



Grassland and Fodder Resources of India: Area and Productivity

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FOREWORD

भारतीय कृषि अनुसंधान परिषद
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FOREWORD

The maintenance and advancement of animal husbandry, a crucial component of Indian agriculture, depends on grasslands, pastures, and fodder resources. However, the lack of nutrient-rich forage and feed and the animals' reduced production capacity are the major causes of the country's poor livestock performance. Henceforth, providing productive animals with a sufficient amount of high-quality fodder is essential to the livestock industry's profitability. Circumstantially, significant national efforts have been made to estimate the quantity of the herbage by cultivating potential and enhanced grass/legume species in marginal, sub-marginal, and degraded habitats.

The present bulletin focuses on area, production, and productivity of grasslands, pastures, and fodder resources including vegetation coverage and grassland degradation evaluation based on mutual data resource, remote sensing monitoring and driving mechanism exploration. It aims to provide a guide seeking to understand the overall situation of grasslands, pastures, and fodder resources in India in the context of global climate change and build a scenario for improving the situation. I believe it will be an essential reference to the terrestrial ecosystem carbon cycle and degraded grassland ecological restoration programme also. Contents are carefully developed to cover (1) situation of grasslands, pastures, and fodder resources in India; (2) spatial-temporal grassland coverage in India; (3) spatial-temporal coverage of fodder crops in India; (4) area, production, and productivity of grasslands, pastures, and fodder resources in India; (5) grassland degradation evaluation based on remote sensing.

The new scenario make it a valuable read for researchers on land, ecosystem, carbon cycle, ecosystem degradation, remote sensing as well as organizations engaged in eco-restoration practices.

Attempts made by Dr J. P. Singh and his team in compilation of important information on various grasslands, pastures and fodder resources are appreciable. I hope this bulletin will be useful to all those engaged in forage production, feed resource development and livestock management.


(T R Sharma)

Place : New Delhi
Dated 26th October 2023

PREFACE

Animal husbandry has been a vital component of the traditional setup of rural livelihood patterns. The dependence upon pasture and fodder crops has been the major source of feed demand and supply scenarios. At national and international forums, there is a pressing need to improve grasslands and other grazing resources, not only for the purpose of considering feed sources but also as a source of revenue for pastoral communities that are poor and marginal. Grasslands in the Indian sub-continent are particularly vital as they have evolved under varied ecological conditions, edaphic, bio-edaphic and climatic climaxes, each stage harbouring a rich array of flora and fauna. However, these are degrading rapidly due to lack of proper management, overgrazing and deforestation, besides, conversion to croplands due to invasion, diversion and allotment for other uses. Anthropogenic pressures, rampant landfills, habitat fragmentation, proliferation of invasive species and the influence of climate change has further added to risks to grasslands. The losses to grasslands will definitely have far-reaching consequences leading to loss of biodiversity, ecosystem imbalances and potential biomass availability.

There are multiplicities of fodder crops mostly occupying area in minute pockets. Further threatened cuttings makes it difficult and complex to monitor crops using remote sensing tools at state or national level. No reliable or government agency is taking data of forage area cultivation except for Punjab or may be one or two more states. The knowledge base of IGFRI, its regional research centres and AICRP on Forage crops and Utilization was used to estimate the area under fodder crops in different states. AICRP forage has centres in 22 locations spread in 21 states operating through several decades. The GFY data obtained from fodder crops were converted to DM (dry matter).

In the compilation, the authors made efforts to precisely estimate the acreage and productivity of grasslands of the country using geospatial technology and ground truthing. Authors also calculated the fodder productivity in different season to reach a comprehensive, precise and reliable database, to be utilised by policy makers and planners at national level. We put on record our gratitude to the ICAR, New Delhi, Director IGFRI, National Account Division, Ministry of Statistics and Program Implementation, and the IGFRI and AICRP FCU fraternity for their valuable guidance and encouragement. We duly acknowledge the contribution of our Young Professional, Lokendra Batham for data collection and processing.

Authors

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1. The Inception of Study

ICAR-Indian Grassland and Fodder Research Institute (ICAR-IGFRI), Jhansi and National Account Division (NAD), Ministry of Statistics and Programme Implementation, Government of India conceptualized and executed a collaborative project for estimation of area under fodder / grassland and productivity with the intent to generate and update the forage production data for the country. In parts of the country, IGFRI had earlier carried out similar assignments. In view of the importance of the study, IGFRI formulated the project. After several rounds of discussion and modifications, the present activity was carried out under the project entitled “Study on Productivity of Fodder and Grass” since November 2019.

2. Background Knowledge Base

Much earlier than recorded history, grasses have provided food, shelter, medicine and sports for man. Domestic animals and many types of wildlife are directly or indirectly dependent upon grasses and grassland for food, shelter and even for the completion of their life cycle (G. P. Roy 1984). The evolution of man and his present position in the biological world has been significantly affected by grasses. The historical records suggest that most of the world's civilisations developed around the regions of grassland. It would not be unfair to say that the human population has attained its present level of civilisation and development due to abundance and widespread distribution of grasses on this earth. Further, it may be added that without grasses not only human population but even the very survival of animals also seems to be obscured. The first article dealing with grasses was published in 1708 by Johann Scheuchzer, entitled “*Rostographiae Heevetica Prodomus*”. This may be considered as the beginning of Agrostology. Linnaeus in 1753, listed only a few genera like *Andropogon*, *Cenchrus*, *Panicum*, *Hordeum*, *Triticum* and *Phalaris*. During the 19th century, there was a general shift in the objectives of systematics to the grouping together of morphologically similar plants: this came to be known as natural classification. In his system, 13 tribes grouped into two sub-families namely Panicoideae and Pooideae were recognised, mainly based on morphological characters of the inflorescence and flower. This treatment was presented in *Genera Plantarum* by Bentham (Bentham 1883) and was followed by Hackel (1896). Between 1950 and 1960, much has been accomplished regarding grass systematics, and attempts were made to collect and correlate the results leading towards the phylogenetic arrangement of the major groups of Gramineae (Hitchcock 1920; Hitchcock 1933; Bews 1929).

Natural grassland is an ecosystem in which the perennial grasses are dominant species. In such systems, trees or shrubs are either absent or if present, are few in number. In general grasslands are defined as land covered with graminoid vegetation having less than 10% tree and shrub cover (F. White 1983; Hall, House, and Scrase 2000). The vegetation of grassland in this context is broadly interpreted to include grasses, legumes and other forbs and at times woody species may be present (Allen et al. 2011). Grasslands are known by many names around the globe, such as prairies in North America, Savannah in East Africa, Pampas in Argentina, Compose in Brazil, Llanos in Venezuela, Veld in South Africa, Downs in Australia, Steppes in central Eurasia and Puszta in Hungary.

Grasslands are found at the place where rainfall is intermediate, not as high as to form a forest or woodland and not as low as to experience desert. Worldwide, grassland ecosystems are predominant in the areas of low to moderate annual precipitation, relatively thin soil, and naturally controlled by fire, grazing, drought and extreme fluctuation in temperatures. Grasses and grasslands occur from the equator to the poles on all continents except Antarctica and together with the grazing animals that coevolved with them, constitute the world's major food and biodiversity resources. White et al (2000) has precisely narrated that 'Mankind has depended upon them for his existence ever since our remote ancestors ventured onto the savannahs and began a new mode of existence'. Grasses and grasslands have assumed immense ecological and economic significance for humans, and have strongly influenced the agrarian, agro-pastoral and pastoral communities since the dawn of civilization.

Grasslands produce forage for domestic livestock, which in turn support human livelihoods. Grassland is a highly dynamic ecosystem and supports flora, fauna, and human populations worldwide. It includes rangelands, pasturelands & old fallow lands and eventually fodder crops expanding approximately 3.5 billion ha. It contains about 20% of the world's soil carbon stocks (Ramankutty et al. 2008; FAOSTAT 2009).

The multifunctional grasslands and rangeland constitute the largest ecosystems in the world and contribute to the livelihoods of more than 800 million people, including about 100 million in arid zone only, by providing forage for over 360 million cattle and 600 million sheep and goat, food, wildlife habitat in addition to contributing to carbon sequestration and water harvesting (FAO 2010).

The earth's total land surface (134.05 million km²) comprises 30-31% forest areas (FAO 2010), 26% grasslands, 10-11% croplands and 6.8% other land uses (Panunzi 2008). The world area of pasture and fodder crops was 3.5 billion ha (35 000 000 km²) in 2000 i.e. 26% of the world land area and 70% of the world agricultural area. However, owing to several socio-political reasons, area under pasture and fodder crops is decreasing fast in many tropical countries, although it has shown some increase in Europe and parts of Asia.

According to Zhaoli (2004), the grasslands make 70% of the world's total area where arid and semiarid grassland ecosystems are approximately 45% of the earth's land surface and represent nearly 80% of the areas grazed by livestock. More than 38% of the global populations live in grasslands and a great proportion of the world's poorest are settled on the very ecosystem (Nalule 2010).

Traditional predominance of a mixed farming system characterizes the Indian agriculture system, which is a well-knit combination of crop production and livestock rearing. Livestock rearing is a major source of income, employment and livelihoods for rural families. Livestock production is the backbone of Indian agriculture, contributing >4% to national GDP and providing a source of employment and the ultimate livelihood for 70% of the population in rural areas (A. K. Roy and Singh 2013). Milk alone is credited with one fourth of the increase in total output of agriculture and allied sectors between 1970-71 and 2020-21. Milk production is projected to grow at 6 percent per year in the country as seen in the last decade. Dairy sector contributes one fourth of the total income generated in the agriculture sector and this share has been rising. India now produces nearly one fourth of world milk output. Another positive aspect is that it is pro poor and pro women (Chand 2023). However, according to FAO, milk yield of Indian cows is only 2/3rd of the World average and it is much less compared to milk yield in developed countries. Average milk yield of the world per cow is 7.2 kg and the Indian average is 4.87 kg.

Compound growth rate of milk and meat during 1996-97 to 2021-22 was 4.71% and 6.72% respectively. If we compare the per capita production, it is 154.9 kg/year for milk and 6.6 kg/ year for meat which is a quantum jump from comparative figures of 71.5 and 1.9 respectively in 1996-97. India's livestock sector is one of the largest in the world, with a livestock population around 535.78 million, which is expected to grow at a rate of 0.55% in the coming years. India has 56.7% of the world's buffaloes, 12.5% of the cattle, 20.4% of the small ruminants, 2.4% of the camels, 1.4% of the equines, 1.5% of the pigs and 3.1% of the poultry.

A quick analysis of Livestock population based on census 2012 to 2019, indicate a steady growth on two broad fronts - (i) an increase in the number of stall-fed female bovine livestock, including buffaloes (8.61% increase) and crossbred cows (26.9% increase), owned mainly by people with arable land and resources to grow or procure green fodder. (ii) an increase in the number of small ruminants – goats (10.1% Increase) and sheep (14.1% increase) surviving mainly by free grazing on available pasture lands and tree foliage. The number of female bovines in India increased from 122.7 million in 1972 to 246.7 million in 2019 (BAHS 2019, 2012).

Many of the natural grasslands have degraded due to overgrazing in addition to conversion of large areas to plantations/ protected areas/industrial establishments. Under the British, nomadic pastoralists were sedentarized, and the grasslands they depended on were converted to agriculture leading to salinization of these soils and rendering once productive grasslands to wastelands. This ignores the fact that grasslands

in India have existed as natural ecosystems as far as 50 million years ago as evidenced by fossil records (Vanak et al. 2015).

Since the dawn of civilization, grasslands in India have existed as natural ecosystems. Our cultural diversity including the traditional mixed farming system coupled with agro-climatic variation have led to wide diversity in both our livestock population, breeds as well as grassland types. Our Indigenous traditional knowledge about the livestock breeding and their maintenance since the Vedic period have enriched and helped in conservation of traditional grasslands.

Grasslands in the Indian sub-continent are particularly interesting as they have evolved under varied ecological conditions and represent at places edaphic, bio-edaphic and climatic climaxes, each stage harbouring a rich array of flora and fauna. They support a high density of domestic livestock, which form the backbone of rural livelihood. However, most of the grasslands in the sub-continent are degrading rapidly due to lack of proper management. It will have far-reaching consequences including loss of biodiversity, ecosystem services and human well-being.

Since its inception in 1929, Indian Council of Agricultural Research, limelighted the importance of grasslands through deliberations in Animal Husbandry, Crop and Soil Wings of the Board of Agriculture and Animal Husbandry in India and through financing pasture research schemes. The need for such ecological survey was considered in the 9th Meeting of Animal Husbandry Wing held at Izatnagar in March, 1951. A scheme for the survey of Grassland in Rajasthan was submitted in 1952, by the Indian Agriculture Institute, New Delhi. In 1952-53 on the recommendation of Dr. R.O. White, in his capacity as FAO Grassland and Fodder advisor, Indian Council of Agricultural Research accepted a comprehensive research scheme on the Grassland and Fodder Research in India with *inter alia* included the conduct of a 5-years “Reconnaissance Survey of Grasslands in India”. From 1954-62 the survey was conducted.

Since establishment (1962) the main research activities of ICAR-Indian Grassland and Fodder research Institute have been (i) the management of grasslands and (ii) development of fodder crop varieties and agro-techniques. In the past 6 decades, ICAR-Indian Grassland and Fodder Research Institute has worked on these two aspects and generated technologies to enhance the quality forage availability. Natural grazing lands and cultivated fodder crops play role in the improvement of balanced regional socio-economic prosperity in an eco-friendly way as well as rational land resource utilization capacity.

