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Pastoral Value Chain-Oriented Mid-Career Program for Agricultural Extension Professionals

PARTICIPATORY RANGELAND MANAGEMENT

COURSE CODE: (xxxx)

BY:

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Distance Learning Material

Pastoral Value Chain-Oriented Mid-Career Program for Agricultural Extension Professionals

Participatory Rangeland Management
Course Code: (To be decided)

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MODULE INTRODUCTION

Dear Learner, welcome to the course entitled: " *Participatory Rangeland Management*" . This material covers eight units and has a weight of three credit hours. The general objectives for the module are described in the next page while unit objectives are given at the beginning of every unit to direct you to important points and messages. To make this material interesting for you and achieve the objectives, there are few self-assessment questions and activities in the middle and end of the units. You will find answer keys to these self-assessing questions at the end of the each unit. It is highly appreciated if you try first to work the self-test exercises and activities by yourself before checking the answer keys. This is very important for you to understand the contents in each unit and develop self-confidence in the module to be independent learner. It is also advisable to seek for some assistance whenever you face difficult points in learning this module. For example, if there is an agricultural college or similar institutions in your locality it is important to approach appropriate individuals who can help to solve your difficulty. Discussing with other professionals will help you broaden your knowledge. Dear Learners, upon accomplishing this module, you will have a better understanding of the Rangeland Management Planning, Rangeland Resources Inventory, Monitoring and Improvement for efficient and effective animal production and productivity besides to sustainable natural resources conservation. This knowledge and skill you gain through this course will enable you to have tremendous role in improving livelihood activities of pastoral and agro-pastoral people. Finally, it is hoped that you will find this material interesting, practical to the level of your expectation, and helpful in your future career.

MODULE OBJECTIVE

After accomplishing this module, students will be able to:

- Identify participatory approaches in rangeland management
- Describe rangeland biomes and how rangelands provide the society with goods and services on sustainable basis
- Characterize rangeland environment and vegetation changes in range ecosystem
- Classify Rangelands based on different basis and estimate rangeland resources
- Determine rangeland carrying capacity, range conditions and range trends.
- Evaluate livestock grazing systems and apply based on accessibility
- Do rangeland inventory and monitoring activities
- Determine the ecological conditions of rangelands
- Apply different rangeland management practices
- Identify and control rangeland weeds
- Measure vegetation in rangeland
- Rehabilitate degraded rangelands

Icons/Symbols

The Icons/Symbols whose meaning provided below are used in this module.

Refers to **Objectives**. These appear at the start of the course and at the start of every lecture. The objectives help you to focus on the expected outcomes of each lecture. Please read each objective carefully and check on them again and again throughout the lecture to find out if you are able to do what the lecture is intended to enable you do.

Refers to **Take Note**. It helps to highlight significant points that you need to keep in mind. When making your study notes, take down these points as well.

Refers to **In-text Question(s).** These questions are interspersed within the text of the lecture to help you review and master small chunks of knowledge, skills and values. They are helpful for the mastery of your lessons; please respond appropriately to each one of them (preferably in writing) before you move on.

Refers to **Activity**. The activities are also interspersed throughout the lectures to encourage group discussions, open-ended learning, project work, et cetera. Please endeavor to carry out all the suggested activities individually and in groups, as required. This will help you to master what you are learning.

Refers to **Summary**. Summaries are included at the end of every lecture to assist to quickly recapitulate what you have just learnt in the lecture. You will find summaries also useful when making your personal notes as you study, and when preparing for examinations. Study them keenly.

Refers to **Self-assessment Question(s).** These are tasks set to cover work done in the entire lecture. The set tasks provide summative evaluation of what you have learned in the lecture. If answers to self-assessment questions are provided, do not check on the answers before attempting the questions yourself. Where answers are not provided, check your answers against the relevant portions of the text. Where the text does not provide satisfactory answers to the self-assessment questions, raise these questions in your discussion group and/or during the face-to-face tutorial session.

Refers to **Further Reading**. Although attempts have been made to make every study material as inclusive as possible, it is also true that no single lecture can purport to say the last word on any given topic. It is therefore vital for you to study the additional materials cited in the Further Reading section. This will broaden and deepen your understanding of the subject under discussion.

Refers to **Answer to Self-assessment Question(s).** These are tasks set to indicate the answer for self-assessment questions in the entire lecture

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UNIT 1

PARTICIPATORY RANGELAND MANAGEMENT

INTRODUCTION

Dear Learner, in this unit, you will deal with key terminologies, and the area coverage, classification and importance of rangelands. Specifically, you will explore the bases for classification, and types of rangelands. Besides, you will be familiarized with the current status of rangelands in Ethiopia.

Objectives

At the end of this unit, you should be able to:

- Define terminologies related to participatory rangeland management
- Describe the current status of Ethiopian rangelands
- Classify tropical rangelands in different basis
- State the physical and biological characteristics of rangelands
- List social, economic and ecological importance of rangelands

1.1. Overview of Rangelands

Rangelands cover about 65% of the total area of Africa, and 62% of the total land mass in Ethiopia. It would be easier to describe than define what a rangeland and range management is; because no single feature differentiates a rangeland from other land types such as cropland or forestland. Rangelands are those areas of the world which by reason of physical limitations - low and erratic precipitation, rough topography, poor drainage, and/or cold temperatures - are unsuited to cultivation and which are a source of forage for free-roaming native and domestic animals, as well as a source of wood products, water and wildlife. Rangelands can be classified based on agro-ecology and vegetation types, apart from its importance to human being, livestock, wildlife and the environment.

1.2. Terminologies related to participatory rangeland management

Why do you need to know about rangelands? What makes it particularly important for you?

Dear learner, before going to the detailed discussion to the course, it would be proper to accustom the learners with some terminologies and their meanings, which you will encounter most frequently throughout the time of reading this module.

- ***Rangeland:*** Land on which the native vegetation (climax or natural potential plant community) is predominantly grasses, grass-like plants, forbs, shrubs, suitable for grazing or browsing use. They have also been considered as those found in arid and semiarid areas where intensive agricultural activities or works and forestry practices are difficult to undertake because of low and unreliable rainfall (moisture).
- ***Grassland***: Any plant community in which grasses and/or legumes compose the dominant vegetation.
- ***Shrub***: A perennial woody plant smaller than a tree and having several stems arising at a point near the ground.
- ***Pasture***: A fenced area of land covered with grass or other herbaceous forage plants, with application of agronomic activities, and used for grazing animals.
- ***Pasturage***: Vegetation on which animals graze, including grasses or grass like plants, legumes, forbs, and shrubs.

- ***Forage***: Herbaceous plants or plant parts consumed by domestic animals (generally, the term refers to such material as pasture, hay, silage, deby, and green chop in contrast to less digestible plant material known as “ roughage”).
- ***Range sciences***: the organized body of knowledge upon which range management is base
- ***Tropic***: The tropics are regions of the earth surrounding the equator.

1.3. Ecological view of Eastern African Rangelands

Dear Learner, what do you think is the bases for classifying rangelands?

The interaction between climate, soil and topography determines the potential of a particular tropical range to support the entire livestock. Tropical rangelands are suitable for different drought tolerant invasive weeds and parasite production. They are characterized by low, erratic precipitation, hot temperature, high salinity, arid and semi-arid agro-ecology, harsh environmental condition etc.

Rangelands cover about 65% of the total area of the African continent. The East African rangelands, despite their relative aridity, still support a significant proportion of the region's human population, roughly half of the livestock population, much of the wildlife and a considerable amount of the overall biodiversity. Overall, revenue obtained from the sale of products from rangeland areas, and from wildlife based tourism, is a major support for both the local and national economies within the region. Because of the diversity of goods and services derived from the rangelands, their management and health are linked closely to the economic well-being of many communities.

East Africa rangelands support great number of wild, domestic animal, and pastoralist (with their herd and flocks). Range resources of eastern Africa is so enormous and have potential for production of food, water, mineral, timber, fuel wood, charcoal. They also provide services like, tourism, recreation, hunting, sightseeing etc. Ecological encroachments by weeds and undesirable woody plants have been threatening the pastoral production system in eastern Africa. Herbaceous weedy species like *Xanthium* and *Parthenium*, woody species like *Prosopis juliflora*, *Acacia mellifera*, *A. nubica* and succulents like *Opuntia spp.* are increasing.

1.4. Classification of Eastern African Rangelands

Although there was no standard approach to rangeland classification in Africa, attempt was made by East African Rangeland Classification committee in 1966. The committee recommended the following two as a base for classification.

- Based on the agro-ecology of the environment
- Based on the type of the vegetation

1.4.1. Agro-Ecological Classification

Agro-ecological zones and/or rangeland classes are mainly determined by: rainfall, temperature, altitude and soils.

Table 1.1. Agro-ecological classification of rangelands

Zone 1 (Afro-alpine)	Zone 2 (Humid to dry sub-humid)
• Mainly moorland and grassland • Sometimes barren land • At high altitude above forest line • Of limited use and potential, except as water catchment	• Moisture index not less than -10 • Forest and derived grasslands and bush lands • With or without natural glades • Potential for forestry and intensive agriculture, • Coffee, tea and chat at higher elevations • 1.5 - 2.0 ha/stocking unit
Zone 3 (Dry sub-humid to semi-arid) • Moisture index -10 to -30 • No forest potential • Variable vegetation cover (moist woodland, bush land or savannah) • Broad-leaved trees (brachystegia, combretum) • Larger shrubs mostly evergreen • Agricultural potential is high • Extensive range management systems • Regular burning may be necessary (tall unpalatable grasses) • If intensively managed, < 2 ha/stocking unit	**Zone 4 (Semi-arid)** • Moisture index -30 to -40 • Marginal agricultural potential • Natural vegetation is dry woodland or savannah (often an *acacia-themeda* association) • Potentially productive rangeland • Grasslands sensitive to severe grazing • Management must include occasional burning • < 4 ha/stocking unit
Zone 5 (Arid) • Moisture index -40 to -50 • Very locally suited for agriculture • Woody vegetation: *commiphora, acacia*and allied genera, mostly in shrubby habit • Perennial grasses such as *cenchrus ciliaris* and *chloris roxburghiana* can dominate but succumb to harsh environment • Burning for bush control • > 4 ha/stocking unit	**Zone 6 (Very arid)** • Moisture index -50 to -60 • Rangelands of low potential • Vegetation (dwarf) shrub grassland • *Acacia reficiens* subsp. *Misera* often confined to water courses and depressions • Barren land in between • Mainly annual grasses • Localized perennials (e.g. *Chrysopogon aucheri*) • Productivity is confined to unreliable seasonable flushes • Nomadism • Populations of both wild and domestic stock severely restricted by environment

Source: East African Range Classification Committee, 1977

1.4.2. Classification based on vegetation types/ Physiognomic

Vegetation' s are the major feature for rangeland classification. They are the main factors of concern in grassland and rangeland management. They can be easily interpreted through aerial photographs and Landsat images.

Table 1.2. Classification of rangelands based on vegetation types

<table>
<tr>
<td>1. Woodland
Trees up to 18 m. height
Open or continuous but not thickly interlaced canopy
Canopy cover >20%
Grasses and other herbs dominate ground cover
Shrubs, if present, cover <10% of canopy cover
Often subjected to periodic burning
Sub-types should be classified by reference to the dominant wooded plants
E.g. brachystegia-julbernardia (miombo), acacia seyal with themeda ground cover, combretum coppice woodland, etc.</td>
<td>2. Bush land
Assemblage of trees and shrubs
Often dominated by shrubby habit
Trees always noticeable
Single or layered canopy usually not exceeding 6 m
Total canopy cover >20%
Ground cover is poor
Fires are infrequent
Bush land thicket is extreme form (no value for grazing)
Sub-types classified as with woodlands
E.g. Acacia tortilis, a. Nilotica, a. Mellifera bush land Awash national park</td>
</tr>
<tr>
<td>3. Grassland
Grasses dominate
Occasionally other herbs
Sometimes scattered trees (< 2% canopy)
Usually subject to periodic burning
Example: giant p. Purpureum grassland
E.g. eriochloa-sorghum seasonally waterlogged annual grassland</td>
<td>4. Wooded or tree grassland
Grassland with scattered grouping of trees
Trees noticeable but canopy < 20%
Trees always conspicuous (= very distinct)
Often subject to periodic burning
Sub-type: reference made to grassland type and dominant tree
E.g. tall hyperthelia-combretum wooded grassland</td>
</tr>
<tr>
<td>5. Bushed grassland
Grassland with scattered or grouped trees or shrubs
Combined canopy < 20%
Shrubs always conspicuous
Height of trees usually not exceeding 10 m
May be subject to periodic burning
Sub-type: reference made to grassland type and dominant shrub
E.g. medium-height Panicum-Commiphora bush grassland</td>
<td>6. Shrub grassland
Grassland with scattered or grouped trees or shrubs
Combined canopy < 20%
Height of trees usually not exceeding 3-5 m
May be subject of periodic burning
Classification as for wooded grassland
E.g. short ennapogon-Disperma shrub grasslands</td>
</tr>
<tr>
<td colspan="2">7. Dwarf shrub grassland
On arid or poor lands
Grassland often sparse
Dwarf shrubs not exceeding 1m
Sometimes widely scattered larger shrubs or stunted trees
Fires are rare
Sub-type classification as with wooded grasslands
E.g. Afro-alpine dwarf shrub grassland</td>
</tr>
</table>

Source: East African Range Classification Committee, 1977

Activity 1.1

Dear learner, discuss in groups about the current status of Ethiopian Rangelands; and what the main constraints are?

