of fire in the wildlife habitats:A review. *The Indian Forester* Vol 112(10):845-857.

ROY,P.S, S,JONNA AND D.N,PANT (1991). Evaluation of grasslands and spectral reflectance relationships to its biomass in Kanha National Park. *Geocarto International* (1):39-46.

SAWARKAR,V.B (1986). Fire fighting in India's wildlife areas today. *The Indian forester.* Vol 112(10):926-932.

SCHALLER,G.B.(1967). *The deer and the tiger.* A study of wildlife in India. The University of Chicago press. Chicago and London.

*SCOTT,J.D.(1971).Veld burning in Natal. *Proceedings of the 11th Tall Timbers Fire Ecology Conference*;35-51.

SINGH,A (1987). Corbett National Park: an overview.Wildlife preservation organisations.

SINGH,R.S., SRIVASTAVA,S.C., RAGHUBANSHI,A.S., SINGH,S.and SINGH , S .P.(1991).Microbial C,N and P in Dry tropical savanna; effects of burning and grazing. *Journal of Applied Ecology*(28);869-878.

SKERMAN,P.J. AND RIVEROS,F.(1990).*Tropical grasses.* Fao scientific publishers. P.O.Box9.Jodhpur.

SOKAL,R.R.AND ROHLF,F.J.(1995).*Biometry III* edn.W.H.Freeman and Company.New York.

SOUSA,W.P.(1984).The role of disturbance in natural communities. *Annual Review Of Ecology and Systematics.(*15);353-91.

STANTON, N.L.(1988).The underground in grasslands. *Annual Review of Ecology and Systematics* 19:573-89.

STEWART,O.C.(1963).Fire as the first great force employed by man:*In man's role in changing the face of the earth* . W.L.Thomas(edt);115-133.University of Chicago Press,Chicago,Illinois.

SUNDARAPANDIAN, S.M, S,CHANDRASEKHARAN AND P.S,SWAMY (1996). Influence of disturbance on fire root biomass and productivity in two deciduous forests of Western Ghats. *Current Science* 70(3):242-246.

SUNDRIYAL,R.C.(1995).Grasslands forage production and management in the Himalayas; a review. *Journal of Hill Research* .8(2),135-150.

*THOMPSON,M. AND WALLS,J.N.(1989) *Handbook of ICP Spectrometry*,2nd edn.Chapman and Hall.New York.

*TROLLOPE,W.S.W(1971).Fire as a method of eradicating Macchia vegatation in the Amatola mountains of South Africa .experimental and field scale results. *Proceedings of the 11th Annual Tall Timbers Fire Ecology Conference*;99-120.

*VAN SOEST,P.J.(1963).Use of detergents in the analysis of fibrous feeds,II. A rapid method for the determination of fibre and lignin. *Associated official agricultural chemistry*.46(5);829.

*VIRO,P.J.(1969).Factorial experiments on forests, humus decomposition. *Soil Science*(95);24-30.

*VOGL,R.J.(1967a).Controlled burning for Wildlife in Wisconsin. *Proceedings of the 6th annual Tall Timbers Fire Ecology Conference*;76-109.

VOGL,R.J.(1974).*Effects of fire on grasslands.In fire and ecosystems* (edited by) T.T.Kozlowski and C.E.Ahlgren. Princeton University press.

* Literature not seen in original.

Appendix I

Grasses and dicots as recorded in Dhikala chaur.

Grasses	Herbs	Shrubs	Trees
Andropogon sp	*Blumea laciniatea*	*Artimisia nilagirica*	
Apluda mutica	*Blumea mollis*	*Casearia tomentosa*	*Bombax ceiba*
Aristida cynantha	*Cannabis sativa*	*Clematis gouriana*	*Bombax ceiba*
Arundinella benghalensis	*Cirsium arvense*	*Ehretia acuminata*	*Cordia dichotoma*
Arundinella setosa	*Crotolaria albida*	*Eupatorium adenophorum*	*Cordia dichotoma*
Axonopus rotundifolius	*Curcuma augustifolia*	*Glycosmis pentaphylla*	*Dalbergia sissoo*
Cenchrus cilliaris	*Desmodium gangeticum*	*Grewia elastica*	*Dalbergia sissoo*
Chrysopogon fulvus	*Dicliptera roxburghii*	*Helicteris isora*	*Litsea chinensis*
Cymbopogon flexuosus	*Evolvulus alsinoides*	*Holarrhena antidysenterica*	*Lagerstromia parviflora*
Cymbopogon martinii	*Indigofera hamiltonii*	*Zizyphus mauritiana*	*Murraya paniculata*
Cynodon dactylon.	*Leucas cephalotes*		*Shorea robusta*
Desmostachya bipinnata	*Peucedamum dhana*		*Syzigium operculatum*
Imperata cylindrica	*Pogostemon bengalense*		
Neyraudia arundinaceae	*Premna herbaceae*		
Oplismenus burmanii	*Salvia plebeia*		
Phragmites karka	*Trichodesma indicum*		
Poa species	*Vernonia sp*		
Saccharum benghalensis	*Vicoa indica*		
Themeda arundineceae			
Thysanolaena maxima			