2.1 First reconnaissance survey of grasslands

Grassland is a highly dynamic ecosystem and supports flora, fauna, and human populations worldwide. It includes rangelands, pasturelands and

other fallow lands and fodder crops covering approximately 3.5 billion ha (both irrigated and unirrigated). The first survey of grasslands of India conducted during 1954 to 1962 (Dabadghao and Shankarnarayan 1973) revealed five major grass covers based on distribution and species dominance. The distribution of grasses was primarily governed by climatic factors, latitudinal influence followed by altitude and topography, the soil moisture relationship etc. Based on reconnaissance survey, five grass covers were identified as *Sehima-Dichanthium* type, *Dichanthium-Cenchrus-Lasiurus* type, *Phragmites-Saccharum-Imperata* type, *Themeda-Arundinella* type and Temperate Alpine type (Fig. 1). Brief description of each grass cover are listed below:

- 2.1.1 *Dichanthium-Cenchrus-Lasiurus* type:** This is associated with sub-tropical arid and semi-arid regions comprising the northern portion of Gujarat, the whole of Rajasthan, excluding the Aravalli ranges in the south, western Uttar Pradesh, Punjab, Haryana and Delhi State with a coverage of more than 436,000 km² between 23° N - 32° N and 68° E - 80° E. The principal perennial grass species are *Cenchrus ciliaris*, *C. setigerus*, *D. annulatum*, *Cymbopogon jawarancusa*, *Cynodon dactylon*, *Eleusine compressa*, *Lasiurus indicus*, *Sporobolus marginatus*, *Dactyloctenium indicum*, *Desmostachya bipinnata* etc. Important associate species are: *Chloris*, *Desmostachya*, *Heteropogon contortus*, *Saccharum bengalense*, *Vetivaria zizanioides* etc.
- 2.1.2 *Sehima-Dichanthium* type:** It is spread over the whole of Peninsular India, including the Central Indian Plateau, the Chhota Nagpur Plateau and the Aravalli ranges with coverage of approximately 1,740,000 km² between 8° N - 28° N and between 68° E - 87° E. The cover is also found in the coastal region. Dominant perennial grass species are *Dichanthium annulatum*, *Sehima nervosum*, *Bothriochloa pertusa*, *Chrysopogon fulvus*, *Heteropogon contortus*, *Iseilema laxum*, *Themeda triandra*, *Cynodon dactylon*, *Aristida setacea*, *Cymbopogon* spp. etc. Important associated species are *Apluda mutica*, *Bothriochloa intermedia*, *Arundinella nepalensis*, *Desmostachya bipinnata*, *Eragrostis* and *Eragrostiella* spp.
- 2.1.3 *Phragmites-Saccharum-Imperata* type:** This grass cover occurs throughout the Gangetic Plain, the Brahmaputra valley and extends westwards into the plains of Punjab between 26° N - 32° N and 74° E to 96° E. The area comprises approx. 2,800,000 km² in north-eastern states, W. Bengal, Bihar, UP, Punjab and Haryana. Principal perennial species in drier regions are *Imperata cylindrica*, *Saccharum arundinaceum*, *S. spontaneum*, *Phragmites karka*, *Desmostachya*

bipinnata. Other important species of this grass cover are *Bothriochloa intermedia*, *Vetivaria zizanioides*, *Imperata cylindrica*, *Chrysopogon aciculatus*, *Panicum notatum* etc.

2.1.4 Themeda-Arundinella type: The entire northern and north western mountain tract, on an area of approximately 230,000 km² in the north-eastern states, West Bengal, Uttar Pradesh, Punjab, Haryana, Himachal Pradesh and Jammu and Kashmir is dominated by *Themeda* – *Arundinella* grasses. In the west, this type is found approximately between 29° N - 37°N, and between 73° E - 81° E and in the east approximately between 22°N - 28.5°N, and 88°E - 97°E. This type is associated with undifferentiated forest and hill soils, and with undifferentiated forest sub-mountain regional soils. The principal species of this grass cover are *Arundinella benghalensis*, *A. nepalensis*, *Bothriochloa intermedia*, *Chrysopogon fulvus*, *Cymbopogon jwarancusa*, *Cynodon dactylon*, *Heteropogon contortus*, *Themeda anathera*, *Euloliopsis binata*, *Ischaemum barbatum*. Associated perennial species are *Apluda mutica*, *Arundinella khaseana*, *Pennisetum flaccidum*, *Chloris*, *Desmostachya* etc.



Figure 1: Grass cover of India

2.1.5 Temperate Alpine type: This cover type occurs on the high hills of Uttarakhand, Jammu and Kashmir, Ladakh and Himachal Pradesh in western Himalaya and northern hills of West Bengal and North-Eastern regions in eastern Himalaya. The tract lies approximately between 29° N - 37° N, and between 73° E - 81° E in the western part of the country. On the eastern side, it extends between approximately 27° N - 29.5° N, and 88° E - 97° E. It essentially occurs at higher elevation, beyond timberline, approximately above 3,000 m in the west and above 2,000 m in the east. The principal perennial species are *Agropyron conaliculatum*, *Chrysopogon gryllus*, *Dactylis glomerata*, *Danthonia*

cachemyriana, *Phleum alpinum*, *Carex nubigena*, *Poa pratensis* and *Stipa concinna*. Associated species are *Poa alpina*, *Festuca lucida*, *Eragrostis nigra*, *Bromus ramosus* etc.

This survey, which was purely at reconnaissance level, is now over 60 years old and is not of much use in the present context. Afterwards several reports and papers have emerged, but most of the attention was either on botanical or ecological aspects in selected regions of India. Distribution pattern and identification of the grass covers of certain parts of the Bundelkhand region were assessed using detailed field surveys by quadrant and line transect methods. It indicated suitable species of higher ecological status for introduction in order to upgrade the botanical composition, biomass and carrying capacity of community grazing lands. Detailed studies on the natural and deflected succession in the *Sehima-Dichanthium* grass cover provided basic information needed for planning of natural regeneration of grasslands. In a similar study, score card method, based on vegetation and soil indicators of positive and negative changes in the range health or carrying capacity was used for the *Sehima-Dichanthium* grass cover and with a little modification, this method was found applicable to all the five major grass covers of India. Herbage dynamics, changes in the botanical composition and nutrient cycling were also studied in the *Sehima-Dichanthium* cover under two situations *i.e.* protected and unprotected. Individual grasses and legumes of high forage value were identified. Over 3000 specimens of 801 species, 356 genera and 61 families have been identified and arranged systematically in the ICAR-IGFRI herbarium, which were also digitized for easy accessibility across the globe.

Another monumental work on the 'Systematics of Indian Grasses' was documented by N.L. Bor (Bor 1960). Pioneering efforts of Professor R. Misra resulted in establishment of the first school of ecology at Banaras Hindu University, Varanasi around the same time. There was a spurt of basic research on the ecology of grasslands in India during the 1960s and 70s. The Varanasi school promoted habitat approach to grassland ecology and contributed significantly towards our understanding of structure, functioning and dynamics of Indian grasslands under the International Biological Programme.

Grassland ecosystem is the primary source of income for 550 tribal communities representing 227 ethnic groups living in 5,000 woodland villages. Grasslands are extremely important in the country, which supports 20% of the world's livestock despite having just 2% of the land area. Between 1980 and 2007, the area under permanent pastures and grazing land decreased from 12 to 10.2 million ha. The

average carrying capacity of these grasslands is currently less than one adult cattle unit per hectare, despite a grazing demand of 3.42 adult cattle unit per ha (A. K. Roy and Singh 2013).

There are two types of factors for the loss of grasslands: direct and indirect. Direct factors include overgrazing, poor management, and deforestation, while indirect factors include conversion of pastures to croplands due to invasion, diversion, and allotment because of increasing population pressure. Anthropogenic pressures, rampant landfills, grazing pressures, habitat fragmentation, proliferation of invasive species, and the influence of climate change has put grasslands at risk. Despite the fact that India has one of the world's largest livestock populations, grassland management in India has not been given due attention, mostly due to lack of a real time monitoring system as well as policy framework.

2.2 Major grasslands types of India

India has 2.2% of land, 4% of fresh water, 17% of population and 10% of cattle of the world share. India ranks fourth in Asia after China, Kazakhstan and Mongolia. The Indian grasslands can be broadly grouped into three heads on the basis of their geographical locations.

2.2.1 Tropical grasslands: Tropical grasslands have dry and wet seasons that remain warm all the time. They usually contain quite short plants, which makes it an excellent hunting ground. For instance, the African savanna is one of the tropical grasslands. The tropical grassland is a home for elephants, giraffes, lions, cheetahs, zebras, and other spectacular species. Some of the common examples are East Africa- Savanna; Brazil- Campos; Venezuela- Llanos etc.

2.2.2 Temperate grasslands: These grasslands face cold winters and warm summers. Shrub lands are the best example of temperate grasslands. Some of the common examples are Argentina- Pampas; America- Prairie; South Africa- Veld; Asia- Steppe; Australia- Down

2.2.3 Himalayan grasslands including NEH:

- Alpine moist meadows of Greater Himalayas
- Alpine arid pastures or steppe formation of trans-Himalayas
- Hill side grasslands in the mid elevation ranges of Himalayas
- Chaurs of Himalayan foot hills
- Wet- alluvial or Terai grasslands of Gangetic and Brahmaputra flood plains

- Phumdi or floating grasslands of Manipur
- Dzukou valley in Nagaland and Manipur
- Ukhrul grassland of Manipur
- Saramati grassland of Nagaland
- Rolling downs of Shillong

2.2.4 Grasslands of central, western and southern India

- Banni and vidis of Gujarat
- Savannas of Western and peninsular India
- Plateau and valley grasslands of Satpura and Maikal Hills
- Dry grasslands of Andhra Pradesh and Tamil Nadu plains
- Shola grasslands of Western Ghats
- Sewan grasslands of Arid Rajasthan

2.2.5 Coastal grasslands

- Coastal Mainland sea beaches of tropical coasts
- Island beaches in sea shore of Andaman Nicobar, Lakshdweep
- Salt marsh grasslands like Rann of kutch
- Mangrove grasslands

2.2.6 Ethnic grasslands of India

- Banni Grasslands of Kutchh, Gujarat
- Shola grassland of the Western Ghats
- Sewan grasslands of Thar
- Terai Grasslands
- Kangeyam grassland of south
- Floating grasslands of NEH.

2.3 Past studies using Remote Sensing and GIS tools

There was a need to generate digital spatial information on grasslands using modern tools and techniques, viz., Geographic Information System (GIS), Satellite Remote Sensing (RS), Global Positioning System (GPS) and Field Sampling & Ground Truthing (FSGT). Keeping these points in view, Indian Grassland and Fodder Research Institute (IGFRI) initiated second phase of grassland survey, monitoring and mapping programme through its own budget as well as through collaborative projects with Space Application Centre (SAC),

Department of Science and Technology (DST), Indian Institute of Remote Sensing (IIRS) and Temperate Alpine Pasture Programme, ICAR and NASF, ICAR. The salient progress achieved during 1994 – 2018 is crystallized into following subheads:

2.3.1 Grasslands of Lower Sind Catchment

First time satellite Remote Sensing technique was used at ICAR-IGFRI, Jhansi for the identification, characterization and monitoring of grasslands in 1994. IRS-1A (1989 and 1992) and IRS-1B (1995) false colour composite (FCC) were selected for this study. In this study grasslands distribution pattern and its association with different landform classes were also assessed for lower Sind catchment covering an area of 23,500 km². Based on visual image interpretation of LISS-I images supported with FSGT grasslands classes were identified, area estimated and change detection (1989-1995) were carried out. It was realized that timely and accurately spatial information on grasslands can be generated easily using IRS imagery.

2.3.2 Grasslands of Bundelkhand Region

Digital image (IRS1D FCC during December 2004) processing and geo-spatial technology along with intensive FSGT, SOI toposheets and district statistical reports were used for the generation of following information of Bundelkhand region (Fig. 2):

2.3.2.1 Grazing lands: There is evidence of reduction of area (-14.60%) under grazing lands during the past 22 years. It was 21.08% in 1982 whereas it was only 6.47% in 2004. It is also evident that major portions of these lands have been brought under cultivation. The land available for grazing was found highest in the north-western part of the region especially in Lahar (31.32%), Bhandar (18.50%), Jalaun (12.84%) and Jhansi (12.51%). Moderately distributed grazing lands were seen in Lalitpur (7.84%), Chhatarpur (7.06%), Datia (6.73%) and Sagar (6.35%) districts whereas it was found in limited patches (0.83% to 4.93%) in Damoh, Banda, Mahoba and Hamirpur districts of the region (Singh et al. 2007).

2.3.1.2 Natural grasslands: Hardly 253125 ha (3.54%) of land is covered and dominated with native grass species. The highest concentration of grassland was recorded in Jhansi (7.33%), Lalitpur (6.07%), Sagar (5.12%) and Chhatarpur (4.89%) whereas moderate distribution was found in Mahoba (3.32%), Datia (3.28%) and Tikamgarh (3.27%) districts of the region. The important grass/legume/ shrub species were *Eragrostis sp.*, *Chrysopogon sp.* & *Heteropogon sp.* /

Indigofera sp., *Atylosia sp.* / *Carissa sp.*, *Ziziphus sp.* and *Cynodon sp.*/
Tephrosia sp. and *Acacia sp.*

2.3.1.3 Grazing lands affected by ravines: The study also revealed that about 170943 ha (36.89%) of the total area under grazing lands (463410 ha) was affected by ravines. The severity of ravines was found more along the middle and lower reaches of rivers and streams in the northern part of the region. There is an urgent need to restore these lands through proper land treatments and reseeding of suitable grass and tree species (Pathak et al. 2005).

2.3.1.4 Grazing lands affected by shrubs:

Infestation of grazing lands with shrubs has been considered as a threat to the existing grazing lands in the region. The study reveals that about 0.55% (393.42 km²) land (mostly grazing lands) in the region was affected by shrubs. The situation is more alarming in Panna (0.85%), Chhatarpur (0.82%), Sagar (0.76%) and Tikamgarh (0.71%) district.

2.3.3 Temperate/ Alpine Region

Survey, monitoring and mapping and development of grasslands of Himalayan region was one of the projects of IGFR-EFC IX plan (2007-2012). In this investigation, Geo-database (GDB) for Himachal Pradesh, Sikkim and Jammu & Kashmir were generated using modern tools and techniques viz., GIS, RS, GPS and FSGT. The salient findings are listed below:

2.3.3.1 Himachal Pradesh

On the basis of IRSP6L3 (2008) data, the area under grasslands in the state was found to be only 16.53% (917702.73 ha) of the total area. Grasslands occupied 15.38, 21.56, 17.99 and 15.32 percent area of geo-climatic zone 1 (Low hill sub-tropical), 2 (Mid hill sub humid), 3 (Mid hill temperate wet) and 4 (High hill temperate) respectively. Again, according to the hill zone classification, grasslands covered 15.35, 19.51 and 15.23 percent area of low, mid and high

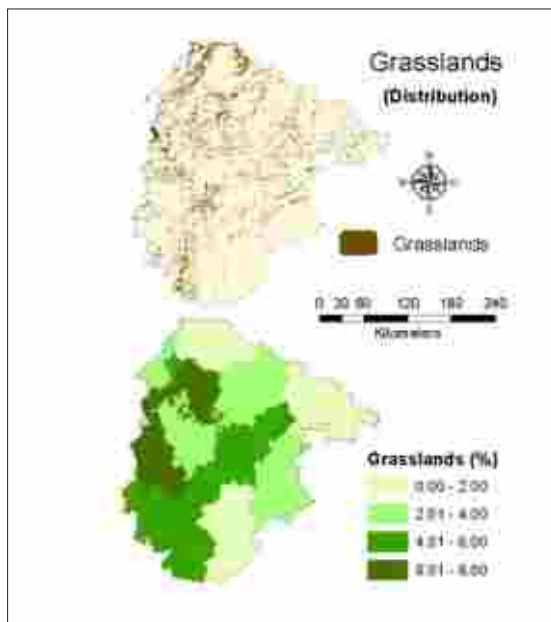


Figure 2: Grassland Map of Bundelkhand Region

hills, respectively. Proportion of area under grasslands was higher in Kinnaur district (27.51%) followed by Bilaspur district (26.14%) whereas it was lower in Una (7.23%) and Hamirpur (8.85%) districts (Fig. 3). The existing annual forage production level from grasslands in the state was assessed to be 4.82 t green and 1.65 t dry on per ha basis and average crude protein was 7%. Taking into account the recent livestock census for the state and the area under grasslands, a regional imbalance was detected. Average grazing pressure in the state was 3.17 ACU/ ha. It was higher in low hills (6 – 14 ACU/ha), moderate in mid hills (2 - 6 ACU/ ha) and low in high hills (0.01 – 1.50 ACU/ha). There was a close relationship between extent of grasslands and landform / geo-climatic conditions. Highest CP was recorded at Kulung (20.22%) followed by Jot (14.89%) whereas lowest CP was found near Neurela falls (7.89%). The main reason for high CP in this zone was dominance of *Trifolium repens*, *Lolium perenne* and other legumes in the grasslands. About 6.40 t/ha/year (fresh weight), 2.34t/ha/year (dry matter) was recorded as existing forage production from mid hills. Proportion of area under grasslands was higher in Kinnaur district (27.51%) followed by Bilaspur district (26.14%) whereas it was lower in Una (7.23%) and Hamirpur (8.85%) districts (Singh, Radotra, and Roy 2009).