1.5. General Characteristics of Rangelands

Dear learner, can you list at least four characteristics of rangelands?

Rangelands are lands on which the native vegetation (climax or natural potential plant community) is predominantly grasses, grass-like plants, forbs, shrubs, suitable for grazing or browsing use but uncomfortable for cultivation. The environment of rangelands are the basic determinant of the nature and productivity of the range ecosystem, which is characterized by highly variable physical, environmental factors like climate, topography and soil that determine the potential of range areas to support definite types and level of land use.

Rangelands are characterized by a cause of physical limitations like low and erratic precipitation, rough topography, poor drainage, hot or cold temperature, high salinity, arid and semi-arid agro-ecology, harsh environment etc., and by extremely seasonal conditions with relatively low rainfall, very long dry season, humidity is also low not suitable for agronomic activities used for grazing and unstable. Rangelands are vast expanses of uncultivable land where normal crop production is not possible (not economical) this could be due to one or more of the following environmental limitations.

- ***Unfavorable climate***: particularly erratic rainfall. Most rangelands receive below 500 mm total annual rainfall, or even as low as 200-350 mm.
- ***Poor soil***: roughness, stone outcrop, Very thin soil horizon, Poor fertility, excessive mineral accumulation (e.g. carbonates, sulphates, fluorides).
- ***Topographic/landscape limitations*****:** Furrow (gully), Sloppy, Water logged. Such lands are typically referred to as marginal lands.

Rangelands can be characterized as the lands, which are not suitable for agricultural practices because of their natural and biological limitations based on two main parameters (agro-ecology and vegetation types).

1.6. Social, Economic and Ecological Importance of Rangelands

Do you know the major importance of rangelands in your area?

You may list a number of importance in your area, and generally, rangelands have the following importance:

- ***Production of animal products:*** On worldwide basis, rangelands contribute about 70% of the feed needs of domestic ruminants. Rangeland plays a major role in supplying human population with animal products in all the land regions of the world. In Ethiopia, the rangeland-livestock production system takes the form of pastoralism and agro-pastoralism in arid and semi-arid agro-ecologies respectively. They are largely depending on livestock rearing for their livelihood. Livestock can use vegetation that would otherwise be wasted, and convert it to valuable, high quality products such as meat, milk, hides, and skins, etc.

- ***Wildlife:*** Rangelands are the primary habitat for nearly all the land-dwelling wild animals highly valued for meat, hunting and aesthetic viewing. Rangeland wildlife has potential as a source of meat for human consumption in many African countries. In Ethiopia there are different national parks, sanctuaries and reserve areas covering about a total of 25000 km^2 located in the dry lands. Rangelands of Ethiopia contribute considerable base of an expanded Eco-tourism.
- ***Water:*** Most parts of Ethiopia are endowed with an enormous potential for water resources development, both surface and groundwater. The arid, semi-arid and dry sub-humid areas have substantive amounts of water resource.

- ***Recreational products:*** To engage in outdoor recreational pursuits, hiking, camping, trail biking, picnicking, hunting and fishing are some of the important recreational uses of rangeland.
- ***Plant products:*** Rangelands produce a wide variety of plants that could be very important in meeting our future needs.

Activity 1.2

Dear Learner, try to visit rangelands and national parks found in your nearby locality by taking a trip and identify the type of vegetation; classify rangelands based on agro-ecology and types of vegetation. Assess the social, economic, and ecological importance of rangelands.

Summary

East African rangelands can be characterized by low, erratic precipitation, hot temperature, high salinity, arid and semi-arid agro-ecology, harsh environmental condition. Rangelands can be classified based on agro-ecology and vegetation types. They can be used as source of feed for livestock, habitat and feed source for wildlife, water source for livestock and human being, recreational purpose, source of fuel and timber production, additional products such as minerals and etc.

Self-Assessment Question 1.1

Direction I. Write "True" if the statement is correct and "False" if it is incorrect on the space provided.

----------1. Rangelands are non-renewable resource.

----------2. Agro-ecologically, rangelands can be classified in to six.

----------3. Ethiopian rangelands mainly found in lowland parts of the country.

----------4. Rangelands are suitable for agricultural activities

Direction II. Choose the correct answer from the given alternatives and write the letter of your choice on the space provided.

---------1. One of the following does **not** indicate the importance of rangelands.

A. Source of feed for animals C. Habitat for wild animals

B. Biodiversity conservation D. Fuel production E. None of above

Further Reading

To have more explanation on unit 1 you can refer the following books:

- Harold F. Heady & R. Dennis Child (1975). *Rangeland Ecology and Management*.
- Tamrat Andargie (2007). Fundamentals of ecology. *Unpublished Lecture Note*, Hawassa University.

UNIT 2

THE ECOLOGY OF RANGELANDS

INTRODUCTION

Dear Learner; in this unit, you will deal with concepts related to ecology, ecosystem structure, ecosystem functions, nutrient cycling and interactions within different populations in rangeland ecosystems.

What do you understand from the term Ecology?

Objectives

At the end of this unit, you should be able to:

- Define the term ecology, and ecosystem
- Describe the importance of biotic and abiotic components in range management
- Explain the interaction between different biotic and physical components
- Apply ecological processes to the management of rangeland resources

Ecology is relatively a new science as compared to the other fields of Biology. The word " ecology" comes into use in the last half of the 19th century by a German zoologist, Ernst Haeckel. It defined as " the study of the total relations of the animal/plant to its both organic and inorganic environments" (Benton and Werner, 1976). Ecology studies the distribution and abundance of living organisms and how these properties are affected by interactions between the organisms and their environment. ***Ecosystem*** refers to an ecological community and its local abiotic environment where the ecological community is a set of local interacting populations of organisms. The concept of ecosystem as basis for natural resource management was first introduced in the mid 1930' s by British ecologist Arthur Tansley. Since then, it has widely been used by natural resource managers and ecologists. However, an ecosystem has no true boundaries with functional discontinuity between them and its boundaries are subjectively delineated for the sake of simplicity.

Ecosystem Ecology is the study of the movement of energy and matter through ecosystems. It is one of the fundamental disciplines of ecology. Ecosystem ecology operates at a scale above that of communities but it is defined more by subject matter than by scale. The ecosystem is an energy processing system whose components have evolved together over long period of time.

Ecology was derived from Greek words: "*oikos*" means "household", " home" or " place to live" and " *logos"* means "study" or " knowledge" . Hence, the study of the household of nature. Even if no consensus has been reached to its definition, different people tried to give a more restricted meaning and scope of the study of

2.1. Ecosystem Structure

Why do you need to study rangeland ecosystem structure?

Although every ecosystem is different from one another, whether it is aquatic or terrestrial is made up of two major components: *the biotic and abiotic*. The biotic component refers to the community, all interacting groups of organisms living in an area. The abiotic part on other hand, embraces the non-living or the physical environment with which the organisms do interact with. One of the essential features of ecosystems is that the components are related functionally. A change in one ecosystem component influence all others. The ecosystem components include:

2.1.1. Biotic Components of an Ecosystem

What are the biotic component of rangeland ecosystem?

There are various ways of interactions between organisms in an ecosystem. The clearly observed form of interaction is revealed in their energy and food source in the ecosystem.

Organisms in any kind of ecosystem can be classified into two broad categories based on their ability to synthesize their organic molecules: *autotrophs* and *heterotrophs*.

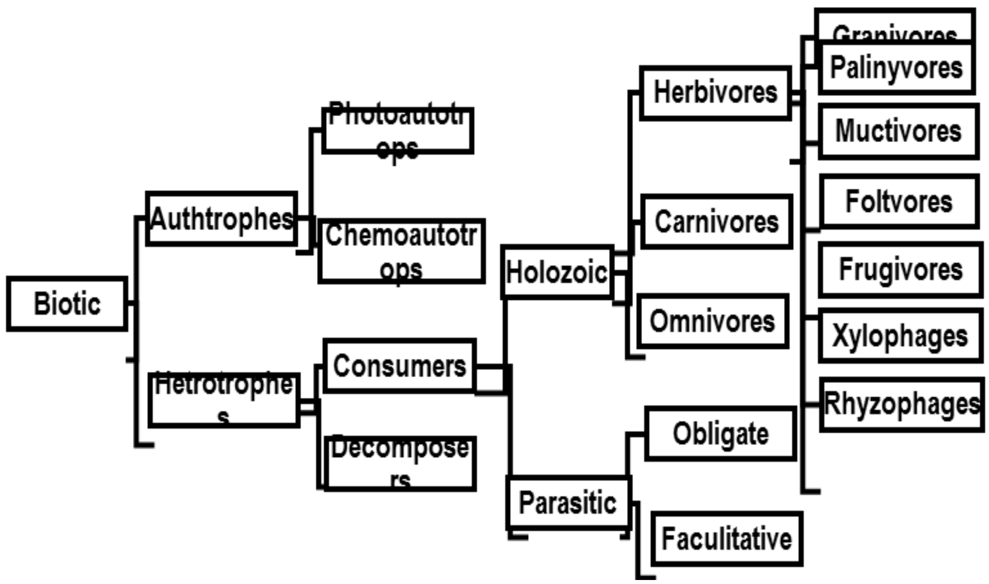

Fig. 2.1. The diagrammatic representation of the tropic structure in an ecosystem

- **Autotrophs:** These organisms are called primary producers, includes all organisms in an ecosystem that can synthesize and store their own chemical energy in the form of organic molecules from inorganic raw materials. Based on the energy source for synthesis and the biochemical pathway of the anabolic process, they are further classified in to two groups: ***Photoautotrophs:*** The group of organisms uses solar energy (sunlight) for the synthesis of organic food (such as glucose) through *photosynthetic* biochemical pathway. The green plants, multicellular algae, photosynthetic protests, bacteria and blue greens are under this category, whereas ***Chemoautotrophs:*** The group of organisms uses energy i.e generated from reduction oxidation reaction of some chemicals involving the electron transfer mechanism. The biochemical pathway is called *Chemosynthesis*.

- **Heterotrophs:** This includes all organisms other than autotrophs that cannot synthesize their own food therefore, dependent on primary producers for organic food. Two categories are under this: ***Consumers*:** organisms that derive their nutrient from primary producers. They can be animals or sometimes insectivore plants that feed on herbivores or another carnivore (animal prey) called *Carnivores***.** Alternatively, *Omnivores* includes those animals that feed on both plants and animals. ***Decomposers*****:** organisms that feed on fallen leaves, twigs and other dead organic materials including remains of plants and animals, which includes most of the bacteria and mushrooms that degrade complex dead organic matter of all categories into simple inorganic compounds and restore minerals to the environment. Some soil invertebrates also fall in this category and have strong mutualistic relations with microorganisms to aid in the breakdown of cellulose and lignin.

2.1.2. Abiotic Components of an ecosystem

What are the biotic component of rangeland ecosystem?

Abiotic component of an ecosystem is made up of all the substances, factors and forces in the habitat that affect the organism. The abiotic environment is the result of the interactions among the energy, inorganic minerals, gases, dead organic matter and a number of other factors and forces. Abiotic component of an ecosystem, generally categorized into

- Lithosphere: all the solid mineral matter including the soil and rocks;
- Hydrosphere: all the water bodies (ocean, lakes, rivers) and its physico-chemical characteristics
- Atmosphere: all the gaseous mixture in the air
- Radiant solar energy: the electromagnetic radiation (including visible light) coming from the sun and stars and
- Position and movement of the earth, the moon and other extraterrestrial bodies, and their gravitational force.

Activity 2.1

Dear Learner, divide into a group of an appropriate size and explain the interrelationship that exist among different biotic, and abiotic components, and how the interaction is important for the wellbeing of a rangeland ecosystem found to your nearby locality by taking a trip.

Self-Assessment Questions 2.1

Direction I. Write " True" if the statement correct and " False" if it is incorrect on the space provided.

--------1. Rangeland plants are the primarily producers that synthesizes and stores nutrients for the sake of other organisms.

-------2. The transmission of energy in rangeland ecosystem is similar in the spatial and temporal distribution without influence of species composition.