APPENDIX II

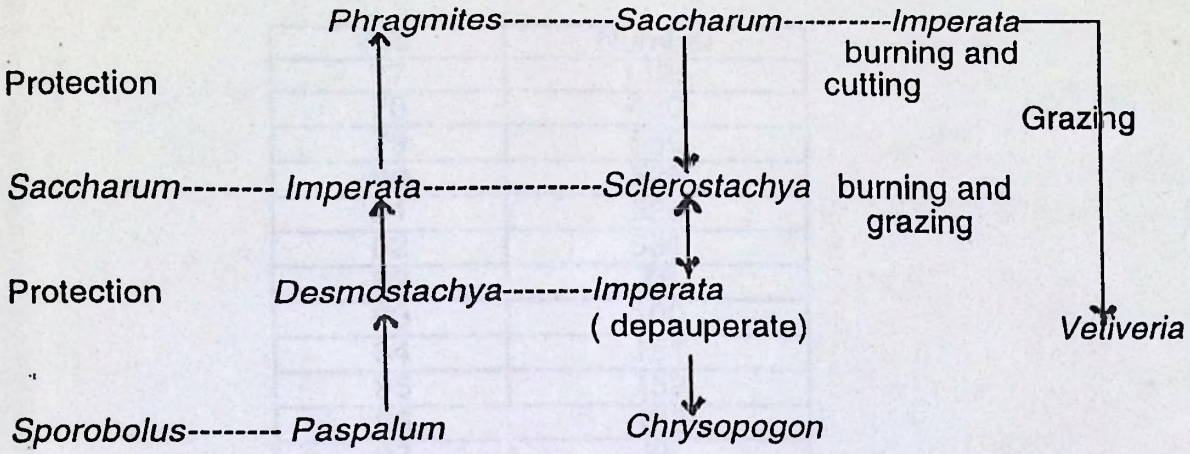
Certain grass genera and their habit with respect to burning
Source : (Skerman and Riveros, 1990)

Genus	fire tolerance	palatability
Andropogon sp	tolerates fire, early dry season promotes growth.	Crude protein 1.5 %when mature.
Aristida sp	fire no effect	
Axonopus sp	survives a fire, but owing to its habit fires are infrequent.	Crude protein 1.8 % when mature
Cynodon dactylon	variable perennial, will stand fires due to the extensive rhizome development	
Chrysopogon sp	prefers moist soils, probably represents the last stage in the deterioration of the Phragmites /Saccharum/ Imperata grasslands.	Crude protein 8.3-14 % when mature
Cymbopogon sp	very resistant to fire and too frequent burning is one of the main causes for its spread, annual burning reduces the size of the plant but does not improve the sward.	Crude protein 1.8 % when mature
Heteropogon contortus	ability to spread naturally if the area is frequently burnt. The seeds survive by burying themselves	Crude protein 5 % when young
Imperata cylindrica	frequent fire encourages the uniformity of an Imperata sward and generally it occurs as a fire disclimax.	Crude protein 10 % when young and 3 % when mature. Wild pigs feed on the rhizomes.
Phragmites karka	tolerates flooding but disappears quickly under the impact of burning and cutting.	Crude protein 1.8 % when mature
Saccharum spontaneum	if theses stands are burnt early before the rains they are ousted by *Imperata* grasslands.	Crude protein 5 -3% when mature
Themeda arundinacea	burning encourages its germination	
Cenchrus cilliaris	Will stand the impact of burning, the crown will not burn and nutritive value may improve	very palatable when young and remains fairly palatable at maturity.