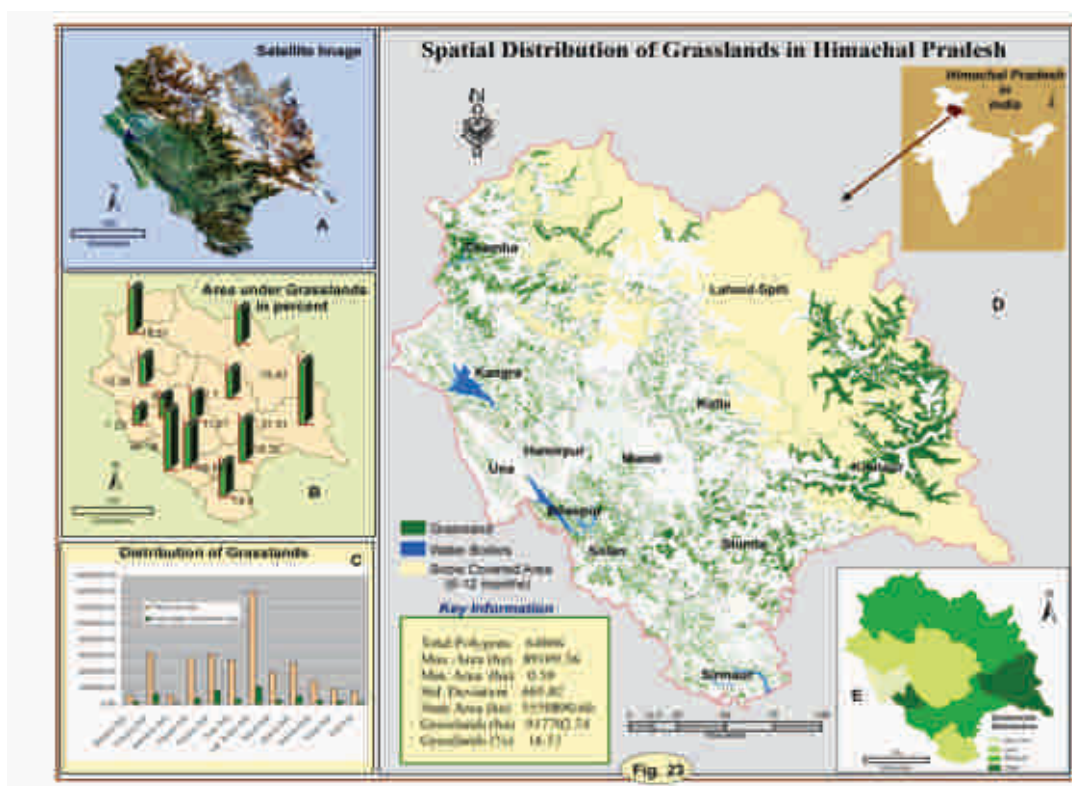


Figure 3: Grassland Map of Himachal Pradesh

2.3.3.2 Jammu and Kashmir (including Ladakh)

IRSP6L3 data dated September 2009 and 2010 was used for generation of geodatabase supported with maps on grasslands of Jammu and Kashmir. Intensive FSGT was carried out in Leh / Laddakh region, Kashmir valley and Jammu region. The total geographical area of Jammu & Kashmir was 222236 km². Presently Indian administrative area (106530 km²) can be grouped into 3 regions viz; Ladakh (64958 km²), Kashmir (15936 km²) and Jammu (25636 km²). Ladakh, Zaskar and Pirpanjal are the major mountain systems in the state which are being modified (through denudational processes) by Sindhu, Jhelum and Chenav river systems. The relief ranges from 500 m in Jammu to >6000 m in Ladakh region. The hilly terrain of the state supported many intervening basins, plains, uplands plateau and hill slopes where pastures were used by grazing animals. The climatic conditions, especially temperature and precipitation (both rainfall and snowfall) are quite different in these regions. The structure and composition of grasses changed according to elevation. The study reveals that

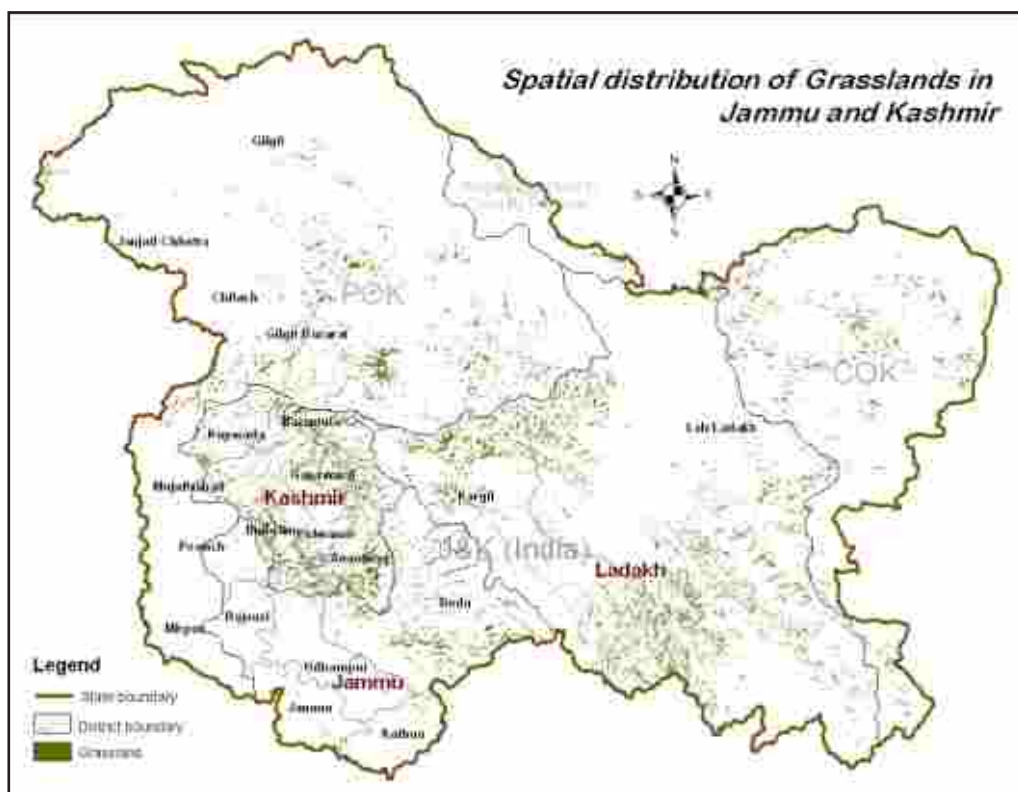


Figure 4: Spatial distribution of grasslands in Jammu and Kashmir

about 9595 km² (4.32%) area is under productive grasslands, whereas other grazing lands including scrubs and other unpalatable grasslands were 10455 km² (9.81%) of the total geographical area. Area under grasslands in Jammu, Kashmir and Ladakh were 3.53, 13.22 and 5.76 percent respectively, together contributing about 6756.5 km² or 6.34%. Whereas in POK it was 2.16% and in China occupied area, it was 3.04 percent (Fig. 4). The area under grasslands in alpine pasture (above 3000 m) of the western Himalaya have been an age-old summer grazing regions for pastoral communities (Singh, Ahmed, et al. 2015; Singh, Dev, et al. 2015; Dad and Khan 2011). The study further reveals that about 70% of good grasslands of the state are under the control of India. The vertical distribution of grasslands was highest between 1500-3500 m. The grasslands of the state was classed as tropical, tropical to sub-tropical, sub-tropical to sub-temperate, sub-temperate to alpine and alpine meadows. *Festuca* is the most dominant species observed in the alpine pastures. White clover, red clover, Alfalfa, *Cyperus*, *Sibbaldia* were some of the species observed in the pasturelands. Other important grasses viz; *Carex (longma)*, *Elymus*, *Kobresia*, *Eurotia*, *Caragana*, *Ranunculus*, *Pedicularis (lokruserpo)*, *Peduncularis (toma)*, *Utricularia hypnoides (zatsot)* and *Arabia eudora (demok)* etc. were widely observed in the cold desert of Ladakh region.

2.3.3.3 Sikkim

Remotely sensed satellite data supported with GPS linked ground information provides timely and accurate knowledge base on landform features, soil status and associated pastureland conditions. In this investigation, temperate/ alpine pasturelands as well as associated landforms and soil status of Sikkim were assessed using IRS P6 LISS3 data. Intensive FSGT of 104 sites located at different elevations in mid hills and high hill zones were selected for the study of soil status, forage production and landform features. The area under alpine pastures in the high hill zone was 7.38% of total geographical area and 6.76% in mid hills (Fig. 5). The various soil characteristics of alpine pastures in Sikkim were assessed as organic matter (0.95-2.82%), available N (319-1402 kg/ha), available P (10-29 kg/ha), and K (103-599 kg/ha). These soil characteristics in alpine pasturelands in varying altitudes determine the forage production (0.31 – 3.25 t DM/ha) and CP content (8.5 – 19.5 %). About 36.5% of the total pasturelands (14.13% of the total area) were at various stages of degradation (Singh et al. 2011). Pasturelands (43.65%) located at different altitudes and slopes in mid hill zones were more susceptible to soil erosion/ depletion and landslides. The study reveals that the sustainability of pasture lands and pasture

production depends upon the soil health and associated landforms. Different types of grasses, legumes and shrub species were recorded in Sikkim. *Juniperus squamata*, *Juniperus indica*, *Rhododendron*, *Morainic* were mainly recorded in the glaciated valleys along the lateral and terminal moraines. Species like *Riverine willow* (*S. sikkimensis*) and *Riverine* (*M. rosea*) were usually found in the upland valleys whereas *Kobresia nepalensis* (moist meadows), appeared as dense soft mat-like formation, has an average height of 0.1 m, occurs on smooth slopes and ridge tops in the upper reaches of moist and exposed glaciated valleys. Important moist meadows like *Kobresia duthiei* was found in shady moist valleys and rocky slopes whereas *Kobresia pygmaea* (dry meadows), having an average height of 0.05 m, was found in the upper reaches of the glaciated and relatively dry valleys of Zemu and Lhonak. *D. caespitosa*, marsh meadows, mainly occurred in the form of tussock on waterlogged flats adjacent to alpine lakes and in the upper courses of meandering streams. The top height of *D. caespitosa* was recorded upto one meter. Species like *Anaphalis xylorhiza* (mixed meadows) normally occur in the inner valleys on the glaciated flats (Pandeya 1988; Tambe and Rawat 2009).



Figure 5: Spatial distribution of grasslands in Sikkim

2.3.4 Grasslands of Gujarat

2.3.4.1 Porbandar

Under the IGFRI – SAC (ISRO) collaborative project on grassland mapping of Kuchh- Saurashtra region IRS1DLISS3 standard FCC of October, 1998 was used for the identification, characterization and mapping of grasslands. Total area under grass cover in this region was 14.93% whereas it was 14.83% in Kuchh and 15.01% in Saurashtra. The study also revealed that about 4% grasslands were badly infested with *Prosopis juliflora*. Detailed field survey work was conducted for *Banni* grasslands and *Vidis* of Porbandar district (Fig. 6). The area under grasslands (*Vidis* / *Banni*) in Porbandar was 13.11% in which open grasslands was 5.52% and grasses under tree cover was 7.59%. About 2% grasslands were infested with *Prosopis juliflora* (Singh and Trivedi 2002). In the *Banni* area, vegetation comprises grassland, shrubs and legumes. Normally the area was covered with coarse and low perennial grasses and other non-grass species in *Banni* area for example *Dichanthium-annulatum*, *Sporobolus helvolus*, *Chloris barbata*, *Cenchrus biflorus*, *Eleusine bianata*, *Elysecarpus rugosus*, *Heylandis latebrosa*, *Digitaria sanguinalis*, *Var Ciliaris*, *Crotolaria*



Figure 6: Vidi near Kutiyana, Porbandar

medicaginea, *Indigofera* spp. *Sida* spp. *Malanocenchrus jacquemontii*, *Sporobolus diander*, *Cenchrus setigerus*, *Aristida adscensionis*, *Aristida funiculata*, *Setaria rhachitricho*, *Eragrostis minor* and *major*, *Eragrostis trimula*, *Cyperus rotundus*, *Desmostachya bipinnata*, *Cyperus rotundus*, *Cressa cretica*, *Eragrostis bulbosa*, *Kochia* spp. *Suaeda fruticosa*. Out of the above 26 grass/ legume species, first 12 species are palatable and rest of them are salt-tolerant grasses. Banni area deterioration is linked to the increasing salinity ingress, impoverishment and illiteracy of its inhabitants, a growing human and livestock population, and invasion of *Prosopis juliflora*, which offers quick fuelwood, but its proliferation is dangerous for the grassland.