--------3. Abiotic component of an ecosystem is made up of all the substances, factors and forces in the habitat that affect the organism.

--------4. Ecosystem ecology is a branch of ecology that studies the movement of energy and matter through an ecosystem

Direction II. Choose the correct answer from the given alternatives and write the letter of your choice on the space provided.

---------1. Comprises biotic and abiotic elements on which man has placed boundaries for purposes of manipulation.

A. Range ecology C. Range management

B. Rangeland ecosystem D. Range resource

---------2. The correct statement about decomposers, which overlooked in rangeland ecosystem

A. primarily function in the decomposition processes

B. responsible for preventing accumulation of organic matter
C. without them world become suffocated that threatened life
D. aid in nutrient cycling through breaking down organic matters
E. all of the above

1.2. Ecosystem Functions

Why are the ecosystem function?

1.2.1. Energy Flow

How does energy flows in rangeland ecosystem?

The most important relationships between living organisms and their environment are ultimately controlled by amount of energy reaching the earth from the sun, beside the water and nutrients they require for metabolism and growth. Only a very small proportion of energy that the earth receives from the sun is trapped by green plants and converted it into a biochemical form. It is estimated that the most efficient ecosystems are rarely able to trap more than 3% of energy. The remaining is radiated back to the atmosphere or other objects in the form of heat.

The flow of energy throughout the ecosystem operate under the first law of thermodynamics-that states energy is neither created nor destroyed, but only changes its form. At each step of the ecosystem, there is energy dissipation through respiration and inefficient energy harvest. Green plants trap and process the solar energy of the sun into chemical energy, consumers then use for their survival and reproduction each involves dissipation, which can be depicted using an energy pyramid. In a rangeland ecosystem however, the flow of energy is not the same and is influenced by plant life form and species composition, both temporally (seasons) and spatially (vertical structure of vegetation).

Indicators of change in this temporal and spatial distribution need to be part of a rangeland health evaluation programs.

- Solar energy is received by the grasses, forbs and shrubs and transferred by the processes of photosynthesis into stored chemical energy in green plants tissues
- When the herbivores eat plant tissues, they gain energy stored in plant tissues through the processes of digestion.
- Carnivores in turn eat other animals and derive their energy requirements for feed
- However, energy is dissipated in the food chain through respiration. In addition, the organism at each step in the food chain are not completely efficient at harvesting all available food sources, so energy transfer diminishes considerably at each stage
- Once energy is dissipated in the form of heat, can never be recovered and reused thus it is a one-way path and must be continually refueled by energy from the sun.

Ecosystem function refers to the interrelationship that exists among its components in terms of *energy flow and nutrient recycling*. It can be viewed as mainly from two standpoints: energy flows and chemical cycles (nutrient cycles), which represents physiological processes within the ecosystem. The way in which these processes take place strongly influence ecosystem productivity and sensitivity under a given land use practice.

Food chain and Food Web

What do you now about food chain and food web?

A food chain is a simple food relationship between organisms, which is a link or chain of organisms, one supplying food for the next. Like many simple models, the idea of a food chain only provides an idea of the way energy flows through an ecological community. A food chain cannot really exist as a single series of connections, isolated from any others. In ecosystem, food chain begins with fixation of light, water and CO_2 by photosynthetic autotrophs. Primary producers include green plants, photosynthetic bacteria and *protists*. Primary consumers (ants, termites, sheep and others) form the second link in food chain, when they gain energy by consuming the primary producers. The third link-are the primary carnivores (secondary consumers), such as foxes, cats and spiders, which kill and consume primary consumers. A further step is the secondary carnivores (tertiary consumers), which feed on primary carnivores, and the chain goes the same way.

Decomposers (Detritivores) usually retain the last level in the food chain decomposing all dead organic matter but sometimes themselves consumed by some of the organisms they digest. A model describing the relationship between organisms in many different food chains called a ***food web***. It demonstrates complex patterns of energy flow in an ecosystem. It is believed that the more complex a food web is, the more resistant it is to outside interference. The level of each of the different organism in the food chain called ***trophic level***. The number of steps through which energy passes in order to reach the organisms in the food chain defines each trophic level. Despite huge differences between different communities, most have 3 to 5 trophic levels since, energy is lost between each level and the amount gradually diminishes.

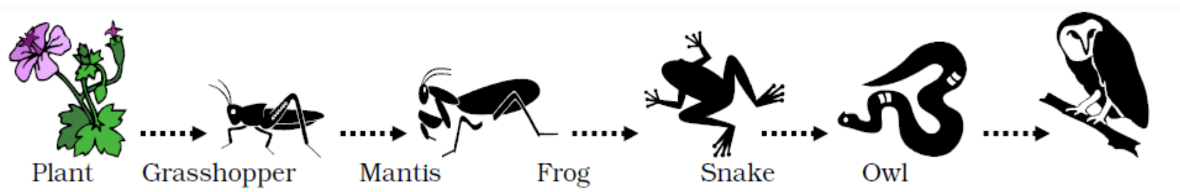

Fig. 2.2 A schematic representation of food chain in a terrestrial ecosystem

Ecological Pyramids

What is Ecological pyramid?

Food chains are morphological systems of energy flow in an ecosystem. However, the energy flow within a system may be described in more quantitative terms using ***ecological pyramids*.** When energy flows and accumulates in the body of organisms at any trophic level in a certain food chain, it either is revealed in terms of increase in biomass (weight), calories (energy) or numbers (new individuals born). For example, the quantities and the relative number, biomass or calories of each organism at each trophic level in the specific food chain, broader at the base and narrower at its apex. This implies that the amount of energy stored at each trophic level gradually decline in process of transfer from the lower trophic level, at the base to the highest trophic lever, at the apex. This helps to demonstrate the relative amount of energy fixed and transferred in the process of food chain at each trophic level. However, in certain circumstances, the shape of the ecological pyramid might be distorted somewhere, and might not have exactly a pyramid shape, hence call it an inverted pyramid. There are three kinds of ecological pyramids:

Pyramid of numbers: This shows the relative number of individuals at each trophic level. The unit of measurement is number of individuals per a given area. It can be drawn just by counting the number of individuals in each of the trophic level in that specific food chain. It can be inverted in either of these occasions; (a) if there are few and large producers that can support many smaller herbivores, or (b) if there is parasite infestation in the ecosystem that a host at the lower trophic level can support a large number of parasites situated at the upper trophic level in the food chain.

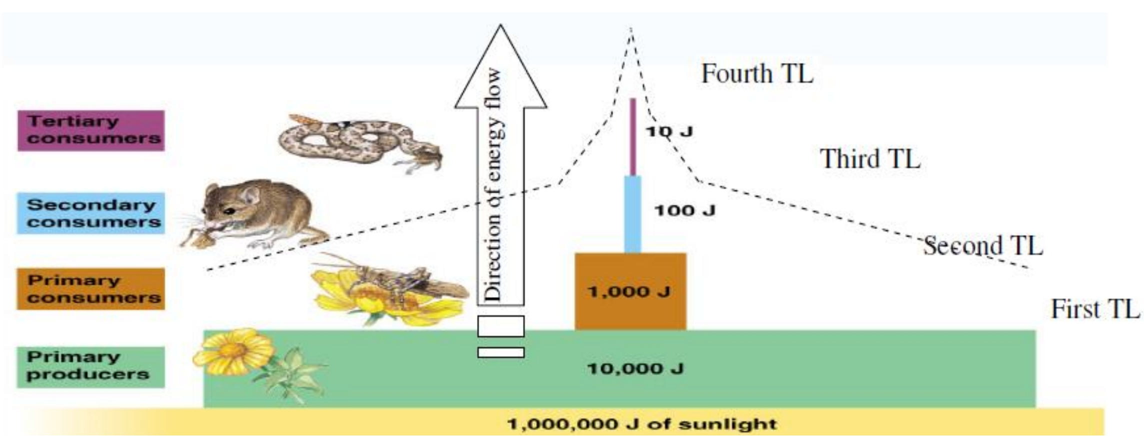

Fig. 2.3 A schematic representation of ecological pyramid an ecosystem

Pyramid of biomass: This quantifies all of the living biomass accumulated at each trophic level. In most systems, the amount of biomass decreases as one move from the lower end to the upper end of the food chain. The unit of measurement here is Kg/ha/year. This demonstrates the volume of biomass available to living organisms in the next trophic level. It can be inverted if the food chain is in aquatic systems in one of the following cases: (i) if the ecosystem is heterotrophic (rivers or lakes) that are characterized by large imports of biomass in the form of dead organic matter. This may cause consumer production to be higher than the autotrophs present in the system; (ii) if the ecosystem is dominated by high density of planktons (floating plants and animals).

Pyramids of Energy: This shows the relative amount of calories flowing from one trophic level to the next in an ecosystem. The unit is Kilo Joule or Kilocalories per hectare per year. Unlike the other two, it can never be inverted due to the law of thermodynamics.

Activity 2.2

Dear Learner, let's make a group of having two individuals and indicate the trophic level of each of organism in the food chains given above and try to look how energy flows through the ecosystems.

Forms of Energy

What forms of Energy do you know?

Living organisms may use energy in two basic forms either radiant or fixed energy. *Radiant energy* is electromagnetic radiation such as solar light. For example, green plants use this energy to synthesize glucose molecule. *Fixed energy* on the other hand, is the chemical energy stored within the carbon bonds of organic molecules such as glucose. This energy is then released through either aerobic or anaerobic respiration to yield ATP, which stored in the tissue and utilized for different biochemical activities when oxidized in to ADP and AMP. The process of storing or producing fixed energy referred to *Biological Production*. The two kinds of biological productions: primary production and secondary production.

- ***Primary production:*** The form of fixed energy accumulated by autotrophs by converting the radiant energy. The total amount of the fixed energy, which incorporated into the body of photosynthetic organisms termed as the *Gross Primary Production* (GPP). The rate at which this energy is incorporated into the body of plants at a given time, usually for most ecosystems measured per year known as *Primary Productivity*. It simply measures the net amount of CO_2 absorbed by the plant since at the same time, a substantial amount is also produced as a byproduct of respiration. In terrestrial ecosystems, the primary production is affected by various factors as temperature, precipitation, and nutrient availability, length of growing season, animal, and fire.

- **Secondary production:** Once it has been fixed by autotrophs, energy may travel in an ecosystem through consumption of dead or living organic material. On decomposition, the complex organic molecules may be broken down again into inorganic forms allowing them to be taken up once again by autotrophs. The total amount of energy stored at a consumer level called *Secondary production*. The total energy assimilated in the tissue of the consumer, which is equivalent to GPP in primary producers called *Assimilation energy*. The net amount of energy, which is equivalent to NPP in primary producers, left from maintenance and respiration called *Production Energy*, which is stored in the form of production of new tissue, fat deposit, growth and production of new individuals.

Ecological Efficiency

How is ecological efficiency measured during flow of energy?

The fate of fixed energy assimilated by organisms ultimately ends up through four different routes; *respiration* for different activities, *accumulation* in form of biomass, *consumption* by other organism or *decaying* of organic materials. The gross volumes consumed do not determine the real amount of energy, which is incorporated into the tissues of consumers at each level but it is the amount of energy converted into the actual biomass. Consumers due to inefficiencies; loses a significant amount of energy during assimilation and due to respiration for morphological and physiological maintenance, reproduction and in the process of finding or capturing food. The energy that plants fix is used to support all the life forms in all other trophic levels.

The amount of energy available in the biomass of primary consumers is much smaller than the amount present at the primary producer level. Herbivores do not consume all available plant material due to various mechanisms, which plants have developed. That percentage which is consumed does not all become herbivore biomass, because of loss of biomass that occurs due to inefficiencies and respiration. The primary carnivore, in their turn, consumes the greater portion of herbivore biomass for their survival, but again, not all herbivores are consumed due to defense mechanisms. In general, the gross ecological efficiency of terrestrial ecosystems ranges from 5 to 30 persons, averaging from 10% from the producers to herbivores and 15% from herbivore to carnivore (Kormondy, 1996).