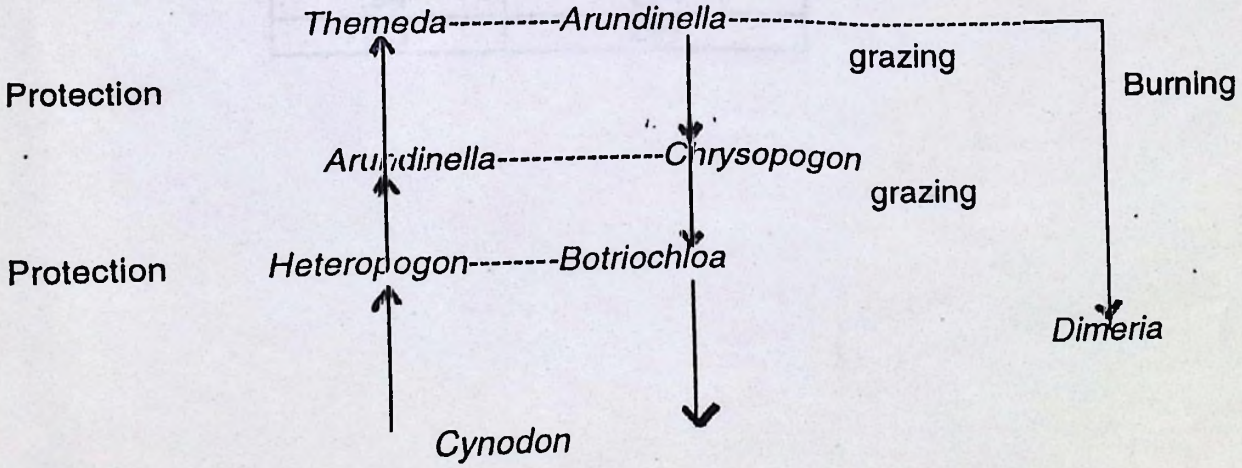
APPENDIX III

Source: Patil and Pathak (1978)

1.Succession in *Phragmites-Saccharum-Imperata cover.*



2. Succession in *Themeda-Arundinella* cover



APPENDIX IV

Hog deer populations at Corbett Tiger Reserve from 1977 to 1995 (Source:Research cell Corbett Tiger Reaserve).

Year	Number
77	1125
78	430
79	550
80	525
81	528
82	531
82	76
83	100
84	151
85	159
86	188
87	88
88	127
89	135
90	173
91	--
92	210
93	270
94	274
95	291

Appendix V

Lists of Birds seen at Dhikala during bird transects from Jan'97 to Apr'97.

Black Drongo	*Dicrurus adsimilis*
Black Partridge	*Francolinus francolinus*
Black Winged Kite	*Elanus caeruleus*
Blossom Headed Parakeet	*Psittacula cyanocephala*
Collared Bush Chat	*Saxicola torquata*
Common Myna	*Acridotheris tristis*
Crested Bunting	*Melophus lathami*
Crested Serpent Eagle	*Spilornis cheela*
Green Bee-eater	*Merops orientalis*
Haircrested Drongo	*Dircurus hottentottus*
Hoopoe	*Upupa epops*
Indian Peafowl	*Pavo cristatus*
Indian Ringdove	*Streptopelia decaocto*
Indian Robin	*Saxicoloides falicata*
Indian Roller	*Coracias benghalensis*
Jungle Babbler	*Turdoides striatus*
Jungle Crow	*Corvus macrorhynchos*
King Vulture	*Sarcogyps calvus*
Magpie Robin	*Copsychus saularis*
Marsh Harrier	*Circus aeruginosus*
Pariah Kite	*Milvus migrans govinda*
Pied Bush Chat	*Saxicola caprata*
Purple Sunbird	*Nectarinia asiatica*
Red Junglefowl	*Gallus gallus*
Red Munia	*Estrilda amandava*
Red Wattled Lapwing	*Vanellus indicus*
Redvented Bulbul	*Pycnonotus cafer*
Roseringed Parakeet	*Psittacula krameri*
Rufousbacked Shrike	*Lanius schach*
Scarlet Minivet	*Pericrocotus flammeus*
Spotted Dove	*Streptopelia chinensis*
Streaked Laughing Thrush	*Garrulax lineatus*
Verditer Flycatcher	*Muscicapa thalassina*
Whitecheeked Bulbul	*Pycnonotus leucogenys*
Whitenecked Stork	*Ciconia ciconia*