2.3.4.2 Kachchh

Satellite images (Resourcesat-2 AWIFs and nine scenes of LISS-3 B4) revealed that the area under grasslands including degrading rangeland is approximately 18.6% of which *Prosopis* infested area forms about 5.7% (Fig. 7 & 8). GPS based ground truthing (GT) and field survey was conducted in the months of August

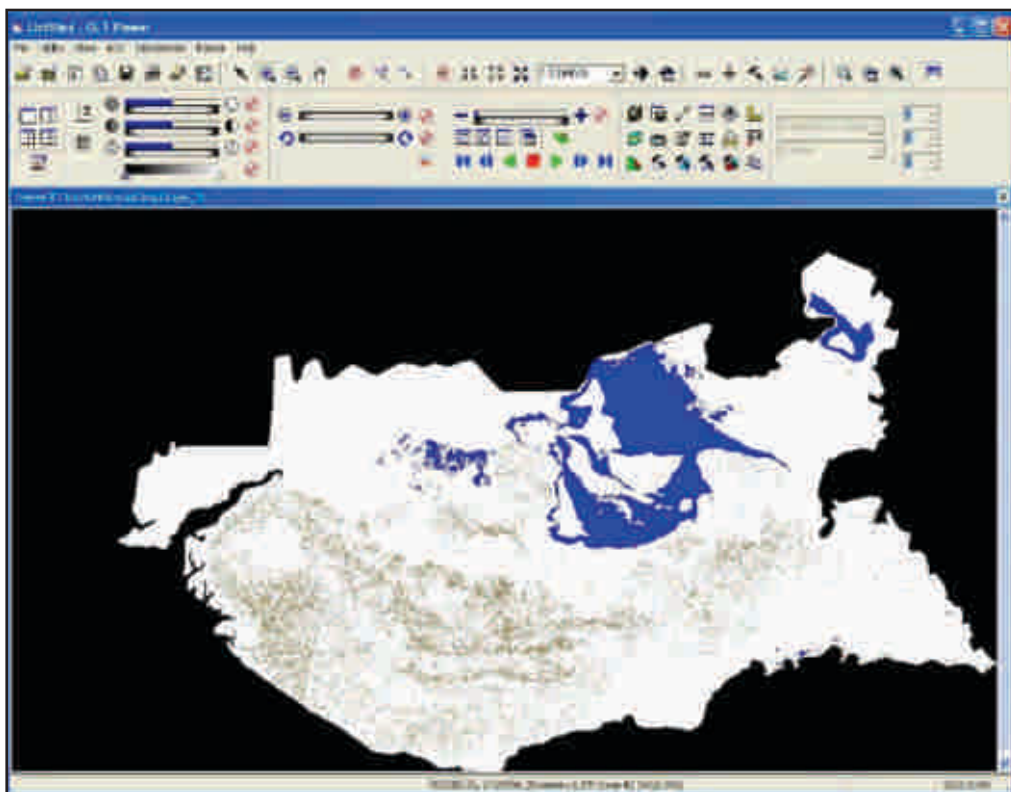


Figure 7: Spatial distribution of Grasslands in Kachchh

and September. During the field visit, samples were collected from a total 29 GPS points (mostly in grassland/ Banni area). Due to drought conditions in the region, very poor initial growth of grasses was recorded in August 2014 (Fig. 9). In the month of September 2015, the initial growth of grasses of Banni area was comparatively rich (Kumar et al. 2018). During the GT it was also realized that in such a topographic condition and existing land cover the identification of halophytes vegetation species using LISS-3/LISS-4 data is very difficult as the pixel size in LISS-3 is 23m and in LISS-4 it is 5.6m were as the tussock size was hardly 1/3 of pixel size as well as mixing of different grass species of annual and perennial.



Figure 8: Thematic Map of Grasslands of Kachchh



Figure 9: Pre and post monsoon Banni grasslands of Kachchh

2.4 Pastoral Communities

The utilization of grasslands/ grazing lands by animals involve a third important traditional component i.e., nomadic pastoral communities. It is a traditional form of human-livestock-grassland interaction and is still predominant in the drylands of western India, the Deccan Plateau, and in the mountainous reaches of the Himalayas. Nearly 200 castes are engaged in pastoral nomadism. They represent endogamous (discrete) social units, and specialize in the breeding of traditional animals. These pastoral groups are concentrated in certain regions such as the semi-arid and arid Thar Desert region, salty marshy lands of Kutch, and the alpine and subalpine zones in the Himalayas. In mountainous areas, nomadic grazing descends in winter to the lower slopes and in summer it progresses up the hills to get the maximum benefit from the good pastures that regenerate after the snow melts. In plateaus, plains and desert areas, the pastoralists move according to the alternation of the monsoon and dry seasons, in response to the availability of forage resources, including tree fodder. Usually in the dry season, they move to the coastal tracts, and leave when the rains come (A. K. Roy and Singh 2013). Some important pastoralist communities in the Himalayan and western India are listed below:

Table 1: Pastoral communities of Himalayan region

Pastoral community	Area	Predominant livestock species
Bakarwal	Jammu and Kashmir	mainly goats
Bhotia	Uttarakhand, Garhwal, Kumaon – upper regions	sheep, goats and cattle
Bhutia	North Sikkim	sheep, goats and cattle
Changpa	Jammu and Kashmir, mainly in Zaskar	yaks
Gaddi	Himachal Pradesh, Jammu and Kashmir	sheep and goats
Kinnaura	Kinnaur – Himachal Pradesh	sheep and goats
Gujjar	Jammu and Kashmir, Rajasthan, Himachal Pradesh	buffaloes, some cattle
Monpa	Tawang, West Kameng of Arunachal Pradesh	yaks and cattle
Van Gujar	Uttarakhand, Uttar Pradesh	buffaloes

Table2: Some important pastoral communities in Western India.

Pastoral community	Area	Predominant livestock species
Bharwad	Gujarat	sheep, goats and cattle
Charan	Gir forest region of Gujarat	cattle
Dhangar	Maharashtra, Karnataka and Madhya Pradesh	sheep
Gavli	Gujarat, Goa, Karnataka and Maharashtra	cattle
Gayri	southern Rajasthan (Mewar)	sheep
Ghosi	Bihar, Rajasthan and Uttar Pradesh	cattle
Golla	Andhra Pradesh and Maharashtra	cattle
Jath	Kutch region of Gujarat	cattle, occasionally camels
Mer	Saurashtra region of Gujarat	camels, some cattle
Rath	western Rajasthan (Ganganagar, Bikaner)	cattle (mainly of Rathi breed)
Rebari/Raika	Rajasthan and Gujarat	camels, cattle and goats
Sindhi Sipahi or Sindhi Muselman	Marwar and Jaisalmer	mainly camels, also cattle and sheep

2.5 Knowledge Base and Past Research on Cultivated Fodder Crops

Since the inception of ICAR-IGFRI, the major research thrust was on improvement and management of different fodder crops as well as developing technologies for grassland and pastureland. In the past 62 years, ICAR – IGFRI has developed more than 60 high yielding fodder crop varieties, which are suitable to different agro-ecological regions for both cultivated lands as well as rangelands. All India Coordinated Research Project on Forage Crops (AICRP FC) has been instrumental in developing and notifying nearly 300 forage crops varieties at zonal and national level. The National Action Plan for Dairy Development envisages achieving a milk production target of 300 Million MT by 2023-24 from nearly 221.06 Million MT at present level. This would require putting more emphasis on increasing the productivity of cultivated lands as well

as grasslands/ pasturelands, besides bringing new niche areas under fodder cultivation. IGFR and AICRP on forage crops estimated the demand supply scenario of green and dry fodder in the country considering various parameters like the condition of livestock gender, age and stages viz., dry, in milk, stall fed etc. Similarly, the estimation of green and dry forage availability as well as crop residues indicated the deficit to be 11.24% in green and 23.4% in dry forage (A. K. Roy et al. 2019).

3. Need for revisiting estimation

The data/estimates of fodder production in the country vary widely. Fodder production from rangelands and cultivated lands and its utilization depend on the climate, cropping pattern, socio-economic conditions and type of livestock. The regional and seasonal deficits are more important than the national deficit, especially for cultivated fodder, which is not economical to transport over long distances (Bhagmal et al. 2009). The pattern of deficit varies in different parts of the country. The situation is further aggravated due to increasing growth of livestock particularly that of genetically upgraded animals. The available forages in the grazing land are poor in quality, being deficient in available energy, protein and minerals. As per the 10th Five Year Plan Document, total forage production (green) in India was about 379 million tonnes (mt) in 1995, 390 mt in 2005 and 401 mt in 2015. However, in the case of grasslands/ CPR or even village *gochar* lands, it is evident from the previous studies; the area and productivity have declined. Precise estimates on area and productivity are not available at national level, which is a prerequisite for the planning and development of this sector.

India's livestock sector offers considerable scope for enhancement as far as productivity is concerned. Our cattle and buffalo produce less than 1000 kg of milk per lactation as compared to 4500 kg in Europe, more than 7000 kg in the United States and 10,000 kg in Israel. The low productivity of livestock is due to various reasons and inadequate supplies of quality feeds and fodder is one of the major reasons. Hence, there is considerable scope of increasing or attaining the genetic potential of our superior indigenous breeds as well as judicious utilization of exotic breeds. In this scenario, quantification of existing feed resources is necessary for the development of efficient feeding strategies and for the judicious utilization of available feed resources, besides, planning to develop a feed security system in the country covering all the states. Non-availability of adequate feed resources is one of the major limiting factors in improving livestock productivity. The area and productivity of cultivated fodder crops depends on various biophysical conditions (mainly rainfall) and farmer requirements. Hence, like other crops, the data of fodder crops (both area and productivity) should be generated and updated every year. Thus, efforts were made to develop a more realistic methodology.

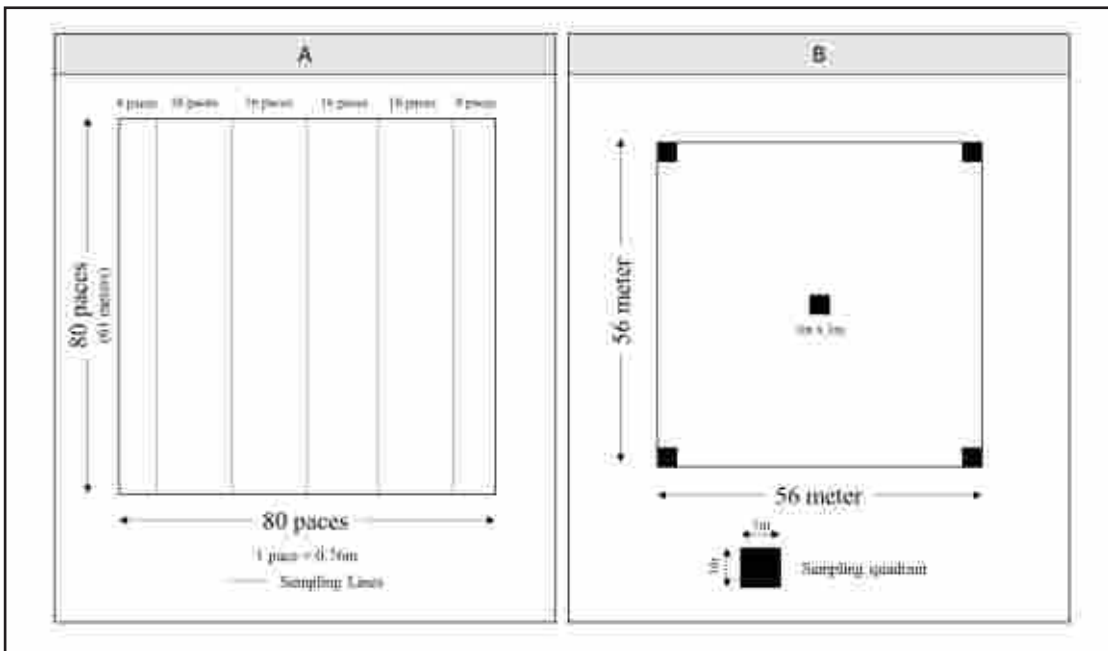
4. Objectives

The major objectives of the present study were:

- Area and productivity estimation of range forage (forage from grasslands) i.e. fodder from rangeland/pasture land of different states.
- Area and production estimation of fodder crop for both *rabi* and *kharif* seasons and from perennial systems.

5. Materials and method

With the unlocking process after the first phase of COVID 19, the work on data collection and laboratory analysis started. Review of old literature, geodatabase creation and image processing using ERDAS Imagine and ArcGIS s/w were taken up in the laboratory using advanced computing software. The method followed by P.M. Dabadghao and K.A. Shankarnarayan (Dabadghao and Shankarnarayan 1973) in the study of 'The Grass Cover of India' was the field adaptation of the 'Line interception method', called the 'Pace transect method' as the major objective was ecological study of grassland. The actual sampling procedure consisted of determining the base line of the one- acre sampling plot. Sampling for composition was done on five imaginary lines at right angles to the base line. The first line was taken at a distance of eight paces (20 ft) from the starting point of the base line. Subsequent lines were taken each at an interval of 16 paces (40 ft), so that the fifth line was situated at eight paces (20 ft) from the end point of the base line. The total length of the base line was then 80 paces or 200 ft (Fig. 10A). Total 507 sites were observed in different states of India. The present study, estimation of area and productivity, geo-spatial tools viz., satellite remote sensing, GIS, GPS etc. were used to collect the information from 558 sample sites (Fig. 10B).



**Figure 10: The pictorial depiction of sampling methodology
(A) Dabadghao et al., 1973. (B) Adopted in the present study**

Collection of information on cultivated fodder crops and range grasses initiated with the help of IGFR-Regional Research Centres located in J&K, HP, Rajasthan and Karnataka as well as 22 centres (Table 3 & Fig. 11) of ICAR-All India Coordinated Research Project on Forage Crops & Utilization (AICRP on FCU) located in different states and different Agro-ecological regions of the country.

Table 3: AICRP on Forage Crops & Utilization

S. N.	AICRP Centers	States/ UT	S. No.	AICRP Centers	States/ UT
1	AAU, Anand	Gujarat	12	CSKHPKV, Palampur	Himachal Pradesh
2	OUAT, Bhubaneswar	Odisha	13	GBPUAT, Pantnagar	Uttarakhand
3	SKRAU, Bikaner	Rajasthan	14	MPKV, Rahuri	Maharashtra
4	TNAU, Coimbatore	Tamil Nadu	15	BAU, Ranchi	Jharkhand
5	NDUAT, Ayodhya	Uttar Pradesh	16	UAS (B), ZARS Mandya	Karnataka
6	CCSHAU, Hisar	Haryana	17	BAIF, Urulikanchan	Maharashtra
7	PJTSAU, Hyderabad	Telangana	18	KAU, CoA, Vellayani	Kerala
8	JNKVV, Jabalpur	Madhya Pradesh	19	SKUAST, Srinagar	J&K
9	AAU, Jorhat	Assam	20	IGKV, Raipur	Chhattisgarh
10	BCKV, Kalyani	West Bengal	21	CAU, Imphal	Manipur
11	PAU, Ludhiana	Punjab	22	RPCAU, Pusa	Bihar

<i>ICAR-IGFRI Regional Research Centers</i>		
1.	Srinagar	Jammu & Kashmir
2.	Palampur	Himachal Pradesh
3.	Avikanagar	Rajasthan
4.	Dharwad	Karnataka