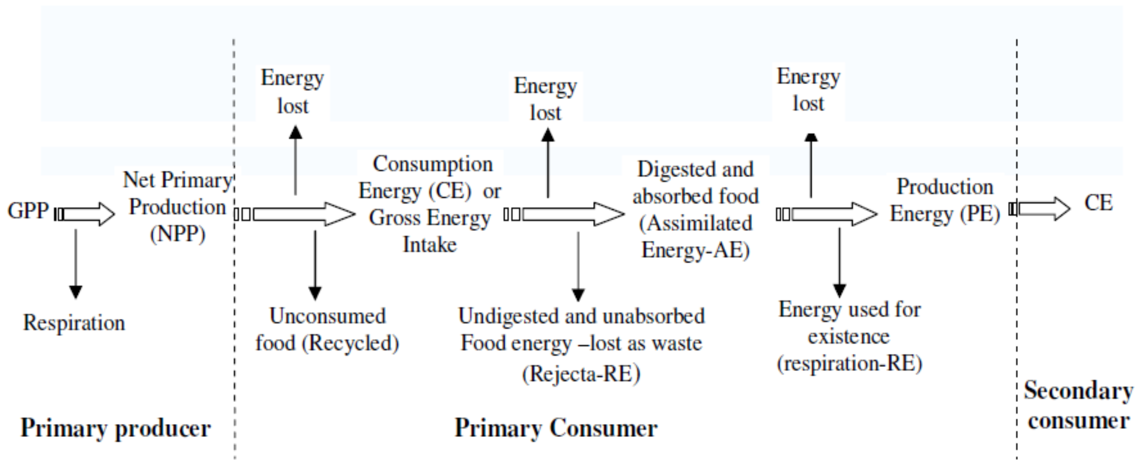

Fig. 2.4 The overall mechanism of energy transfer at consumer level in the food chain.

The energy efficiency of a consumer in an ecosystem is affected by the quality of the NPP, the amount of energy expenditure, and its conversion efficiency. There are three different measures of efficiency of a consumer in an ecosystem:

- ***Consumption Efficiency*** *(*trophic efficiency): It measures the efficiency of a consumer to take the produced NPP. Depending on the palatability of the NPP, much of the energy is not consumed, hence decomposed to the soil. The Consumption Efficiency of the consumer is given by:

$$Cons.Eff. = \frac{Consumption\ Energy\ (CE)}{NPP} X\ 100\%$$

- ***Assimilation efficiency***: the measure of percentage of assimilated energy that is absorbed across the wall of the digestive system of the consumer as compared to the consumed food Energy. Assimilated Energy is the deference between consumption energy (ingested) and egested energy (rejecta).

$$Assim.Eff. = \frac{Assimilated\ Energy\ (AE)}{Consumption\ Energy\ (CE)} X\ 100\%$$

- ***Production efficiency****:* the percentage of the energy storage remaining in the tissue of the consumer after a considerable amount is utilized for respiration (growth or reproduction), etc. Production energy is the difference between assimilated energy and respiration energy.

$$\text{Prod.Eff.} = \frac{\text{Production Energy (PE)}}{\text{Assimilated Energy (AE)}} X\ 100\%$$

2.2.2. Nutrient cycling

How nutrients are recycled in rangeland ecosystem?

The two basic types of biogeochemical cycles in an ecosystem are *gaseous* and *sedimentary* cycles. a) *Gaseous (atmospheric) cycle*: the main reservoirs of elements are the atmosphere and oceans. Examples of those elements cycling in the gaseous or atmospheric cycle include the following: hydrological, oxygen, carbon, and nitrogen cycle. b) *Sedimentary (edaphic) cycle*: the main reservoirs of elements are the soil and rocks. Examples include sulfur, phosphorus, and nitrogen cycle.

Hydrological/ Water Cycle

How water cycle in an ecological ecosystem?

Solar energy is the driving force behind the water cycle. The heating of the atmosphere and its role in evaporation provide the basic mechanism of the cycle. Water evaporates from the water bodies, soil, and the tissue of plants and animals and is held in the atmosphere. Water vapor in atmosphere when condensed, it falls in the form of rain as droplets or in the form of ice crystals. The precipitation that reaches the soil run off to surface water bodies (rivers, lakes and streams) or gets into the ground by infiltration.

The rate of infiltration is influenced by the nature of the soil, landform (slope) and characteristic of the vegetation. The water that is retained by the soil is absorbed by plants, which used for different physiological activities such as cooling, photosynthesis and transportation of elements. Animals also drink and use surface and ground water. They also get a considerable amount of water while consuming other plants and animals.

The water in the tissues of organisms and the soil again evaporates and returns back to the atmosphere or oceans, reservoirs, the cycle continues the in same way.

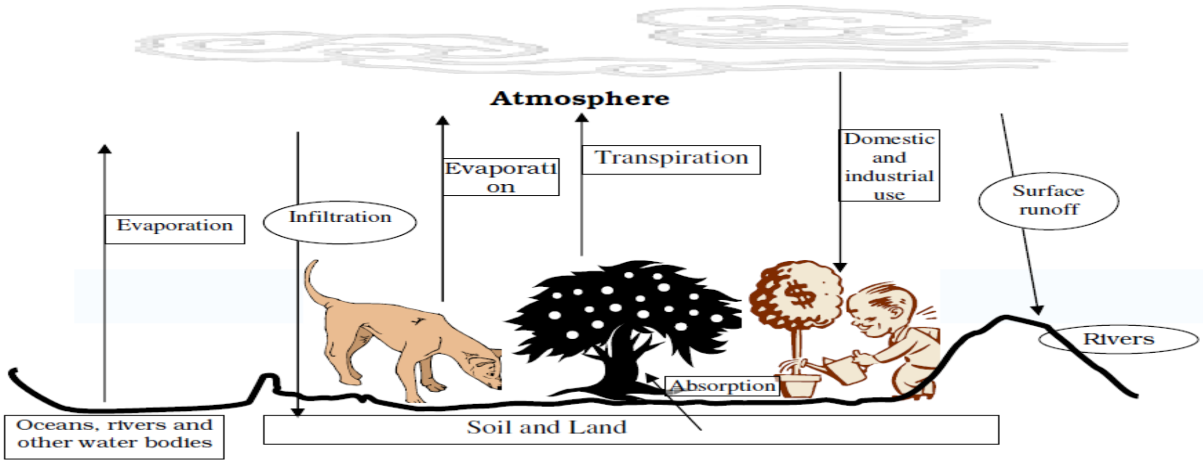

Fig. 2.5 Water Cycle in a terrestrial ecosystem

Nitrogen cycle

How is nitrogen recycled in ecological ecosystem?

About 78% of the air is composed of nitrogen, which is essential for many biological processes. All nitrogen obtained by animals can be traced to the consumption of plants at some stages of food chain however; the molecular form of nitrogen is not usable by plants. Thus, plants get the usable nitrogen from the soil through absorption by their roots in the form of either *nitrate ions* or *ammonia*. The mechanisms to fix atmospheric N_2 and converts it into a more chemically reactive form:

- ***Biological fixation*****:** some bacteria (associated with certain leguminous plants) and certain blue green algae (*cyanobacteria*) are symbiotic microbes able to fix nitrogen and assimilate it as organic nitrogen. It contributes much of the nitrogen fixation.
- ***Lightening*****:** the formation of NO from N_2 and O_2 due to photons and lightning are important in process of nitrogen fixation however, it contributes little for terrestrial/aquatic nitrogen turnover. ***Combustion of gasoline and fossil fuel***: A fossil fuel has different impurities of nitrogen gas. The combustion of fuel by

automobile engines and thermal power plants transfers elemental nitrogen gas into oxides of nitrogen (NO_x).

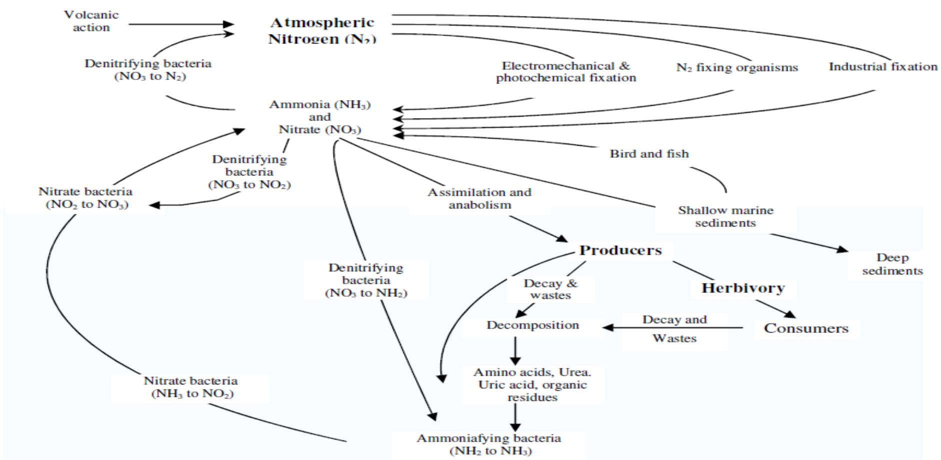

Fig. 2.6. Nitrogen Cycle in terrestrial and aquatic ecosystem

Activity 2.3

Dear Learner, please form a group of 5 individuals and look into how energy and nutrients move through ecosystems in a rangeland found to your nearby locality by taking a short trip.

Self-Assessment Questions 2.2

Direction I. Write " True" if the statement correct and " False" if it is incorrect on the space provided.

---------1. Range plants are the primarily producers and they synthesizes and stores nutrients for the sake of themselves and other organisms.

---------2. The transmission/flow of energy in the rangeland ecosystem is similar in the spatial and temporal distribution without influence of species composition

--------3. Rangeland biomass is qualities of rangeland resource at a particular point of time.

1.3. Population interaction

What do you mean by population, and how it differ from species?

How population interact to each other in rangeland ecosystem?

Individuals of a population interact with individuals of another population, as they are doing to one another. The two ways of population interactions: *Intraspecific interactions*: a kind of interactions that are established between individuals of the same species forming a population. These include relations like co-operation, competition and specifying areas for growth. Even if it is uncommon in most of the natural populations, cannibalism could be also considered as intraspecific feeding relationship. *Interspecific interactions:* This is interactions between different populations of different species. The major kinds of interaction could be explained in terms of feeding relationship.

Organisms interact differently with another organism in various ways. The interactions are mostly the results of ecological adaptations. ***Symbiosis*** ("living together") is a phenomenon in which two organisms, which are phylogenetically unrelated, co-exist over a prolonged period of time, usually the lifetime of one of the individuals. The degree of interaction could be weak or very strong, an interaction between individuals or populations so mutually detrimental that it results in death, as in the case of some parasitic relationships.

2.3.1. Mutualism

What mutualism in population of rangeland ecosystem?

Mutualism refers to an interaction between two or more species whereby both species derive benefits. Mutualism can be lifelong interactions involving close physical and biochemical contact such as those between rangeland plants and *mycorrhizal* fungi. They can also be briefer, non-symbiotic interactions, such as those between flowering plants and pollinators. Mutualisms may also be *obligatory* or *non-obligatory* (facultative). For example, bacteria known as rhizobia can reproduce either in the soil or in (usually) mutualistic symbiosis with legume plants.

Mycorrhizal fungi, on the other hand, can be totally dependent on their plant hosts. Lichen is a general name for association between algae and fungi species. The fungi partner in the association (called *mycobiont*) absorbs nutrients and moisture from dusts in the atmosphere and provide to the algae partner (called *phycobiont*). In return, the *phycobiont* uses the raw materials for photosynthesis and provides food to the *mycobiont*. This association helped them to colonize most degraded and harsh environmental conditions.

2.3.2. Commensalisms

What commensalism in population of rangeland ecosystem?

The term commensalism is derived from the Latin word *com mensa*, meaning sharing a table. Commensalism is an interaction between two living organisms, where one-organism benefits and the other is neither harmed nor helped. It is an association wherein two organisms co-exist in the same space, and one-organism benefits while neither harming nor helping the other. As with all ecological interactions, commensalisms vary in strength and duration from intimate, long-lived symbioses to brief, weak interactions through intermediaries.

The different forms of commensalism include the following: *Phoresy*: Using a second organism for transportation. Examples are the remora on a shark, or mites on dung bugs. Both temporary and permanent *phoresy* exists. *Inquilinism*: Using a second organism for housing. Examples are epiphytic plants (such as many orchids) which grow on trees, or birds that live in holes in trees. *Metabiosis*: A more indirect dependency, in which the second organism uses something the first created, however after the death of the first. An example is the hermit crabs that use gastropod shells to protect their bodies.

2.3.3. Amensalism

What is Amensalism in population of rangeland ecosystem?

Amensalism is refers to a biological interaction, a type of symbiosis, between two species in which one impedes or restricts the success of the other without being affected, positively or negatively, by the presence of the other. Usually this occurs when one organism exudes a chemical compound as part of its normal metabolism that is detrimental to another organism. Example is the black walnut tree (*Juglans nigra*). Its roots secrete *juglone*, a chemical that harms or kills some species of neighboring plants. Some eucalyptus trees are also known to have a similar effect. Antibiosis or *allelopathy* also explains similar interactions.

2.3.4 Predation

What is predation in population of rangeland ecosystem?