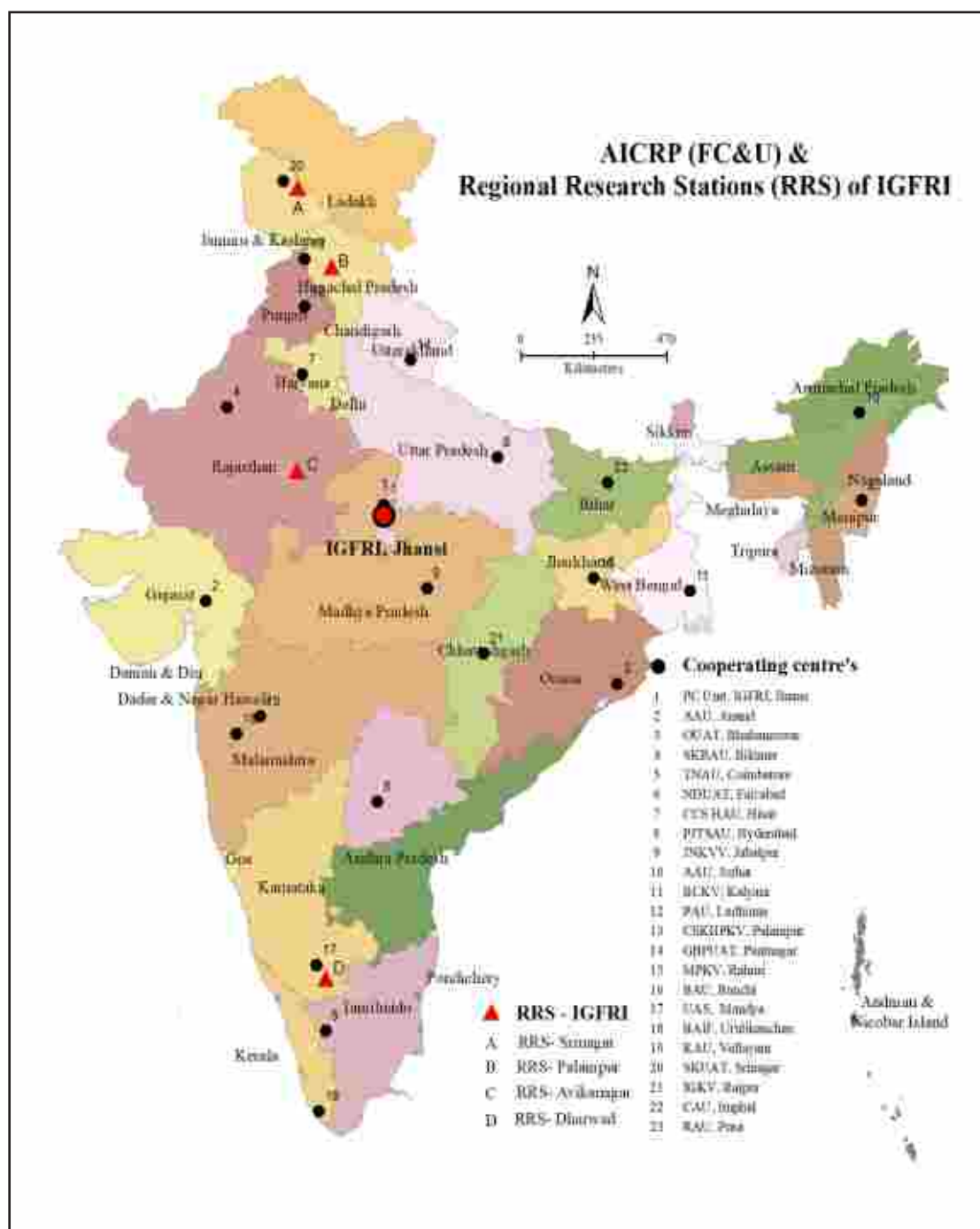


Figure 11: AICRP Centers & RRS - IGRI

Grasslands/ rangelands and pasture lands are used more or less synonymously in the Indian context. All are under free or range grazing except those under protected and reserved forest. We have not taken into account the area under reserved or protected forest. Grazing lands / other grazing lands covers the area or land cover viz., grasses under miscellaneous tree, shrubs and bushes, culturable waste land, permanent/ old fallow lands (excluding the current fallow and cultivated lands), which are generally browsed, grazed or lopped by bovine, ovine and caprine groups of animals. District/state level 'Land use' statistical reports provide the classes like 'Land under Miscellaneous Tree Crops', 'Culturable Waste Land' and 'Fallow Lands' etc. In this study, aWiFs scenes were used to generate the information on area under grasslands including other grazing lands and productivity at state level. These scenes took around 1700 computer hours (10 months) for its processing and validation with GPS linked ground truth (GT) data. The productivity estimate matches perfectly with GT.

The precise estimates of rangelands/ pasturelands are not available in any government reports. However, DAC (<http://aps.dac.gov.in/lis>) land use data is available but it provides a crude estimate about the area under grasslands/ rangelands/ pasturelands of different states of India. To cope with this problem, Geospatial technology (Remote Sensing, GIS and GPS) were used. To validate the information compiled by DAC through remotely sensed satellite images, a mosaic of 284 scenes with multi-date (2017-2020) selected because cloud free satellite data (Resourcesat-1&2) of the same year was not available. The aWiFs having 56 meter ground resolution were downloaded from Bhuvan (<https://bhuvan-app3.nrsc.gov.in/data/download/index.php>). Images were corrected (both geometric and radiometric correction) and mosaic operation done using ERDAS Imagine Pro. s/w. Finally, to generate the satellite images of India, it was clipped using *shapefile* (vector layer) of India. To identify the grazing lands, two geo-processing tools viz., signature based supervised classification and NDVI class were used. NDVI is an important remote sensing tool and used to assess vegetation cover, growth, and plant vigour. It is calculated by measuring the difference between near-infrared (NIR) and red reflectance (IR) of vegetation. Temperature and rainfall are two of the key environmental factors that influence vegetation growth and development. To ensure the classification accuracy of grasslands/ grazing lands, correlation and regression between NDVI, temperature, and rainfall for the years 2018 and 2021 were carried out to test the accuracy of classification. For this purpose, a total of 198 GPS data were selected from arid to semi-arid regions along with the temperature and rainfall data. The analysis was based on NDVI, temperature, and rainfall for the years 2018 and 2021.

Correlation analysis was used to determine the relationship between the variables i.e., NDVI, temperature and rainfall. ANOVA was performed to assess the significance of

temperature and rainfall in explaining the variation among NDVI values. Multiple linear regression models were also applied with rainfall and temperature as predictor variables. The correlation analysis showed high correlation (more than 0.9) values between temperature and rainfall for all the years. NDVI and temperature showed a negative correlation, whereas NDVI and rainfall showed a positive significant correlation (Fig. 12).

ANOVA showed that temperature and rainfall both played a significant role in explaining the variation amongst NDVI values. When multiple linear regression models were applied with rainfall and temperature as predictor variables to predict the NDVI, they produced coefficient of determination values of 0.43 and 0.37 for the years 2018 and 2021, respectively.

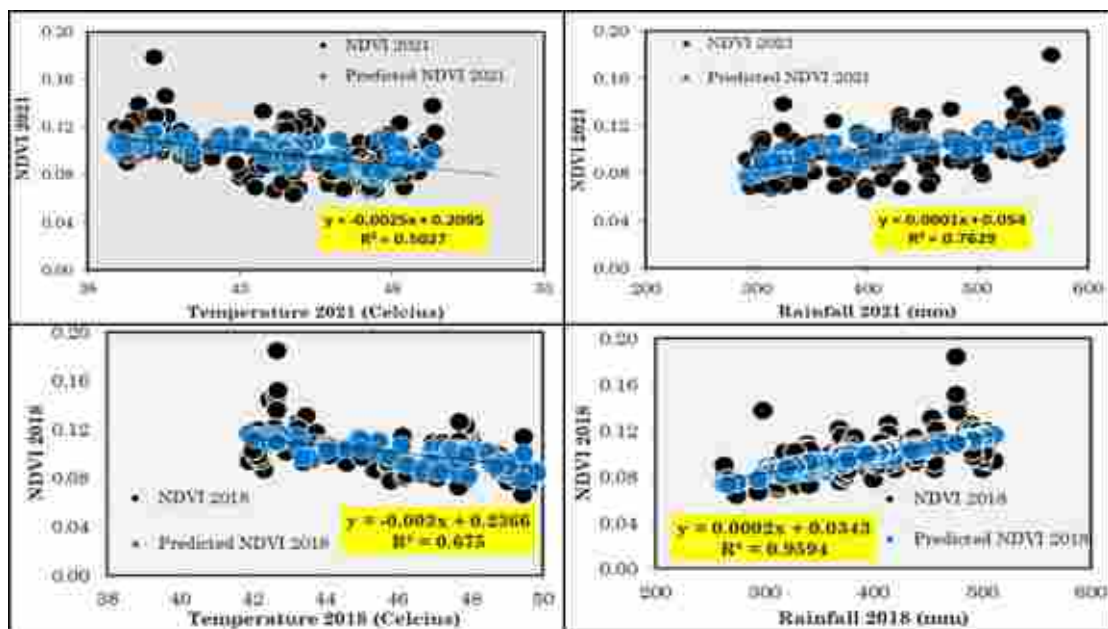


Figure 12: Relationship between temperature, rainfall and NDVI

High correlation between temperature and rainfall indicates that these two factors are closely related and have a significant impact on vegetation growth. The negative correlation between NDVI and temperature indicates that higher temperatures may inhibit vegetation growth. The positive correlation between NDVI and rainfall suggests that more rainfall may lead to increased vegetation growth. The ANOVA results confirm that temperature and rainfall are both significant factors in explaining the variation amongst NDVI values. The multiple linear regression models demonstrate that rainfall is a stronger predictor of NDVI than temperature for both 2018 and 2021 (equations 1 and 2 respectively).

$$\text{NDVI} = 0.0018 \times \text{temperature} + 0.0002 \times \text{rainfall} - 0.08 \quad \text{----- (1)}$$

$$\text{NDVI} = 0.0064 \times \text{temperature} + 0.0003 \times \text{rainfall} - 0.32 \quad \text{----- (2)}$$

In conclusion, the results of this study suggest that temperature and rainfall are important factors that influence vegetation growth and development. The positive correlation between NDVI and rainfall suggests that increased rainfall can lead to improved vegetation cover, while the negative correlation between NDVI and temperature suggests that higher temperatures may hinder vegetation growth. The multiple linear regression models demonstrate that rainfall is a stronger predictor of NDVI than temperature. Based on this information, thematic maps on spatial distribution maps on grasslands along with geodatabase were precisely generated. It can also be valuable for policymakers and environmentalists in planning and managing land use and natural resources. Further, geo-database is also generated for different agro-climatic zones (ACZ) to get the precise estimate of grazing lands/ grasslands. Classified image (grasslands and other grazing lands) and productivity validated with ground truth data.

IGFRI was actively involved in nationwide grassland mapping programme (SAC, ISRO), temperate alpine pasture programme (ICAR) and Geosphere Biosphere programme / national carbon project (ISRO/IIRS). Satellite remote sensing was used in the assessment of grasslands/ grazing lands/ rangelands. Stratification and sampling methods are widely used in agriculture, more particularly in assessment of field food/cash crops, forest cover and production estimates etc. This method is also used in the study of different types of land/ Forest cover. In this study, on the basis of NDVI range, supervised classification has been done for the assessment of grasslands and other grazing lands and accuracy was assessed using validation of GPS linked actual field signatures. Keeping in view of heterogeneity of grasslands/grazing lands ACZ wise NDVI and supervised classification carried out to get more accurate information. A total of 558 widely distributed GT points, covering all the 14 ACZ, were selected using NDVI Range from 0.12 to 0.29 for the evaluation of spectral signature and estimation of area and productivity.

IGFRI was actively involved in the 'Nationwide Carbon Pool Assessment Programme' of ISRO. In this programme, based on different NDVI classes, field sample sites (250m × 250m) were selected. Further from all 4 corner subset of 50m × 50m (tree), 10m × 10m (shrubs) and 1m × 1m (ground vegetation/ grasses/legumes) were selected. The standard procedure used for land/ forest cover cannot be applied as such in the assessment of Indian grazing lands/ grasslands/ rangelands because of heterogeneity in tropical to subtropical natural grasslands, which are at various stages of degradation. Productive grasslands / pasturelands are found in patches only in southern hills, eastern coast and

northern Himalayan zone. We adopted the same procedures with modification as our interest is only grasslands/ grazing lands/ pasturelands hence our field site size was as per the pixel size of a WiFs data. Further from all corners and central point $1\text{ m} \times 1\text{ m}$ plot size (total 5) were selected from each sample site. Keeping in view of tropical to subtropical (hot dry to moist) conditions LTM (line transect method) also applied to collect samples within and even outside sample sites.

IGFRI and AICRP on Forage Crops and Utilization have centers in almost all states and the scientific and technical staff in those centers are regularly updating the various information regarding fodder crops cultivation and productivity based on their demonstrations and experiments. In various reports, the area under fodder crops has been estimated to be nearly 9 million ha. Based on cropping intensity, as reported in various government documents for each state, the cropping intensity multiplied with the area to get the total cropped area under forage. Figures and values have been given for only major states. JK figure is reported as one unit and includes both UT of JK and UT of Ladakh. In many other states and UT like NEH states, Delhi, Chandigarh, A&N islands, Goa, Daman Diu etc., fodder crops cultivation is not in practice and area under fodder crops are negligible.

Besides the experimental research fields, the from FTD and NGO's, farmer producing fodder crops around the district of 22 AICRP centres, 15 voluntary centres and 4 IGFRI-RRS centres located in 21 states were also considered. Farmers' fields were selected from different villages in 89 districts that fall under 14 ACZs. For the collection of field data on cultivated fodder crop productivity, total 89 districts spread over in 21 states and covering 14 ACZ's (ACZ 1 – 8 district, ACZ 2 – 3, ACZ 3 – 4, ACZ 4 – 5, ACZ 5 – 8, ACZ 6 – 8, ACZ 7 – 8, ACZ 8 – 12, ACZ 9 – 5, ACZ 10 – 6, ACZ 11 – 6, ACZ 12 – 5, ACZ 13 – 8 and ACZ 14 – 3 were selected. Field sample sites were selected for the estimation of forage productivity on the basis of randomly selected minimum three points (1 m^2) from each selected field crop for the harvesting and measurement of green fodder. These biomass yields were recorded in annual crops at appropriate harvest stage of fodder crops (50% flowering stage) at which it contains optimum biomass as well as nutritive parameters. For the perennial crops, the multiple harvest as per production technology recommendations of the crops are taken into account.

The productivity obtained from farmer's field, experimental research farms, results of 'Forage Technology Demonstrations' were taken into account for reporting data along with the principal crops of that area/state. The average size of experimental fields are 0.05 ha whereas farmers' fields varied in size and shape as per the fodder requirement of the farmer and availability of land. The data reported is based on the average yield of for

important fodder crops of the area. Depending upon the number and type of fodder crops in both Rabi and Kharif season, fields were selected from area/ villages producing fodder. For the estimation of productivity 1m x 1m crops were harvested from different fields from that area/ villages and data recorded. In the study, estimates for green fodder production based on important fodder crops of each state. Since a large number of fodder crops are grown in each state. The dry matter content for various forage crops on an average ranges from 15 to 35% depending on crop species, cutting stage as well as climatic factors. For computation of dry matter, a uniform figure of 22% dry matter was taken to get the dry fodder production.

6. Estimation of area and productivity

Thematic maps were generated using ArcGIS-ArcMap ver. 10.1. Spatial distribution of grasslands were generated for different agro-climatic zones and states. The productivity estimates of natural grasslands/ grazing lands were validated based on the result of 558 sample sites (Table 4 & 5). Grasses are perennial in nature, our previous studies indicate that single cut (1m^2 production in gram/m^2) provides around 60% forage of annual production in temperate/alpine/meadows in the months of June to September, about 72% in sub temperate to subtropical between June to August, 85% in tropical between August to September and around 65% in coastal region (wet humid) between July to October. After the addition of respective factors, productivity was finally presented in tonnes dry matter per hectare (t DM/ha). The fodder in the report includes largely grasses and accompanying legumes, which are usually edible for ruminants. The productivity and production of forage yield of natural grassland or fodder yield from cultivated croplands are being presented on DM (dry matter) basis not on GFY (green fodder yield) basis because variation in moisture content in different crops and in different Agro Climatic Zones (ACZ) may result in erroneous estimate. The dry matter is usually computed by drying 1kg of green fodder random samples till constant weight and then weighing the dry matter content. The obtained value is converted into percentage and the total green fodder yield is multiplied by the factor to get the dry matter. Since this method has already been standardised for rapid assessment of a big area, hence no need was felt to collect season wise samples.

Table 4: Estimation of forage productivity using field data

Sample Collected	No. of samples	Agro-Climatic Zones (ACZ)	States /UT Covered	Productivity (tDM/ha)
ICAR-IGFRI, Jhansi				
Vegetation Carbon Pool Assessment (ISRO-IGFRI)	145	5 & 8	UP & MP	1.95
Grassland Mapping, Porbander/ Saurashtra Region, Gujarat (SAC-IGFRI)	40	13	Gujarat	2.65
Halophytes/Grassland Mapping, Kachchh region, Gujarat (IGFRI)	37	13	Gujarat	1.85

Grassland Mapping, Bundelkhand Region (IGFRI)	33	8	UP & MP	1.85
Grassland assessment, Chhattisgarh (IGFRI)	54	7	Chhattisgarh	2.82
Temperate/ alpine pasture (ICAR-IGFRI)	42	1 (Cold Desert)	Ladakh	1.10
	36	1	J & K	5.0
	50	1 & 6	Himachal	3.75
	15	1 & 5	Uttarakhand	3.57
	28	2 & 3	Sikkim	4.25
	15	2	Arunachal Pradesh	4.42
Fodder Productivity (NAD – IGFRI)	26	2 & 3	North Bengal & Assam	3.60
	18	8	UP	1.35
	19	8 & 9	MP	3.05

Table 5: Cultivated fodder productivity – collected from various sources

AICRP (Forage Crop) Centres	Agro-Climatic Zones (ACZ)	States /UT Covered	Productivity tDM/ha
AAU, Anand	13	Gujarat	3.10
OUAT, Bhubaneswar	11	Odisha	6.30
SKRAU, Bikaner	14	Rajasthan	1.28
TNAU, Coimbatore	10	Tamil Nadu	2.65
NDUAT, Ayodhya	5	UP	3.50
CCS HAU, Hisar	6	Haryana	2.90
PJTSAU, Hyderabad	10	Telangana	2.20
JNKVV, Jabalpur	8	MP	3.20
AAU, Jorhat	2	Assam	5.10
BCKV, Kalyani	3	West Bengal	4.30

PAU, Ludhiana	6	Punjab	3.50
CSKHPKV, Palampur	1	Himachal	4.95
GBPUAT, Pantnagar	1	Uttarakhand	5.65
MPKV, Rahuri	9	Maharashtra	3.20
BAU, Ranchi	7	Jharkhand	2.00
UAS(B), ZARS Mandya	10	Karnataka	2.35
BAIF, Urulikanchan	9	Maharashtra	3.15
KAU, Vellayani	12	Kerala	6.90
SKUAST, Srinagar	1	J&K	5.20
IGKV, Raipur	7	Chhattisgarh	3.10
CAU, Imphal	2	Manipur	5.25
RPCAU, Pusa	4	Bihar	4.00

(Singh et al. 2021)

6. Findings

6.1 Area and productivity estimation of fodder from rangelands/pasturelands

State wise area estimates on rangelands/ pastureland/ grazing lands as reported by DAC&FW is presented in table 6. It is evident from the table that total area under the head 'permanent pasture including other grazing lands' is 3.39% of the total reported area of the contrary. It is lowest (0.03 %) in West Bengal and maximum in Himachal Pradesh (32.94 %). This estimate of DAC & FW is purely based on the Land-use data compiled by the Statistical Department.

In the present study, Geospatial technology was used to generate the area under grasslands/ pasturelands and other grazing lands using IRS Resourcesat aWiFs satellite image (Fig. 13). This study provides a precise estimate about the area in different states. It is evident from table 6 that total area under grasslands is 3.5 % (11.5 million ha) of the total geographical area. The maximum area (16.38 %) under grasslands was observed in Himachal Pradesh and minimum in Delhi (0.33%), Punjab (0.48%) and Haryana (0.52%). The spatial distribution is presented in figure 14.

Table 6: State wise area under grasslands/ grazing lands (2019-20)

S. N.	State / UT	DAC* Report		IGFRI estimate (based on RS / GIS)**		
		Reporting area (ha)	Permanent pasture and other grazing land (%)	Geographical Area (ha)	Permanent pasture and other grazing lands (ha)	Permanent pasture and other grazing lands (%)
1	Andaman & Nicobar Island	757380	0.49	665862		
2	Andhra Pradesh	16296690	1.30	15751891	189504.21	1.20
3	Arunachal Pradesh	5632818	0.32	8316273	215480.75	2.59
4	Assam	7843800	2.16	7865820	436377.10	5.55
5	Bihar	9359568	0.16	9423009	100863.57	1.07
6	Chandigarh	7025	0.00	12809	199.53	1.56
7	Chhattisgarh	13789836	6.43	13434381	794382.05	5.91

8	Dadra Nagar	48882	1.89	47169	1319.32	2.80
9	Daman & Diu	4154	3.54	12316		
10	Delhi	147488	0.04	131462	433.39	0.33
11	Goa	361113	0.36	363137	2576.26	0.71
12	Gujarat	17032000	5.00	18486243	588773.99	3.18
13	Haryana	4371487	0.58	4675307	24360.03	0.52
14	Himachal Pradesh	4577742	32.94	5811735	951845.52	16.38
15	Jammu & Kashmir	2417683	4.60	5804202	261769.53	4.51
16	Jharkhand	7970075	1.46	7785158	149903.08	1.93
17	Karnataka	19050068	4.75	19263239	959036.46	4.98
18	Kerala	3886287	0.00	4078149	29297.67	0.72
19	Ladakh	17921778	368767.50	2.06		
20	Lakshadweep	2659	0.00	3798		
21	Madhya Pradesh	30756303	4.25	30965469	1353406.53	4.37
22	Maharashtra	30758300	3.80	30253495	1277977.12	4.22
23	Manipur	179530	0.00	2231355	23589.24	1.06
24	Meghalaya	2195719	0.00	2249839	33906.91	1.51
25	Mizoram	2038988	0.54	2113060	14520.94	0.69
26	Nagaland	1652271	0.00	1692437	12910.80	0.76
27	Odisha	14839603	3.45	15363920	708849.44	4.61
28	Pudducherry	48258	0.00	80333	1395.96	1.74
29	Punjab	5032732	0.09	5097683	24594.94	0.48
30	Rajasthan	34278551	4.87	34894301	1461378.42	4.19
31	Sikkim	442100	0.27	663914	9184.82	1.38
32	Tamil Nadu	13033116	0.83	12998941	308174.61	2.37
33	Telengana	11207700	2.67	11312586	545838.10	4.83
34	Tripura	1049209	0.10	1064066	20049.35	1.88
35	Uttar Pradesh	24170454	0.27	23882719	333794.39	1.40
36	Uttarakhand	5992604	3.21	5560311	167881.55	3.02
37	West Bengal	8684113	0.03	8493732	130785.22	1.54
	India	299916306	3.39	328771900	11503128.3	3.50

*aps.dac.gov.in/lus; In DAC report - J&K included the data of Ladakh.

**In IGFRI report - Information of A&N Island, Daman & Diu, and Lakshadweep could not be generated due to non-availability of cloud free satellite images selected for this study.

As per the estimates of ICAR-IGFRI, Jhansi total area under permanent pasture and other grazing land in India is ~ 11.50 Mha, sharing 3.5% of the total geographical area. The highest share of permanent pasture and other grazing land to the geographical area is seen in Telengana, Karnataka, Assam, Chhattisgarh, and Himachal Pradesh. The highest area under permanent pasture and other grazing land was observed in the states of Himachal Pradesh, Karnataka, Maharashtra, Madhya Pradesh, and Rajasthan. The lowest area under permanent pasture and other grazing land was observed in the states of Goa, Sikkim, Nagaland, Mizoram, and Tripura.

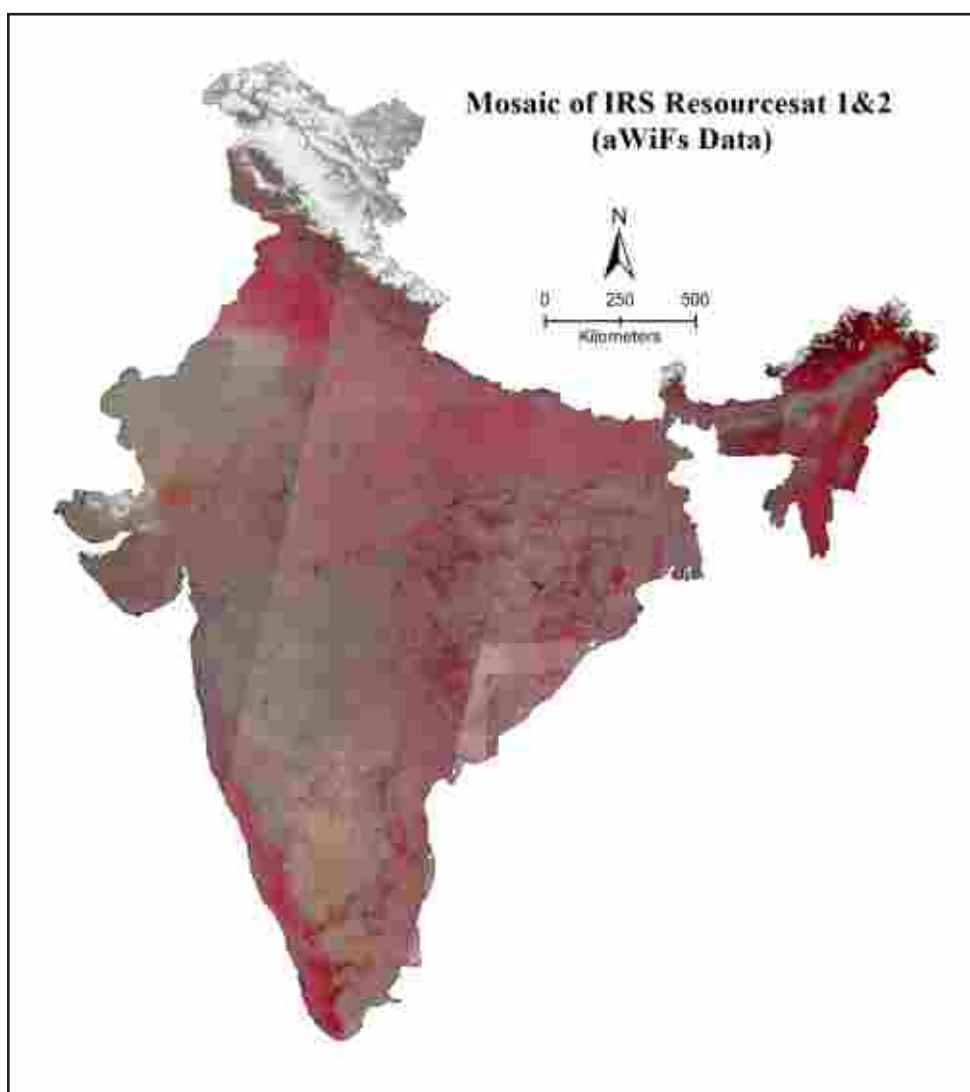


Figure 13: IRS Resourcesat-1&2 aWiF's Mosaic

Spatial Distribution of Grasslands in Different States

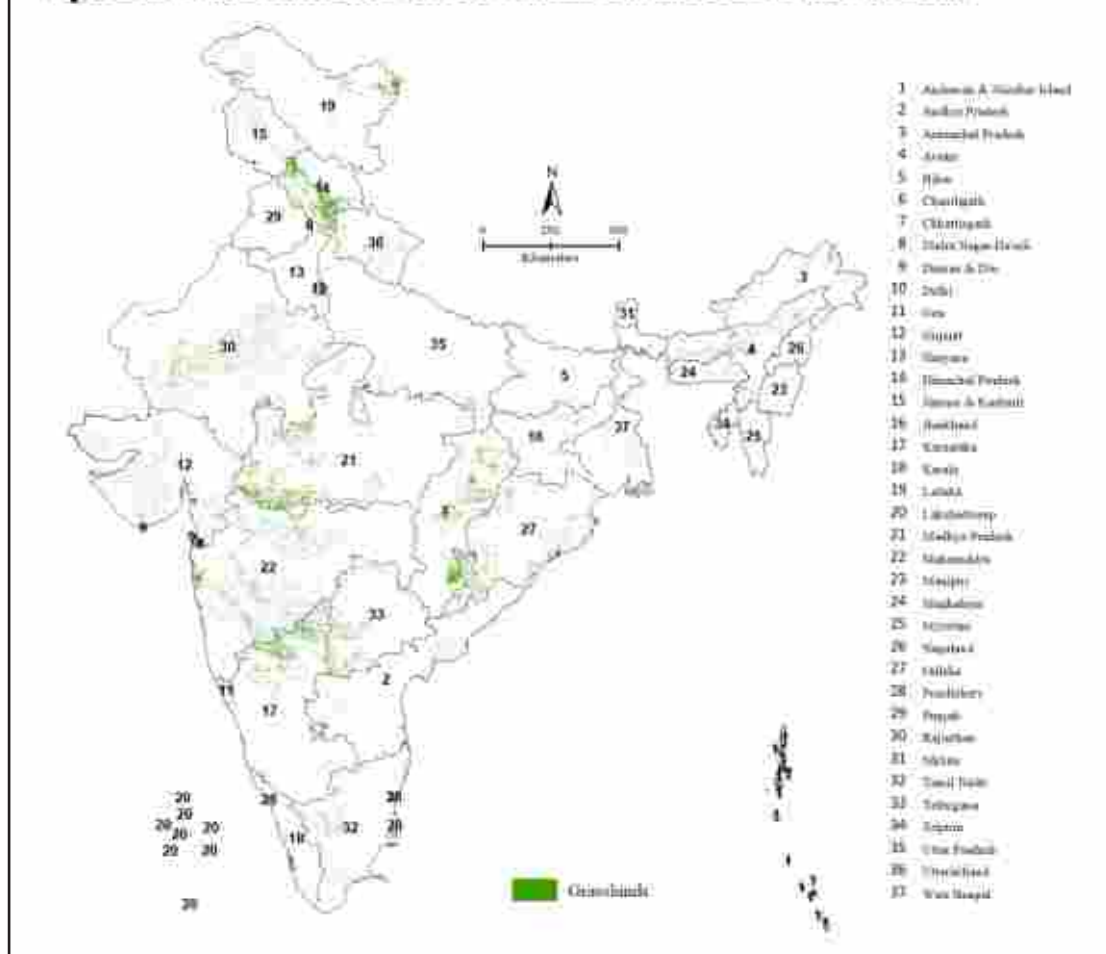


Figure 14: Spatial distribution of grasslands / grazing lands

Distribution pattern of grassland and other grazing lands map clearly shows that it is uniformly distributed (3-5%) in the central western part except Kerala and AP, whereas in the northern plain it ranges between 0.48 to 1.54 percent. The western Himalayan zone (except Ladakh) grasslands ranges between 3.0 – 16.38 percent. The spatial distribution pattern of grasslands shows in figure 15.