A predator is an animal or other organism that hunts and kills other organisms, called prey, for food in an act called predation. Predators are either *carnivores* or *omnivores*. Parasites may also consume other animals in part. Unlike in predators, for which killing prey is necessary in order to consume it, it is usually undesirable for a parasite to kill its host. Herbivores also consume other species, generally only in part, leaving the organism alive. However, where the prey consists of single-celled algae, the activity of the herbivorous grazer is generally of the same nature as that of a carnivore. As often in ecology there is seldom consensus on the distinctions, some ecologists prefer functional definitions like the one outlined above, others rather look at the ecological dynamics of the relationships between the species.

Herbivore is a part of predation. Herbivore is often defined as any organism that eats only plants. According to this definition, many fungi, some bacteria, many animals, about 1% of flowering plants and some *protists* can be considered herbivores. Many people restrict the term herbivore to animals. Fungi, bacteria and *protists* that feed on living plants are usually termed *plant pathogens*. Microbes that feed on dead plants are *saprotrophs*. Flowering plants that obtain nutrition from other living plants are usually termed *parasitic plants*. In zoology, an herbivore is an animal that is adapted to eat primarily plant matter. Although such animals are referred to as being vegetarian, this term is more properly reserved for humans who choose not to eat meat as opposed to animals that are unable to make such choices.

2.3.5. Parasitism

What is parasitism in population of rangeland ecosystem?

Parasitism is one version of symbiosis through which one species (the parasite) is benefited from the association by harming the other (the host). Parasites include those animals and plants that depend on the host plants and animals for the search of food and shelter from a living host. They can also act as disease vectors for even smaller bacterial or viral parasites. They are often highly specialized in their feeding habit. A number of smaller invertebrate animals (tapeworm and ascaris), *protozoas* (plasmodium), and bacteria (*Salmonella thyphi*) are known to establish this kind of interaction with higher plants and animals. Some higher plants also lost their chlorophyll through evolution and developed parasitic behavior. Host parasite interactions can have very interesting and complex dynamics.

2.3.6. Competition

What is competition in population of rangeland ecosystem?

A rangeland ecosystem at a given time is endowed with a limited amount of resources, such as food, water, territory, that several species may depend on these resources. Thus, species, and often individuals within a species, compete to gain these resources. As a result, several species less suited to compete for the resources may either adapt or die out. According, to evolutionary theory this competition within and between species for resources plays a critical role in natural selection.

If two populations are equally computing for the same resource both of the partners are harmed. However, in nature, organisms with exactly identical ecological requirement or the same niche (feeding habit) cannot occupy the same habitat. Competition between members of a species is referred to *intraspecific competition* while competition between members of different species is called *interspecific competition*. Moreover, it can be *interference competition*: if one species on the other by denying access to the resource. Examples: *allelopathy* secretions (compounds like phenols) by some plants to prevent the germination of seeds, occurs directly between individuals via aggression or intimidation mechanisms when the competitive individuals interfere with foraging, survival and reproduction of others, or by directly preventing their physical establishment in a portion of the habitat.

Exploitive competition: the kind of competition demands over exploitation of the limited resource by one of the competent range plants to reduce its availability for the other. The outcome is determined by the efficiency of each of the competitors. Very rapid growth in some rangeland plants is good adaptation to exploitive competition. It occurs indirectly through a common, limiting resource, which acts as an intermediate. A number of exotic plants are aggressive in exploiting environmental resources that may cause resource depletion.

Self-Assessment Question 2.3

Direction I. Write " True" if the statement correct and " False" if it is incorrect on the space provided.

---------1. In asymmetric competition, the effects are proportional to size of individuals as for belowground resources but symmetric as in the case of light competition.

--------2. Allelopathy is any direct/indirect harmful/beneficial effect of one plant on another by production of chemical compounds that escape into the environment

--------3. Productivity is the capability of the organisms at a particular trophic level to store and use the materials necessary for life.

--------4. Ecology less emphasis on individuals rather it focuses on integrated components of environment and their involvement in processes of energy flow and material cycling.

--------5. Primary productivity is the rate at which energy is stored by green plants in the form of organic substances expressed as GPP of biomass of carbon per unit area per unit time.

Direction II. Choose the correct answer from the given alternatives and write the letter of your choice on the space provided.

---------1. The contributing reasons for the association between different organisms to live together.

a. have a similar requirement for an environmental factor
b. alteration of environment allows the establishment of another
c. to protect a common enemy or to get shelter by the stronger
d. interdependence of one on the other through feeding
e. none

----------2. An interaction between individuals brought about by a shared requirement for a resource leading to a reduction in survivorship and/or reproduction of members of individuals.

a. species interaction
b. species competition
c. cyclic and periodic changes
d. community dynamics
e. species succession

---------3. The modification of abiotic environment so that it becomes more suitable for the establishment, growth and/or survival of others either in space or in time.

a. parasitism
b. mutalism
c. facilitation
d. ammensalism
e. commensalism
f. allelopathy

---------4. Which group of organisms categorized under primary producers in a given grass/rangeland?

a. autotrophs and green plants
b. small mammals
c. a variety of carnivores
d. large herbivores
e. invertebrates
f. insectivores and omnivores

---------5. Which of the following factors directly or indirectly affect ANPP in a given grass/rangeland.

a. soil moisture
b. occurrence of fire
c. herbivory activity
d. N_2 levels and light
e. topographic location
f. All

Direction III: Match the words/phrases listed under column " B" with their appropriate terms listed under column " A" on the space provided.

A	**B**
---1. Mutualism	A. climax community is disturbed by fire and over grazing
---2. Interspecific competition	B. the currency of ecosystem
---3. Energy	C. photosynthesizes; obtains products only from host root
---4. Holoparasites	D. fragmentation and size reduction by macro-arthropods

---5. Physical breakdown E. type of interaction benefits both partners

---6. Intraspecific interaction F. the interaction between members of the same species

G. reduction of NO_3^- to gaseous N_2 by soil bacteria

H. the interaction between different species

I. dependent on their host for both roots and shoot product

J. the nitrogen-rich enzyme

Summary

In ecology, an ecosystem is a naturally occurring assemblage of organisms such as plant, animal and other organisms also referred to as a biotic community or *biocoenosis*, living together in their physical environment (biotope), functioning as a loose interacting unit. *Abiotic components:* include the soil, topography, and climate. The soil is important source of many nutrients required by rangeland plants and soil factors are responsible for the dynamic nature of the biotic components such as vegetation. Climatic factors especially precipitation and temperatures have influence on both primary producers and consumers. They consist mainly of the soil and climatic factors and are not usually manipulated by the range manager. The soil serves as habitat for soil animals and microorganisms, anchorage of plants and reservoir of water and nutrients of plants.

Manipulation of soils generally involves fertilization mechanical treatments to increase infiltration, water shortage, and so on. Major features of the climate include temperature and precipitation. Climatic factors directly impinge on biotic components and indirectly on the biotic components and indirectly on consumer and decomposer groups through their influence on the plants. *Biotic components:* The biotic components of an ecosystem include primary producers, consumers and decomposers. *Primary producers* are plants with pigment chlorophyll, which is responsible for converting solar energy to chemical energy, which can then be used by the plant itself as well as by animals that consume the plants. They support directly or indirectly all other groups of organisms/components.

Primary productivity: be defined as the rate of organic matter storage by photosynthetic and chemosynthetic activity of producer organism in the form of organic substances, which can be used as food materials (Odum, 1959). *Consumers* are those that either live directly off plants (herbivores) or indirectly by consuming the herbivores (carnivores-secondary and tertiary consumers). Consumers eat, rearrange, and distribute the energy captured by green range plants. *Decomposers* and micro-consumers are critical but often overlooked components of range ecosystems. They function primarily in the decomposition process and are responsible for preventing accumulation of organic matter. Without them, our world would have been suffocated with organic matter that threatened life.

Organisms interact differently with another organism in various ways. The interactions are mostly the results of ecological adaptations and the degree of interaction could be weak or very strong as in the case of *Synnecrosis,* an interaction between individuals or populations so mutually detrimental that it results in death as in the case of some parasitic relationships. Mutualism: in interaction between two or more species where both species derive benefits. It can be lifelong interactions involving close physical and biochemical contact interaction between two living organisms, where one-organism benefits and the other is neither harmed nor helped.

Amensalism is a biological interaction, a type of symbiosis, between two species in which one impedes or restricts the success of the other without being affected, positively or negatively, by the presence of the other. A predator is an animal or other organism that hunts and kills other organisms, called prey, for food in an act called predation. Predators are either *carnivores* or *omnivores*. Unlike in predators, for which killing prey is necessary in order to consume it, it is usually undesirable for a parasite to kill its host. Parasitism is one version of symbiosis through which one species (the parasite) is benefited from the association by harming the other (the host). Thus, species and often individuals within a species, compete to gain these resources. Neutralism describes the relationship between two species, which do not interact with or affect each other or absolutely no effect whatsoever on the other.

Further Reading

Tamrat Andargie, (2007). The Fundamentals of Ecology. *Unpublished Lecture Note*, *chapter three*; Hawassa University.

UNIT 3

PARTICIPATORY RANGELAND MANAGEMENT PRACTICES

INTRODUCTION

Dear learner, in this unit, you will study rangeland degradation, different participatory rangeland management practices, pastoralists' indigenous knowledge, types of grazing systems and stocking rate and carrying capacity as rangelands management tool.

Objectives

At the end of this unit, you should be able to:

- Define terminologies related to participatory range management
- Describe the practices of rangeland management
- List the aims and guidelines of grazing management
- Describe the types of grazing systems
- Identify applicable grazing system/s to the pastoral areas
- Combine indigenous management practices with the scientific methods

3.1. Definitions of Basic Terminologies

- ***Participatory rangeland management***: the science of maintaining of maximum range forage production without jeopardy to other resources or uses of the communal land in a participatory approach. It is the science and art of optimizing the returns from rangelands in those combination most desired by suitable to society through manipulation of range ecosystem. It is the manipulation of rangeland components to obtain the optimum combination of goods and services for society on sustainable bases.

- ***Rangeland degradation:*** the loss of utility or potential in relation to biological organisms as well as changes in the physical environment that would alter the functions of natural system. A degraded land according to herders does not support livestock productivity at optimal levels due to the loss of important fodder species. It used to describe changes which are reversible with management or when anthropogenic pressures are removed.

- ***Grazing systems***: the application of basic management principles based on how grazing affects plants. Grazing systems are necessary to protect plants from grazing and allow for maximum leaf production, seed production, seedling establishment and accumulation of litter between plants. It also important to note that the purpose of applying a given grazing system is to get an optimum production/output with possible minimum damage on plants.

- ***Stocking rate*****:** is the actual number of animals or animal units on a unit of land for a specific period of time, usually for a grazing season**.**

- ***Stocking density*****:** is the relationship between the number of animals per unit area of land at any instant of time. It differs from stocking rate, which expresses animal to land allotment for the entire grazing season. A high stocking density often requires a short grazing period and it is used to attain full forage utilization before re-growth can be grazed.

- ***Carrying capacity***: generally expressed as the number of Animal Unit that can be maintained on a specific parcel of land, and is based on the average amount of forage produced annually.
- ***Over stocking*** the placing of a number of animals on a given area that will result in overuse if continued to the end of the planned grazing period. Continued overstocking will lead to over grazing.

- ***Over grazing***: defined as a repeated heavy grazing which results in deterioration of the plant community. The grazing of a number of animals on a given area that if continued to the end of the planned grazing period, will result in less than satisfactory pasture forage production. Caution must be taken when declaring a range as overgrazed since it is difficult of truly assessing whether land is " overgrazed" Pastures can be heavily grazed but that may not lead to land degradation.

- ***Grazing period***: the length of part of the grazing season within which grazing actually occurs. It is the length of time that grazing livestock or wildlife occupies a specific land area. A rangeland grazed intermittently or a rangeland grazed yearlong may have several grazing periods. The beginning and ending dates of one or more grazing periods on each land units are stipulated in grazing plans and may not be the same from year to year.

- ***Non-grazing period*****:** a period of rest (grazing animals are prevented access) that follows each grazing period within a paddock.

- ***Grazing event***: the length of time that an animal grazes without interruption.

- ***Grazing cycle***: the time elapsed between the beginning of one grazing period and the beginning of the next grazing period.

- ***Repeated seasonal grazing***: involves grazing a range unit at the same time each year, followed by migratory game animal as wildebeest in East African parks (Serengeti-Mara)
- ***Deferment/Defer grazing*****:** the avoidance of grazing until plant reproduction is complete, establishment of new plants or restoration of plant vigor. Deferment permits gain in plant vigor, increased seed production, storage of TNC in roots, stem bases, and improves range health. This can also defined as the deferment of grazing in a non-systematic rotation with other land units. This is done in order to achieve a specific management objective. This may include providing time for plant reproduction, establishment of new plants, restoration of plant vigor, a return to environmental conditions appropriate for gazing or the accumulation of forage for later use.

- ***Rest****:* is the total absence of grazing for a full growing season and larger than the deferment. Unlike the deferred grazing, the rested portion is not grazing at all.

- ***Grazing area***: is the unfenced divisions, which are grazed according to the marks of the herders.

- ***Grazing cell***: refers to land managed as a unit for grazing.

- ***Paddock***: refers to fenced divisions of a grazing cell.

- ***Animal unit day***: the amount of dry forage consumed by one animal unit per 24 hours period. This is used to express the quantity of forage intake for a period of time and may be extrapolated to other time periods such as week, month or year.

- ***Continuous stocking*****:** is a method of grazing livestock on a specific unit of land where animals have unrestricted and uninterrupted access throughout the time period when grazing is allowed. In this case, the length of gazing period should be defined.

- ***Set stocking***: is a special case of continuous grazing in which a fixed number of animals remain on a specified or on a fixed area for a prolonged period of time.
- ***Creep grazing***: refers to the practice of permitting juvenile animals to graze areas that their dams cannot access at the same time.

- ***Animal unit***: a mature cow with calf weighing 450 kg or one mature non lactating bovine weighing 500 kg and fed at maintenance level or the equivalent of (Body weight) $^{0.75}$.

- ***Animal day/AD***: refers to the forage a standard animal unit harvests in a day. This amount depends on the number of animals and grazing days.

- ***Animal day hectare/ADH***: is the grazing days multiplied by the number of animal units divided by land size.

ADH=G*AU/ha Where, ADH=Animal day hectare
G= Grazing days
AU = Animal unit
ha= Hectare of land

ADH shows the amount of forage that each land unit will have to render on average. The concept of ADH is used to plan for draught reserves, avoid competition with wildlife, grazing needs at all times of the year and decide which paddocks will supply it.

3.2. Rangeland Degradation

Dear learner, can you define rangeland degradation by your own words?

Dear learner, before dealing with different participatory rangeland management practices; you have to know about rangeland degradation. It is define as the deterioration in range ecosystem services and functions, such as decrease in plant species composition and diversity, plant height, vegetation cover and reduction in plant biomass production;

decreased water and soil conservation, recreation values, carbon balance and so on, which results to decrease in secondary productivity (animal out puts). It is also defined as a reduction in the quantity and/or nutritional quality of the vegetation available for grazing/browsing animals. Major causes of degradation include climatic conditions causing drought and arid conditions and human factors leading to the overuse of natural resources such as expansion of arable land, human population pressure and overstocking, and bush encroachment.

Rangeland degradation is a measurable decline in the condition of the land. Rangeland degradation leads to reduce above and below ground biomass production and therefore to reduced C storage and increased CH_4 production per animal. Degraded rangeland soils have reduced water infiltration rates giving rise to increased run-off and erosion. It is evident therefore, that rangeland degradation is a major contributing factor to the worsening condition of the earth and that a worldwide policy of rangeland conservation, and where possible improvement, would materially contribute to a reduction of environmental damage.

Rangeland degradation is caused by a lack of knowledge about ecologically correct management and overgrazing. Although it is in the producers' own interest to conserve rangeland under their control, there are many instances of overgrazing. Overgrazing can be caused by droughts, when the managers fail to destock in time, which can be made difficult because of low prices for livestock. However, the use of supplements and the over sowing of legumes allow for a greater percentage utilization of the native herbage, causing the disappearance of desirable grasses and exceeding the safe limit of soil protection, when the stocking rate is increased to the maximum level of animal production.

Overgrazing can also be caused by unforeseen economic events, for example, when suddenly the world market prices for animal products from rangelands (meat and wool) fall and the managers are not able to sell surplus stock. Increased population pressure in developing countries leads to encroachment of villages and the taking into cultivation of the best rangelands, with increasingly shorter fallow periods, thus continuously reducing the area and quality of rangeland for an ever increasing animal population. Firewood collection further denudes the rangelands. Inevitable erosion removes topsoil with organic matter and nutrients, preventing the establishment of seedlings of perennial plant species, necessary for the regeneration of the vegetation. Thus the potential productivity and the protection of the ecosystem against degradation are lost.

Rangeland degradation leads to erosion, which in turn can lead to desertification, which is the end point and irreversible, leaving the soil unprotected and without any potential for food production and productivity.

3.3. Participatory Rangeland Management Practices

Resources management in participatory approach in pastoral areas should be practiced because things in such areas are in common.

3.3.1. Pastoralists Indigenous rangeland management practices

Pastoral community’ s participation in decision making for environmental monitoring is regarded as one of the pillars of sound range management. There are three assumptions involved. Firstly, it is acknowledged that pastoralists have their own experiences and knowledge, which they have used for generations to manage the rangelands. Secondly, it is assumed that their knowledge is measurable and comparable across communities.

Thirdly, it is assumed that their knowledge and its outcomes can make an important contribution to the development of local policies. Nevertheless, rangeland researchers have generally not incorporated into their research how this knowledge is generated and may be applied. Its usefulness in complementing existing scientific knowledge for the assessment and monitoring of rangelands, therefore little understood. Indeed, there is limited information on the comparability of indigenous knowledge across pastoral communities in different regions of Africa.

Pastoralists manage their livestock herds by managing their rangelands and their mobility across those rangelands. The indigenous system of range management has complex features reflecting the interrelationships between human adaptations, environmental variability, systems of land use and local decision-making systems. Indigenous rangeland management knowledge is the product of environmental management over time. In the words of a Somali elder rangeland cannot be a rangeland without pastoralists' knowledge and pastoralists cannot practice pastoralism without rangelands (Bouh and Mammo, 2008) the two are mutually interrelated. Environmental condition, livestock production and the social setting influence herders' indigenous knowledge.

Herders generally use two types of indicators. These are diagnostic ecological indicators and anthropogenic indicators. The diagnostic ecological indicators reflect relationships between biophysical landscapes and livestock productivity. Plant indicators reflect utility preferences, suggesting that some landscapes (because of their poorer grazing potential) will always be able to support less livestock than others, even under the most favorable weather conditions and management. By linking livestock productivity performance to indicator changes, herders are acutely aware of the production indicators that influence their decision-making on herd movements.

The main reason for this is that herders often combine ecological and anthropogenic indicators in rangeland assessments (Oba *et al*., 2008a). The anthropogenic indicators are part of human environmental history, products of people's perception of local environments. The types of indicators provide information about the productivity of livestock in terms of milk yield, body condition, and mating frequencies, as well as changes in body weight. Adverse changes in both ecological and anthropogenic indicators would imply declining rangeland and livestock productivity.

The customary institutions and indigenous knowledge are main tools for participatory range management and pastoralists are scientist of their environment. Local communalities have accumulated information on the past and present events of rangelands that might have changed the local vegetation. Thus, provides an important source of data for understanding past rangeland status and for better appreciation of management and environmental drivers that might have adversely affected the rangelands.

3.3.2. Grazing management

What is grazing management?

Grazing management**:** the manipulation of grazing animals to accomplish desired results in terms of animal, plant, land, or economic responses. Managing grazing to achieve sustainable use of grazing lands has been the primary theme of rangeland management. Control of animal numbers is the first and most important range management principle. As each animal grazes, it reduces available herbage in both quantity and quality, thereby changing the habitat for itself and altering future animal/habitat relations. The timing and degree of forage utilization by animals are the principal controls over species composition and forage production in manager's hands. The concept of rangeland resources signifies a synthesis of physical environment; plants and animals as enhanced by the manager and produced for society. One hears the term related resources for range forage, game, recreation, watershed, soil, timber, etc., and multiple-use when two or more of grazing of livestock, wildlife production, recreational facilities, more water, timber production, etc. occur on the same land.

Grazing management aims

- To provide a supply of nutritious herbage over the growing season at low cost.
- To avoid physical waste of herbage and inefficient utilization by the animal.
- To maintain the productive capacity of the sward
- To protect plants from adverse effects of grazing by herbivores
- To allow for the maximum leaf & seed production, seedling establishment and accumulation of litter between plants grazed
- To improve water and mineral cycling
- To provide more efficient use of solar energy, and improve rangelands to a desired ecological stage.

Grazing management guidelines

The following guidelines are management approaches, actions and practices necessary to achieve desired rangeland condition goals.

- Stocking rates will be established to balance livestock numbers with forage plant production
- Appropriate grazing systems (methods of grazing and resting pastures) will be employed to allow plant forage species to recover from grazing, reproduce and accumulate soil cover (foliar, basal and litter).
- Utilization level of key forage species will be used as guidelines for achieving sustainable use of renewable forage resources.
- Practices such as fencing, improving available water supplies, range seeding, shrub management and prescribed burning may be used as indicated by monitoring plant community response to applied management.
- Habitat will be managed to provide for ecosystem health and the maintenance of diverse populations of native plant, fish and wildlife species.

- Special wildlife habitats identified, conserved and enhanced through appropriate actions to maintain habitat values during implementation of management actions.

Methods of achieving uniform livestock distribution

Grazing distribution: The ideal distribution of any use on rangeland reduces number and area of places damaged by congestion of animals and people, and extends the area of proper use as widely as possible. The objective of distribution management is uniform and moderate or maximum use that does not damage soil and vegetation. Failure to correct uneven distribution of grazing pressure results in considerable damage to vegetation and soil. Livestock and wild animals cause damage for several reasons. They may be territorial, have memory for certain places, and prefer certain habitats; and they naturally congregate near water or in favorite resting places. Correction of distribution problems is often the first applied rangeland management practice.

Factors influencing animal distribution

- ***Vegetation types***: All animal species prefer certain vegetation types to others. For example, domestic animals normally stay away from dense timber, except at the edge where they find shade. Patches of thick trees restrict livestock movement, making uniform grazing difficult to achieve.
- ***Distance from water*****:** grazing sites far from watering point areas are inefficiently utilized by livestock.
- ***Topography*****:** The steepness and length of slope influence the use of forage by domestic and wild animals. Those slopes greater than 40 percent had little value for cattle grazing. Steepness of slope significantly influences distribution of cattle, but this factor does not operate alone. Different species of animals prefer different positions on the topography
- ***Animal behavior, intelligence and memory*****:** Animals travel farther on poor than on good range and as percentage of forage utilization increases. It is known that

the vegetation mosaic, physical improvements such as fences and water points, improvement of range condition, and changing livestock numbers in a pasture alter distribution of animals and their behavior. Failure by the manager to consider animal habits reduces the effectiveness of other rangeland practices and may result in local overuse. Division of large pastures often increases the evenness of animal distribution and forage utilization. However, a pasture size exists whereby animals graze them evenly and further reduction in size is of no advantage.

Practices to lessen animal concentrations

Range management includes many practices to spread animals in accord with the herbage resources.

- ***Development of water*****:** Development of water, especially new water, on rangeland has several purposes. For livestock, the aim may be better utilization of little-grazed land, or increased, length of the grazing season through greater supply. For wildlife, the aim is essentially the same, uniform use and more available land for the ungulates. Birds and smaller animals use the water for drinking, and some for habitat. Riparian problems may be relieved if livestock are drawn elsewhere. Fundamentally, the purpose is to improve rangeland condition for all the users. Water for livestock and game has been developed, with ditches, dams, earthen ponds or tanks, vertical wells, horizontal wells that open springs, pipelines, troughs, metal tanks, and guzzlers with sealed runoff aprons. The water has to be found, stored, and delivered in adequate amounts at the right times and places. Water harvesting is the gathering of runoff water from aprons that have been treated to reduce water infiltration into the soil.

- ***Fencing*****:** Efficient use of fences requires an initial concept of the different uses of the landscape on either side of the proposed boundary. Different classes of livestock sometimes may require separate pastures for animal management.

Fences will aid management if they can be placed between different range condition classes and where high and low-value vegetational types can be separated. Before any fence is constructed, the need for that fence, in terms of conserving soil and added use of forage to repay the cost of the fence, should be determined.

- ***Roads and Trails*:** Construction of livestock trails and roads over rough, rocky areas, through dense timber, and across other barriers increases efficiency in use of rangeland. Range roads have many values for the landowner, livestock, recreationists, and wildlife. Roads, as open strips through the vegetation, are lines of sight for predators and people, fuel breaks, and escape routes. Trailing reduces weight gains in livestock, increases death loss and causes considerable damage to vegetation and soil. However, within management units trails are opened through timber, over cliff barriers, etc. to permit even utilization of range forage.

- ***Herding:*** Herding of cattle is necessary in large unfenced pastures in order that they use the forage evenly. One rider or a person on a wheeled vehicle can take care of approximately 500 head or 125 km^2 of land, in favorable topography. The rider needs to know range condition, effects of grazing, and animal habits. Cattle can be trained to use certain areas and will repeat that use year after year. Duties of the range rider include repairing fences, maintaining adequate water and salt, caring for sick animals, preventing death losses, keeping bulls distributed, and assuring proper forage utilization.