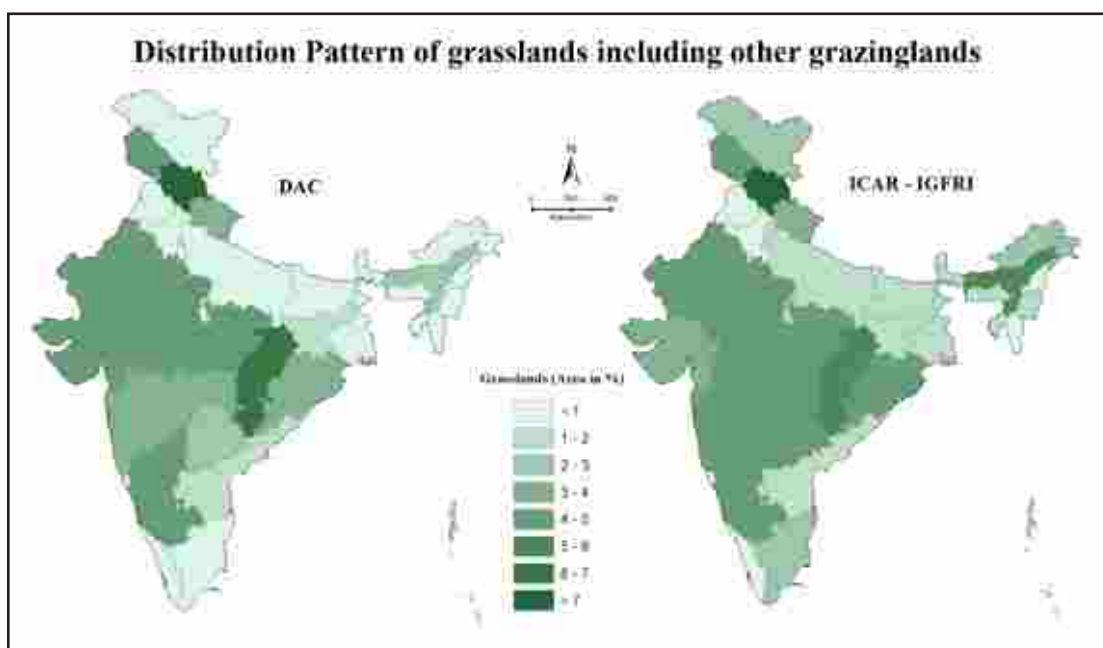


Figure 15: Distribution pattern of grasslands and other grazing lands

The average forage productivity from grasslands including other grazing lands of the country in metric tonnes dry matter per hectare (tDM/ha) was estimated to be 3.22 tDM/ha (Table 7), but at state level it ranged from 1.4 tDM/ha in Ladakh and Andhra Pradesh (2.1 tDM/ha) to Kerala (7.2 tDM/ha) and 7.65 tDM/ha in Meghalaya (Fig. 16). The distribution pattern is depicted in figure 6 based on the data generated, efforts have been made to estimate the total range fodder in the country and it is estimated as 36.99 million tonnes dry matter.

Table 7: State wise estimate of range fodder productivity and production (2019-20)

S. No.	State Name	Permanent pasture and other grazing land (ha)	Permanent pasture and other grazing land (%)	State Average range fodder productivity (tDM/ha)	Estimated Range fodder production (million tDM)
1	Andhra Pradesh	189504.21	1.2	2.1	0.398
2	Arunachal Pradesh	215480.75	2.59	4.42	0.952
3	Assam	436377.1	5.55	3.74	1.632
4	Bihar	100863.57	1.07	3.82	0.385

5	Chandigarh	199.53	1.56	3.5	0.001
6	Chhattisgarh	794382.05	5.91	3.1	2.463
7	Dadra Nagar Haveli	1319.32	2.8	2.5	0.003
8	Delhi	433.39	0.33	2.8	0.001
9	Goa	2576.26	0.71	5	0.013
10	Gujarat	588773.99	3.18	2.78	1.637
11	Haryana	24360.03	0.52	3.25	0.079
12	Himachal Pradesh	951845.52	16.38	4.35	4.141
13	Jammu & Kashmir	261769.53	4.51	4.8	1.256
14	Jharkhand	149903.08	1.93	2.75	0.412
15	Karnataka	959036.46	4.98	2.4	2.302
16	Kerala	29297.67	0.72	7.2	0.211
17	Ladakh	368767.5	2.06	1.4	0.516
18	Madhya Pradesh	1353406.53	4.37	3.05	4.128
19	Maharashtra	1277977.12	4.22	3.14	4.013
20	Manipur	23589.24	1.06	6.25	0.147
21	Meghalaya	33906.91	1.51	7.65	0.259
22	Mizoram	14520.94	0.69	5.95	0.086
23	Nagaland	12910.8	0.76	6.12	0.079
24	Odisha	708849.44	4.61	4.25	3.013
25	Puducherry	1395.96	1.74	5.02	0.007
26	Punjab	24594.94	0.48	3.5	0.086
27	Rajasthan	1461378.42	4.19	2.75	4.019
28	Sikkim	9184.82	1.38	5.25	0.048
29	Tamil Nadu	308174.61	2.37	2.81	0.866
30	Telangana	545838.1	4.83	2.2	1.201
31	Tripura	20049.35	1.88	5.84	0.117
32	Uttar Pradesh	333794.39	1.4	2.75	0.918
33	Uttarakhand	167881.55	3.02	6.05	1.016
34	West Bengal	130785.22	1.54	4.5	0.589
	India	11503128.3	3.50	3.22	36.99

(Singh et al. 2021)

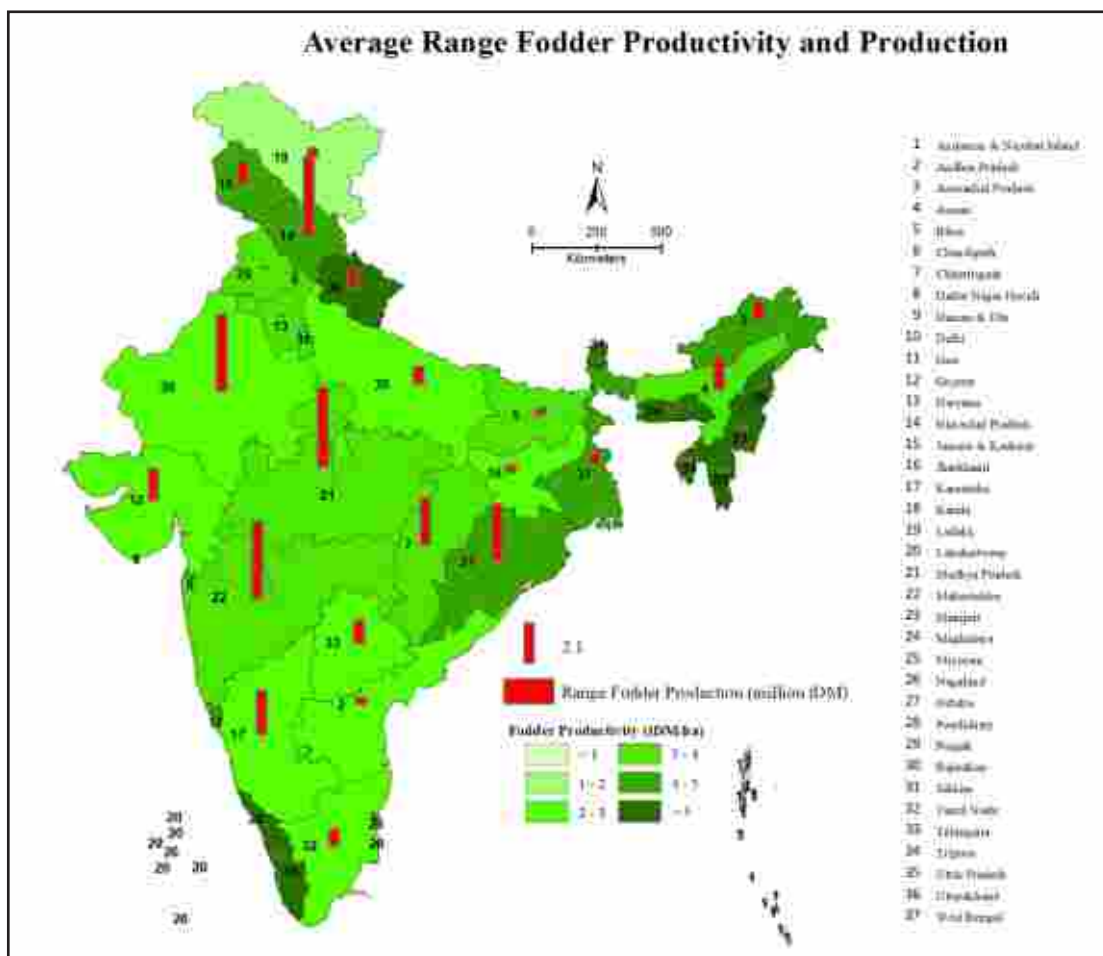


Figure 16: Range fodder productivity and production

Agro-climatic conditions affect the distribution pattern of grasslands so grassland data was also extracted using the ACZ *shapefile*. It is evident from table 8 that maximum area (5.03%) under grasslands is found in ACZ-1 (Western Himalayan Zone) whereas minimum (0.82%) in Trans Gangetic Plain (Fig. 17).

Table 8: Spatial distribution of grasslands/ grazing lands in different ACZ (2019-20)

Agro-Climatic Zones (ACZ)		Geographical Area (ha)	Grasslands (ha)	Grasslands (%)
ACZ - 1	Western Himalayan	34191393.81	1720198.60	5.03
ACZ - 2	Eastern Himalayan	26206323.13	763480.86	2.91
ACZ - 3	Lower Gangetic Plains	8385036.13	135376.68	1.61

ACZ - 4	Middle Gangetic Plains	16311284.17	192839.97	1.18
ACZ - 5	Upper Gangetic Plains	14412291.06	187300.43	1.30
ACZ - 6	Trans Gangetic Plains	11759494.96	96173.42	0.82
ACZ - 7	Eastern Plateau & Hills	33641391.35	1184276.57	3.52
ACZ - 8	Central Plateau & Hills	39009319.63	1085280.76	2.78
ACZ - 9	Western Plateau & Hills	32908244.36	2127797.16	6.47
ACZ - 10	Southern Plateau & Hills	39842430.65	1693226.62	4.25
ACZ - 11	East Coast Plains & Hills	21003854.65	707301.47	3.37
ACZ - 12	West Coast Plains & Hills	13476678.81	267315.28	1.98
ACZ - 13	Gujarat Plains & Hills	18679305.42	578279.21	3.10
ACZ - 14	Western Dry Region	17587806.27	764281.27	4.35
ACZ - 15	Islands	1357045.60	0.00	0.00
Total		328771900.00	11503128.29	3.50

(Singh et al. 2021)

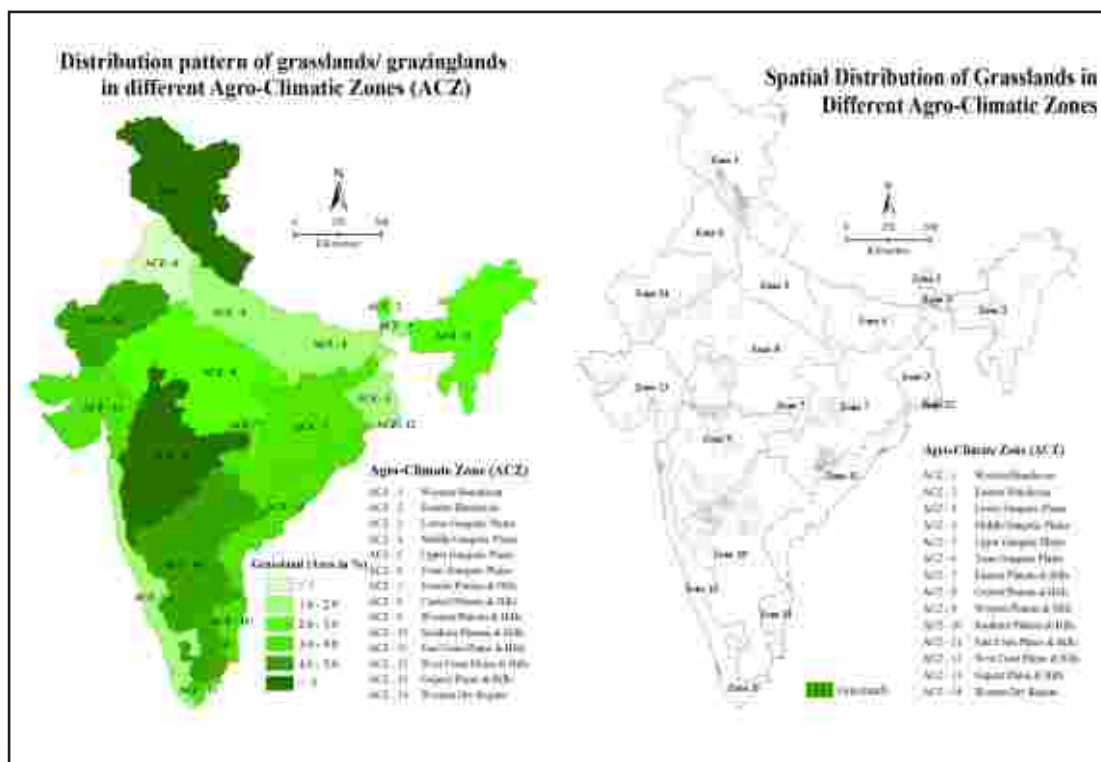


Figure 17: Spatial distribution and pattern of grasslands in ACZ

6.2 Estimation of area and productivity for cultivated fodder

As per reports available, none of government agency or private sector agency is involved in regular recording of forage crop cultivation area and yield data except perhaps for Punjab state where state government department record and report data on a few important forage crops. Basic data statistics related to agricultural crops, the area, irrigated and rainfed condition, cropping intensity etc. has been compiled by data of the Ministry of Agriculture, Government of India and ICAR-IASRI, New Delhi. There are multiplicity of fodder crops in Rabi & Kharif as well as perennial systems. Forage crops also vary from region to region and as per availability of land and irrigation source.