- ***Salting*:** Salting is the planned distribution of the amount of salt required by livestock for the grazing period. Cattle movement can be altered effectively by proper placement of salt grounds. Locations should be selected so that animals will move to them and are drawn away from overgrazed or heavily trampled areas. Likely, these salt grounds will be on flat places, near shade, on accessible ridges, on level spots on slopes, in lightly used openings in forests, in patches of vegetation with low palatability, and in accessible corners of ranges where animals seldom graze. In forested areas, salt should be placed so as to attract cattle away from the meadows and onto the dry slopes. As slope and distance from water increase, more salting locations should be used. Where abundant dissolved salts exist in soil, water, and vegetation, free salt may have little attractive value for animals.

- ***Agronomic practices*:** Seeding highly palatable species away from water and less palatable ones near water has been suggested as a means of improving animal distribution. Seeding of plants with low palatability or high resilience to defoliation near areas of livestock concentration has value in soil conservation and range rehabilitation. Fertilization and prescribed burning away from water may serve the same purpose as seeding.

- ***Combination of practices*:** Fencing requires assurance of adequate water. Conversely, water developments can improve the uniformity of forage use without fencing. The amount of money that can be expended for range improvements to increase livestock distribution depends upon increased production from the land. Increased grazing capacity stems from newly available range, even use, and a longer grazing season. They are expressed through increased weight of animal products, reduced labor and machinery, and a decrease of the non-range feed requirements. It is well to keep in mind that increased livestock production ascribed to seasonal grazing may be in part due to decreased pasture size and even distribution of animals.

Mixed Species Grazing

Grazing two or more species of domestic animals together or separately on the same range in a single growing season has long been known as common use or dual use. The main principle supporting common use was that differences in forage preferences or lack of dietary overlap required two or more species for uniform use of mixed vegetation. Experience with using cattle and sheep, sheep and goats, or all three together proved more profitable on ranges with mixed vegetation than did the grazing of any one animal species alone. Perhaps even more influential in changing people's attitude toward mixed-species grazing has been the growing interest in preservation of wild animals; game farming for hunting, viewing, and meat products; and recreational services for wildlife and other rangeland resources.

The advantages of mixed-species grazing are complementary food, habits, improved distribution of grazing, diversification of income, parasite and disease management, and fewer losses due to predation. Disadvantages include increased costs due to loss of feeds, breakage of fences, trampling damage, damage by hunters, increased facilities, reduced efficiency within each species, labor conflicts, and need for increased management skills. Optimum conditions for one species is usually a tradeoff and poorer conditions for another; yet the production of two is usually more than either alone.

Prescribed grazing schedule/ systems of grazing

Prescribed grazing schedule is a system in which two or more grazing unit alternately deferred or rested, and grazed in planned sequences over a period of years. The period of non-grazing can be throughout the year or during the growing season of the key plants.

Types of grazing plans (systems)

There are different types of grazing plans of which the following are listed and described as below:

***Continuous grazing plan*:** perhaps the simplest of all plans is continuous grazing; it might be called a single-pasture plan. Continuous grazing is a pasture treatment that is often included in rotation schedules. Its use has been criticized because grazing occurs throughout the growing season, and it is argued that even light grazing during the growing season encourages repeated defoliation and overuse of the selected species and patches, while others are underused. Many areas have been continuously grazed for long periods without permanent damage to the resource.

In tests in which degree of range use has been controlled and proper distribution attained, continuous grazing has shown excellent results. Continuous system of grazing has been blamed by many for its undesirable effects on species composition of the vegetation. This is due to the fact that livestock have preferred areas (sacrifice areas) for grazing, the location of which is where there is water, highly palatable forage species, ground salt licks and shade in close proximity such areas are most productive part of the pasture. These are areas that attract animals and lead to over use of part of the range. Even under light stocking such areas will often receive excessive use and results patch use (selective/spot grazing) of the range. However, a moderate continuous grazing has also some advantages.

Advantages

- There will not be unused forage at the end of the calendar (avoiding wastage of forage not used on time well above its maturity stage).
- Because animals have free access, they can select the most nutritious species before losing their grazing value.
- This system is suitable to low rainfall annual species dominated areas as denying animals access to large portion of the rangeland could lead to wastage of many palatable short-lived grasses and forbs that complete their life cycle in a few days 10-20 days).

- Many studies have shown that continuous grazing outweigh rotational grazing in terms of seasonal gain, weaning weight, average daily gain, 120-day gain (for lambs) etc

- ***Repeated seasonal plans*****:** Seasonal variations in forage resources and animal husbandry may require repeated seasonal use. Vegetation types with coarse, unpalatable herbage and seeded stands of one or two species often are grazed on a repeated period basis. Each year, this pasture should be grazed in Periods 1 and 2 because those are the only times it is palatable.

- ***Rotation grazing plans*****:** in this system pasture is subdivided into a number of encloses with at least one more enclosure than groups of animals. Rotational grazing plans are used in specific rangeland situations, especially in the early growing season, when forage supplies and growth rates are low. Types of rotational grazing plans include daily strip grazing in pastures, short rotations with two or three pastures, and complementary rotations with different species. Rotational grazing plans can be divided in to:

- ***Deferred-rotation plans*****:** Deferred-rotation grazing signifies that at least one pasture is not grazed until after seed production and another pasture receives the deferred treatment the next year. Thus, three years are needed for a three-pasture arrangement or six years if a pasture receives deferment in two consecutive years. These are long rotations with long grazed and un-grazed periods. The simplest deferred-rotation plan employs one herd of animals. The number of pasture units equals the number of grazing periods and the number of years required to complete a rotation cycle.

- ***Strip grazing*****:** is a more intensive method of rotational grazing based on the use of electric fence, which is moved forward once or twice a day. A fixed or variable number of animals are given access to only part of a paddock by a movable fence in addition a movable back fence may be used to prevent access to strips already grazed. Electric fences are commonly employed to enclose the allowed area of forage while another fence may be placed behind the herd to fence off the previously grazed strip.

Advantage: selective grazing is minimized resulting in more uniform consumption.
Applicability: a highly productive and nutritious pasture.

- ***Creep grazing (leader follower systems*)**: is a rotational grazing system whereby the highest producing animals (such as milking cows) are allowed the first grazing in a paddock. This allows for maximum selection of highest quality forage. Once opportunity for selection has declined then less demanding classes of livestock such as the dry dairy cows or beef steers are moved in to graze the after math while the milking cows are moved to fresh grazing.
- ***Soiling or Zero grazing*:** is the feeding of cut vegetation to housed stock. Its advantage: Efficient herbage utilization, no loss due to trampling, uniform herbage intake and control bloat through wilting. Moreover, disadvantage is high cost for labor or machinery, bedding required for housed stock and manure disposal is laborious.
- ***High-intensity/low-frequency*:** The objective was heavy grazing pressure on a pasture for a short time to reduce the unpalatable species, to reduce competition against the better species, and to prevent grazing on the first re-growth. Long un-grazed periods were to provide ample time for recovery of the desirable species before the pasture was grazed again. In the dry season, the aims were to reduce standing dead material, loosen the soil surface by hoof action, and prevent the development of large un-grazed bunches of grass filled with dead stems. Seed production and seedling establishment were emphasized.

3.4. Stocking Rate and Carrying Capacity as Management Tool

Stocking rate is the most important management factor influencing the output of animal products from the pasture the stability and persistence of the pasture components and financial return, which the farmer receives. Estimating the optimum-stocking rate should therefore have the greatest importance in managerial decision-making. Determining stocking rates requires knowledge of forage production and grazing pressure. The amount of forage available for harvest is affected by climate; soil characteristics such as depth, slope and texture and extent of unproductive areas where rocks, brush and unpalatable species are prevalent. Of these factors, climate has the most significant and overriding influence on forage production. Forage production varies between pastures and locations within a pasture.

***Livestock Units*:** In order to compare the suitability of different areas of land when grazed by different species of livestock, they can be described by means of a common reference unit. This is termed Animal unit (AU) or tropical livestock unit (TLU). TLU is equivalent to an animal of 250 kg live weight or preferably of $250^{0.73}$ kg metabolic weights. Metabolic weight rather than live weight is recommended, as voluntary feed intake is proportional to the metabolic weight of an animal, which is live weight $^{0.73}$ kg and is related to the voluntary feed intake of the animal.

Table 3.1 Weights and TLU conversion factors of Livestock (FAO, 1991)

Species	Live weight	Metabolic weight	TLU Conversion Factor
Camels	250kg	56kg	1.0
Horses	200	48	0.85
Cattle	175	43	0.75
Mules	175	43	0.75
Donkeys	125	34	0.6
Sheep	25	10	0.2
Goats	20	9	0.15

Source: FAO, 1999

3.4.1. Stocking rate

This is the actual number of animals expressed in standard units, TLU allowed to graze on a unit of grazing land over a specified period of time. It is an indication between the number of animals and the grazing management unit utilized over a specified time period. It is the relationship between the number of animals and the grazing management unit (the grazing land area used to support a group of grazing animals for a grazing season) utilized over a specified time period. Factors affecting the optimum stocking rate are:

- ***The rate of forage growth:*** More animals may be safely carried as the amount of pasture-grown increases. If farm practices, which increase, pasture growth such as: Sowing improved forage species, applying irrigation water, controlling woody regrowth or fertilizer application are used higher stocking rate can be carried so that proper advantage is to be taken of the additional pasture grown.

- ***Accessibility of forage to animals:*** The occurrence of predators or the danger of animal theft may restrict pasture use. There may be insufficient watering points or sub-division fencing to ensure that all the feed grown is available for consumption. Insufficient watering point' s lead to overgrazing trampling damage and pasture degradation near the water points.

- ***The Nutritive value of pasture:*** Most of the forage species in the tropics have low nutritive value. Hence, in such situations animals selectively graze the most nutrition' s forages and the most desirable components of the pasture such as the greener tissues especially the leaves. In such cases, the optimum-stocking rate is lower. Stocking rate should always base on the total yearly production of roughages available to the livestock.

- ***Botanical composition and ground cover:*** Some pastures are more resistant to heavy grazing and weed invasion than others. For example, *cenchuris ciliaris* (Buffel grass) is resistant to weed invasion under heavily grazed conditions however, *Panicum maximum* is more vulnerable in this respect.

- *Seasonal variations in feed supply:* In areas where annual rainfall varies greatly from year to year the optimum-stocking rate will also vary from year to year. In very dry seasons, it is then possible for these grazers to sell off the dry stock but to retain a nucleus of breeding stock. Access to numbers and ease of restocking after a dry year will encourage higher stocking rate.

- ***Nature of animal product:*** The stocking rate-output relationship will depend on the sensitivity of output to nutritional stress. For sheep wool growth is the product least reduced by stress. Live weight gain reproduction and milk production then follow this. It is therefore possible to run a higher stocking rate for wool growing weathers than for beet producing animals or for fat lamb production. In making this assessment, meat producers are aware of the limits of live weight gain as an index of production. For example: in a rotational grazing system, if a given pasture land area is subdivided into a number of small paddocks each 1 ha. And if the DM yield per ha = 2000 kg and if the daily DM requirement/LU ≈ 10 kg and if a 10 day rotational grazing is practiced then what will be the optimum stocking rate per each paddock for the 10 days.

Solution DM requirement/LU/10days = 10 kg x 10 = 100 kg

DM yield/ha = 2000 kg DM;

$$\text{OSR} = (DM\ yield/ha)/(DM\ requirment/LU/day\ )$$

$$\text{And OSR} = \frac{\text{2000 kg DM}}{\text{100 kg DM}} = \text{20 L.U /ha}$$

Activity 3.1

Dear learners, please give the conceptual explanations about the formula and the final result of the above optimum stocking rate? Moreover, refer related books and do other examples? It is an Individual work.

3.4.2. Carrying capacity

Because of the fact that carrying capacity is a concept used by people in a different implication, the definition for carrying capacity is equally variable. Ecologist (equated with the “ k” value of the logistic curve, conservationist and livestock keepers use it. Originally, carrying capacity was used to balance a given biomass of plants with animals. The following definitions of carrying capacity have been drawn from different sources;

- (FAO) “ Cc is the maximum possible stocking rate of herbivores that a rangeland can support on a sustainable basis” .
- “Cc is the total number of stock of one or more classes which an area will support in a good condition during the time that the edible forage is palatable and accessible without decreasing the forage production in subsequent seasons” . This is purely from ranchers’ perception of cc and has the intention of profit making.
- “Cc is the maximum number of grazing animals of a given class that can survive in a given ecosystem through the least favorable environmental conditions occurring within a stated time interval (one year)” . This definition is more appropriate to wild life conservation objectives as it permits the existence of more surviving animals.
- “Cc is the number of individuals beyond which no major increase in population size can occur_without an improvement in habitat” . This is related to the “ k” value of the logistic curve.
- (UNSO/UNDP) “ Cc is the quantification of the number of animals per unit land area that can potentially use the resource without leading it to long- term degradation” .
- Cc is the maximum stocking rate that will achieve a target level of animal performance, in a specified grazing method, that can be applied over a defined time period without deterioration of the ecosystem. Therefore, in order to avoid such misuse of the concept of Cc as a management tool, any definition of Cc should have the following three elements: production objectives sought, time period over which the figure is used and level of resource use. Currently, there is

preference to split the concept in to two (ecological (environmental) and economic carrying capacity), each with its own objectives.