Data obtained in Forage Technology Demonstrations (FTDs) of new varieties & technologies conducted by State Agricultural Universities (SAUs) and state governments, reports of NGOs & Regional Fodder Production Farm (RFPF), research experiments results formed the basis for estimating the productivity of different crops in various states. Separate estimates for area and productivity were made for Kharif and Rabi fodder crops. Satellite remote sensing technique was not used for the estimation of cultivated fodder crops, biomass yield.

IGFRI and AICRP on Forage Crops have centers in almost all big states and the scientific and technical staff in those centers are regularly reporting estimated areas under various fodder crops based on their survey or estimation. Based on these reports, the area under fodder crops has been estimated to be nearly 9 million ha. State wise forage crop areas estimates are based on the cropping intensity, as reported in ICAR publications for each state.

Analysis of various government reports indicate that concrete data is lacking for irrigated and unirrigated land for fodder crops. In general, as per our knowledge and information gathered from various sources, 90% of area under fodder crops in kharif is unirrigated and grown under rainfed condition. Similarly, nearly 75% of the area under rabi fodder crops has some source of irrigation. We have accounted for the perennial crops yield data and the value for rabi and kharif season productivity (summer season as well as perennial fodder crops were included in Kharif crop in this report) has been taken into account for calculating the yield productivity. There is multiplicity of forage crops and each state has its own preference of fodder crops in different parts and in different seasons. Based on information gathered from farmer's field, AICRP multi-locational trials, Fodder Technology Demonstrations, three - four major fodder crops of the particular state were identified and their productivity and area were estimated. The average productivity of the state in both rabi and kharif season was estimated based on above-mentioned facts. The cultivation of perennial grasses and legumes were also

Table9: Area and fodder productivity of rabi and kharif crops (2019-20)

Fodder Producing States	Area under fodders (000 ha)	Cropping intensity	Total cropped area Forage (000 ha)	Total area under kharif (000 ha)	Total area under rabi (000 ha)	AVG Productivity Kharif Green Fodder (t/ha)	AVG Productivity Rabi Green Fodder (t/ha)	AVG Productivity Kharif Dry Fodder (tDM/ha)	AVG Productivity Rabi Dry Fodder (tDM/ha)	Total production- Kharif (000 ton) GFY	Total production- Rabi (000 ton) GFY	Total production- Kharif (000 ton) DFY	Total production- Rabi (000 ton) DFY
Andhra Pradesh	307.60	123.30	379.27	265.49	113.78	39.50	34.40	8.69	7.60	10486.86	3914.03	2307.11	864.73
Assam	163.32	144.40	235.83	165.08	70.75	30.30	23.80	6.67	5.20	5001.92	1683.85	1100.42	367.90
Bihar	383.55	145.40	557.68	278.84	278.84	45.20	49.00	9.94	10.80	12603.57	13663.16	2772.78	3011.47
Chhattisgarh	229.12	122.40	280.44	196.31	84.13	36.30	47.60	7.99	10.50	7126.05	4004.59	1567.73	883.37
Gujarat	894.11	124.00	1108.70	831.52	277.17	50.20	44.00	11.04	9.70	41742.30	12195.48	9183.31	2688.55
Haryana	392.16	185.60	727.85	436.71	291.14	44.90	56.10	9.88	12.30	19608.28	16332.95	4313.82	3581.02
Himachal Pradesh	27.54	167.00	45.99	29.89	16.10	31.10	23.60	6.84	5.20	929.58	379.96	204.51	83.72
Jammu & Kashmir	47.12	155.30	73.18	47.57	25.61	25.90	27.70	5.70	6.10	1232.06	709.40	271.05	156.22
Jharkhand	62.16	112.20	69.74	48.82	20.92	35.20	36.10	7.74	7.90	1718.46	755.21	378.06	165.27
Karnataka	489.88	121.90	597.16	418.01	179.15	43.50	32.60	9.57	7.20	18183.44	5840.29	4000.36	1289.88
Kerala	26.25	128.50	33.73	20.24	13.49	42.10	42.50	9.26	9.40	852.10	573.33	187.46	126.81
Madhya Pradesh	1190.50	155.10	1846.47	923.23	923.23	31.50	45.90	6.93	10.10	29081.75	42376.26	6397.98	9324.62
Maharashtra	1643.18	135.30	2223.22	1333.93	889.29	46.80	46.50	10.30	10.20	62427.92	41351.99	13734.14	9070.76
Odisha	51.73	115.60	59.80	35.88	23.92	27.30	27.10	6.01	6.00	979.52	648.23	215.50	143.52
Punjab	471.42	190.80	899.47	539.68	359.79	50.20	59.40	11.04	13.10	27091.94	21371.53	5960.23	4713.25
Rajasthan	969.40	138.30	1340.68	938.48	402.20	31.30	32.30	6.89	7.10	29374.42	12991.06	6462.37	2855.62
Tamil Nadu	239.80	124.40	298.31	208.82	89.49	65.40	65.60	14.39	14.40	13656.83	5870.54	3004.50	1288.66
Telengana	212.60	121.40	258.10	180.67	77.43	40.00	45.20	8.80	9.90	7226.80	3499.84	1589.90	766.56
Uttar Pradesh	1045.88	157.50	1647.26	988.36	658.90	34.90	53.80	7.68	11.80	34493.76	35448.82	7588.63	7775.02
Uttarakhand	21.94	156.70	34.38	24.07	10.31	32.40	32.40	7.13	7.10	779.87	334.04	171.57	73.20
West Bengal	193.80	185.00	358.53	250.97	107.56	31.80	25.00	7.00	5.50	7980.85	2689.00	1755.79	591.58
Total	9063.06	144.28	13075.80	8162.57	4913.20	40.74	46.13	8.96	10.14	332578.29	226633.55	73167.22	49821.72

In rest of small states/UT especially in NEH region and islands, the area under cultivated forage crops is negligible, hence no data is presented.

GFY = Green Fodder Yield, DFY= Dry Fodder Yield

(Singh et al. 2021)

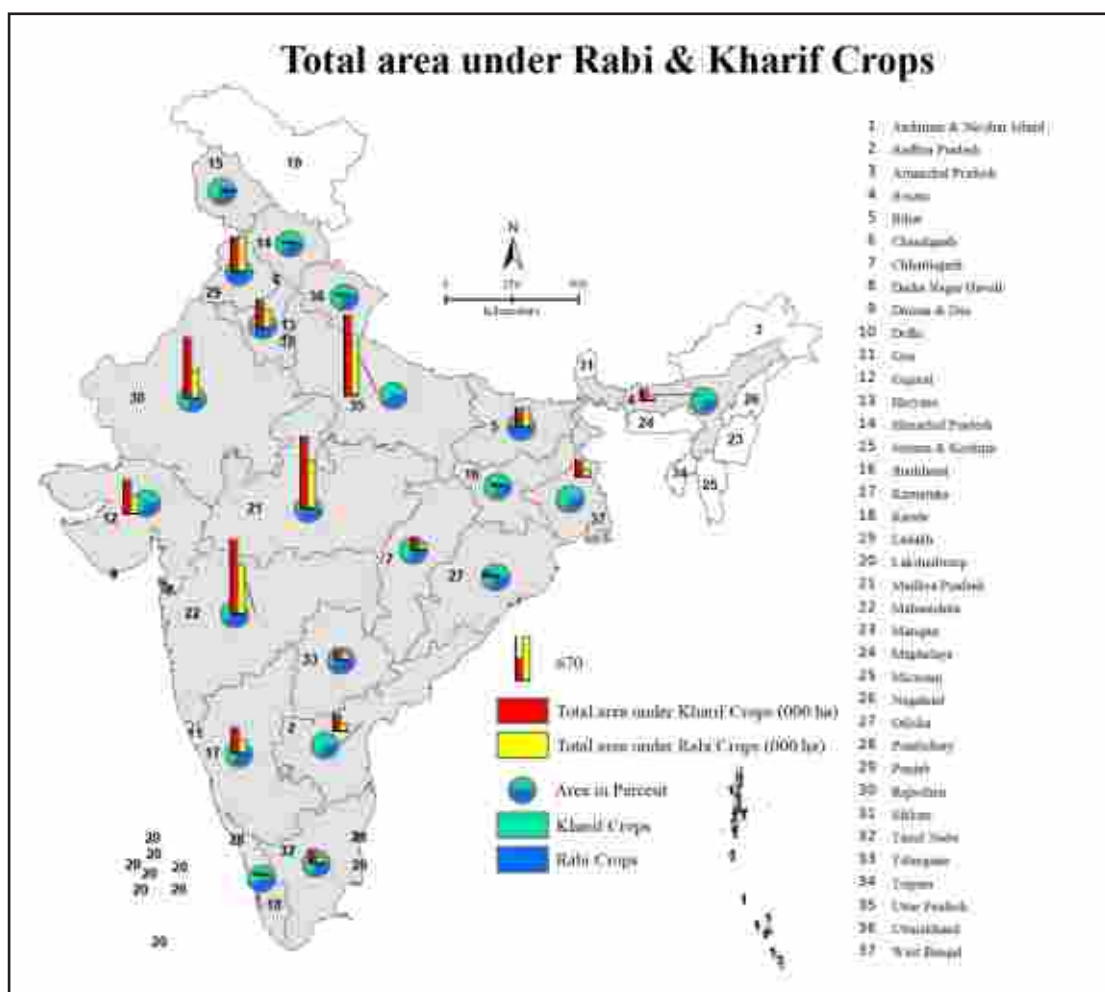


Figure 19: Area under Rabi and Kharif crops

Table 10: State-wise major cultivated forage crops

States/UT	Major Kharif and summer forage crops	Major Rabi forage crops
Andhra Pradesh	Sorghum, BxN hybrid, hedge Lucerne, pearl millet	Oat, Rabi Maize, Rabi sorghum
Assam	Maize, pearl millet, Sorghum, Cowpea, rice bean, BxN hybrid, guinea grass	Oat, Rabi Maize, Ryegrass, setaria, lathyrus
Bihar	Maize, Sorghum, BN hybrid, guinea grass	Berseem, Oat, Rabi Maize, Rabi sorghum

Chhattisgarh	BxN hybrid, Maize, Cowpea, rice bean	Oat, Berseem, Rabi sorghum, Rabi Maize,
Gujarat	Sorghum, pearl millet, BxN hybrid	Lucerne, Oats, Rabi maize
Haryana	Sorghum, Cowpea, pearl millet, BxN hybrid	Berseem, Oat, Lucerne, rye grass,
Himachal Pradesh	Sorghum, BxxN hybrid, guinea grass, setaria grass	Oat, Berseem, white and red clovers
Jammu & Kashmir	Maize, Sorghum, Cowpea,	Oat, Berseem, white and red clovers, sanfoin
Jharkhand	BxN hybrid, Maize, Sorghum,	Oat, Maize, Berseem,
Karnataka	Sorghum, Maize, BxN hybrid, Agase, hedge Lucerne,	Maize, Sorghum, Agase
Kerala	Guinea grass, BxN hybrid, rice bean	Guinea, perennials, Maize, cowpea
Madhya Pradesh	Sorghum, Maize, Guar, Cowpea, rice bean, BxN hybrid	Oat , Berseem, Lucerne
Maharashtra	Maize, Sorghum, BxN hybrid	Lucerne, Rabi Maize, BN hybrid, Rabi Sorghum
Odisha	Maize, Sorghum, cowpea, BxN hybrid	Oat, Berseem,
Punjab	Maize, Sorghum, BxN hybrid, guinea grass	Berseem, Oat, rye grass
Rajasthan	pearl millet, Sorghum, Maize, cowpea, guar	Oat, Lucerne, Barley, Berseem
Tamil Nadu	BxN hybrid, perennial sorghum, Maize, cowpea	Lucerne, Maize
Telangana	Sorghum, Maize, pearl millet, BxN hybrid, hedge Lucerne,	Oat, Rabi Maize, rabi sorghum
Uttar Pradesh	Sorghum, pearl millet, maize, cowpea, BxN hybrid	Berseem, Oat
Uttarakhand	Sorghum, Cowpea, Maize, BxN hybrid	Berseem, Rabi Maize
West Bengal	Sorghum, Maize, BxN hybrid	Lathyrus, barley, Rabi Maize

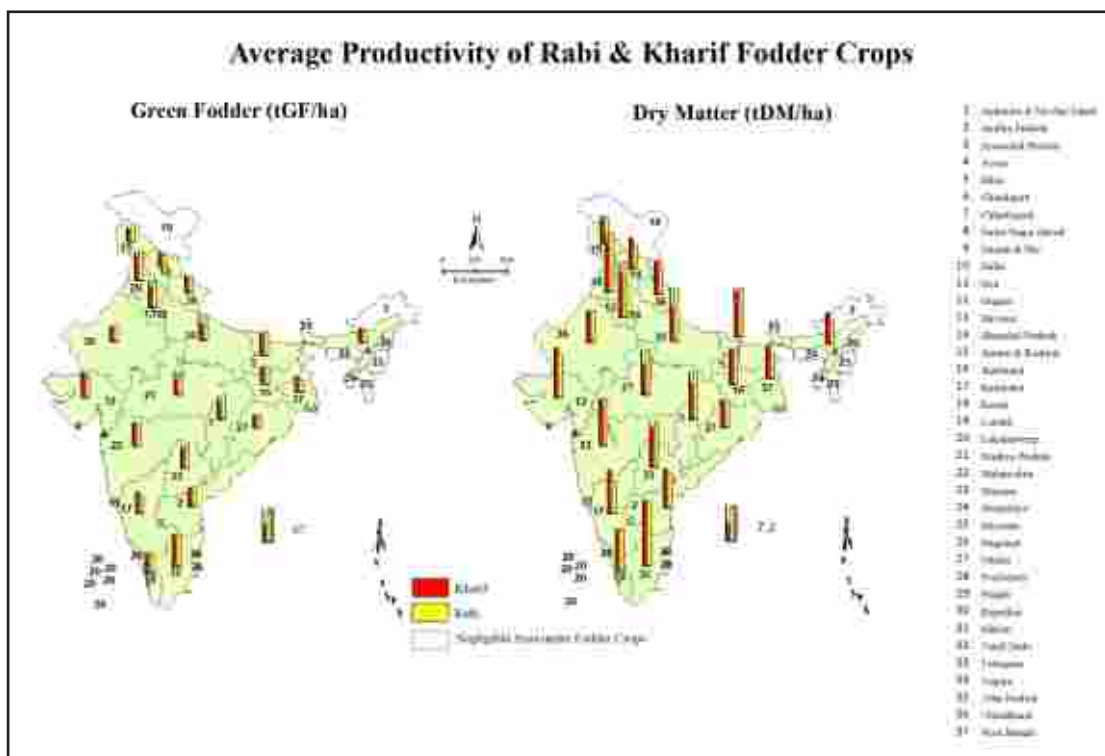


Figure 20: Productivity (green & dry) of fodder crops

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