Summary

The pastoralists' indigenous knowledge is the key tool for the participatory rangeland management. They know the causes for degradation and management strategies. Control of animal numbers is the first and most important rangeland management principle. There are different factors that influence animal distribution on the rangelands. Grazing plans can be classified as continuous grazing plan, rotational grazing plan, repeated seasonal plan, zero grazing, high intensity-low frequency-grazing plan. Stocking rate and carrying capacity are other management tools for rangelands. Stocking rate of the rangelands can be influenced by different factors like the rate of forage growth, accessibility of the forage, the nutritive value of the pasture, botanical composition and ground cover of the pasture, seasonal variation in feed supply, nature of animal products and etc.

Self-Assessment Question 3.1

Direction I: Choose the correct answer from the given alternatives and write the letter of your choice on the space provided.

---------1. The decline in range ecosystem services and functions can be considered as

A. Rangeland improvement B. Rangeland degradation

B. Rangeland restoration D. Rangeland rehabilitation

E. None of the above

---------2. A pastoralist can practice one of the following activity to distribute his animals on his pastureland

A. Fair distribution of watering points

B. Undertaking fencing activities

C. Herding

D. Salting

E. All of the above

---------3. Which of the following is/are the aim/s of grazing management

A. To maintain the productive capacity of the sward.

B. Protect plants from adverse effects of grazing by herbivores

C. Improve water and mineral cycling

D. Provide more efficient use of solar energy and improve rangelands.

E. All of the above

-----------4. The unfenced divisions, which are grazed according to the marks of the herders refers

A. Grazing period

B. Grazing cell

C. All of the above

D. Grazing area

E. Paddock

Further Reading

United States Department of Agriculture, (2003). Management of Grazing Lands National Range and Pasture Handbook.

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UNIT 4

PARTICIPATORY INVENTORY AND MONITORING RANGELAND ATTRIBUTES

INTRODUCTION

Dear learner, in this unit you will deal with different methods of inventory and monitoring rangeland attributes. How pastoralists and agro-pastoralists should be participated during taking important attributes of rangelands during inventory and monitoring, which will, discussed well in this unit.

What are inventory, monitoring, and for what are they used for?

Objectives

At the end of this unit, you should be able to:

- Mention the objectives of range inventory and monitoring program
- Take appropriate sample size and shape for vegetation attributes.
- Undertake measurements of important vegetation attributes.
- Interpret changes observed in vegetation attributes.
- State application of inventory and monitoring during range management
- Devise appropriate means of improving deteriorating rangelands

Vegetation is defined as an assemblage of plants growing together in a particular location, which characterized by its component species or by the combination of structural and functional characters. Many ecologists view vegetation as a component of ecosystem, which displays the effects of other environmental conditions and historic factors in an obvious and easily measurable manner.

Vegetation and its component species, however, are changing due to a variety of factors such as seasonal effect, climatic changes and its consequences, long-term directional changes or succession, management interventions, natural cycles such as grazing herbivores and predators, etc. As a result, there is a need to describe vegetation for assessing the quality or value of resources, which are needed by the society. Inventory and monitoring have always been central themes of rangeland management, as tools to assist in making wise decisions according to the productive potential of the land resource, such as carrying capacity, utilization levels, grazing systems, and range improvements. Today under the philosophy of multiple use and increased legislative demands, however, inventory and monitoring programs serve a greater variety of interests and groups.

The basis for rangeland management planning, inventory, assessment, and monitoring is a map of the basic and relatively permanent rangeland resources; soils and vegetation. Maps of soils, current vegetation, ecological sites and/or terrestrial ecosystems are essential. Rangeland inventory and monitoring are the processes of describing and evaluating the resources at a rangeland site. Inventories are regularly done to determine the present status of variables important to Natural Resource Conservation Services (NRCS) and decision makers, which include physical structures, hydrologic features, rangeland ecological sites, animal resources and other variables pertinent to the planning process.

Biomass data collection, production and composition by species are the standard techniques used by NRCS in characterizing rangeland ecological sites during the inventory process. Data collected from range inventory provides a valuable baseline against which to compare responses but monitoring rarely be conducted at the same level of detail as the information provided by an inventory. Monitoring can be short-term; as to quantify amount of biomass used during a grazing event or long-term, such as to quantify trend in similarity index on a particular rangeland ecological site.

Reliable inventory and monitoring data are difficult to obtain in rangeland situations, which are characterized by extensive areas and considerable spatial and temporal in attributes. Although inventory and monitoring embrace many similar principles, different vegetation attributes and sampling methods are often required to meet the specific objectives of each process. For example, inventories usually aim to provide a detailed overview of resources for the entire management unit. In this situation, sampling strategies should be chosen to give an accurate depiction of important attributes for the whole site, best obtained from observations at many locations.

In contrast, monitoring is conducted over a duration of year, usually limited to detecting range trends in selected areas and for key species. Furthermore, different personnel are often involved in collecting the repeated measurements during monitoring, meaning sampling strategies should be easy to follow and promote precise results that are free

Rangeland inventory is information collected to document and describes the existing resource status within a management unit. The features included depend on the purpose of the inventory but in rangeland, situations are likely to entail vegetation types, range sites, range condition, carrying capacity, soil types, utilization patterns, etc Rangeland monitoring conducted to record changes in resource status usually to assess the response to a management program at a site.

4.1. Applications of Rangeland Inventory and Monitoring Programs

What is the purpose of inventory and monitoring programs?

Inventory and monitoring have always been central themes of rangeland management, as tools to assist in making wise decisions according to the productive potential of the land resource such as carrying capacity, utilization levels, grazing systems, and range improvements. Today under the philosophy of multiple use and increased legislative demands, however inventory and monitoring programs serve a greater variety of interests and groups. For example, Artz (1984) enumerated the following objectives of inventory and monitoring programs.

- To develop high quality land use plans.
- To allocate resources to uses and users.
- To assess current conditions and to monitor conditions in future for measurement of progress towards goals.
- To assess impacts of proposed land use actions.
- To assess capability or potential of resource production under various levels of management.
- To establish a common basis of measurement between various land types and ownerships.
- To assist in defending decisions in hearings and court actions.
- To satisfy legal requirements.

These objectives must be implemented at different time scales and levels of detail, depending on the purpose and end-user of the resource information. For example, local land managers (e.g. ranchers, stewards of local natural public reserves), need detailed site information to plan and evaluate specific projects such as erosion control, reseeding programs, the management of invasive plants or the regulation of wildlife populations.

Conversely, regional and national administrators are increasingly obliged by legal mandates to use inventory and monitoring information for a variety of assignments, from district land use plans to large-scale national inventories reporting on current resource status, which rely on data collected at more general or summarized levels. When planning an inventory or monitoring program, the objectives must be balanced against the availability of resources including time, money, and skilled personnel. In combination, these criteria will influence inventory and monitoring strategies, sampling designs, which vegetation attributes are collected, and evaluation of the final data from ecological and management perspectives.

4.2. General Considerations in Inventory and Monitoring Programs

What are the fundamental premises of range inventory and monitoring?

4.2.1. Site Selection for Sampling

How sites selected for sampling?

Selection of sites for sampling is a critical consideration when designing rangeland inventory or monitoring schedules. Documentation of site locations, either on maps or with clear written directions, is also an important component of the sampling protocol. Site selection typically assumes a procedure of selected sampling for either inventory or monitoring programs. After general locations have been identified, further decisions must be made concerning the layout of sample units within the selected sampling area. This next step entails the adoption of a combination of random sampling and systematic sampling approaches. When undertaking an inventory of an area, it is preferable to establish sampling locations throughout the management unit to ensure a thorough coverage of the site. Sampling efficiency may be obtained by adopting a stratified sampling scheme, often using range sites as the basis of stratification.

In monitoring, it is usually only practical to sample a few areas. Each site should be restricted to relatively uniform areas such as range sites, to facilitate data collection and guide the degree to which interpretations can be extrapolated beyond the immediate sampling area. Permanently located sites reduce sampling error associated with spatial variation of the attributes so that data can provide a clearer depiction of range trend over time. The location of sites and sample size depend upon the selection of attributes and their variability within the management unit, the type of management and expected responses, the availability of sampling resources, and the purpose of the inventory or monitoring program. Effective site selection will minimize sampling requirements, enhance statistical accuracy and precision, and ensure that the collected data can be interpreted in a manner relevant to the objectives of the program.

1.2.2. Range Sites

What does range sites mean?

Range sites are the principal units of rangeland classification that are based on categorizing vegetation according to site potential. Site potential is defined as the capacity of an area to support a distinct species composition and/or total biomass. Range sites act as the primary organizational element to obtain inventory and monitoring information during sampling. Therefore, the vegetation represented by a range site must be sufficiently uniform for the valid interpretation and extrapolation of data for management applications, yet incorporate the inherent variability expected in rangeland landscapes.

The Soil Conservation Service (Natural Resources Conservation Service) developed the range site concept by adopting ideas previously introduced into forestry science. Other government agencies with land management responsibilities (Bureau of Land Management, and Forest Service) use similar, but not always equivalent, concepts and terms to classify rangelands, such as ecological site, ecological type, or habitat type. The most important range site classification is centered on identifying differences in potential productivity rather than simply categorizing the existing vegetation. A classification based on site potential is more meaningful to planning and management because it encourages the consideration of a wider range of options, rather than being restricted to existing conditions.

However, deciding the nature of the potential plant community is also subject to the biases of personal judgment, particularly when the vegetation has been modified under a long tradition of land use. These differences among range sites reflect the combined influence of environmental factors, including climate (total precipitation, seasonality of precipitation, temperature, frost free days, etc.), soils (soil surface texture, water holding capacity, etc.), topography and fire. Therefore, common principles of ecological succession are incorporated into the range site concept, by assuming that only one distinctive plant community (the climax community), can evolve under a certain set of environmental conditions.

The importance of soil characteristics and topography on plant growth is well recognized, and these factors are usually included when naming range sites (e.g. Limestone Hills, Sandy Loam Upland, Clayey Bottom, etc.). Soil maps are often adopted as the foundation of range site maps, but extensive field reconnaissance, coupled with sampling of vegetation attributes such as biomass and species composition, must also be followed during the process of delineating range sites within an area. The same range site can occur at different locations across an extensive region, wherever the vegetation is considered to exhibit a similar potential for productivity and species composition.

Comprehensive descriptions have been developed for each range site, based on research, field surveys and professional observation. The description includes climate, topography, soils, potential vegetation, and management interpretations such as carrying capacity and resource value ratings. A major disparity between the various government agencies is that descriptions of the potential plant community are restricted to native species under Natural Resource Conservation Service (NRCS) procedures, whereas other agencies include naturalized introduced plants. This difference has considerable consequences, particularly when using the descriptions as benchmarks of site potential for range condition assessments.

1.2.3. Key Areas

What are the key areas?

Key areas are sampling sites deliberately selected, based mainly on professional judgment, in rangeland inventory or monitoring programs to be representative of the entire management unit. Data from key areas are interpreted as an indicative guide of average responses to land use throughout the management unit. Key areas are indicator areas are indicator areas that are able to reflect what is happening on a larger area as a result of management actions. A key area should be a representative ample of a large stratum, such as a pasture, grazing allotment, wildlife habitat area, herd management area, watershed areas, etc., depending on the management objectives being addressed by the study. Key areas represent the ' pulse' of the rangeland. Proper selection of key areas requires appropriate stratification. Statistical inference can only be applied to the stratification unit.

As a type of selected sampling, the capacity of a key area to represent the entire area depends on the experience and skill of observers selecting the location. In general, key areas should represent common range sites of the management unit, and address the objectives of the monitoring program. For example, when monitoring utilization, key areas should provide important sources of forage, but not be too close nor too distant from water points since neither of those locations will be a typical indication of grazing patterns over the entire area. Key areas should also contain the key species or key management features on which the inventory and monitoring program is interested in.

Selecting key areas

- The most important factors to consider when selecting key areas are; management objectives found in land use plant, and coordinated resource management plan.

- An interdisciplinary team should be used to select these areas.
- In addition, permittees, lessees, and other interested publics should be invited to participate, as appropriate in selecting key areas.
- Poor information resulting from improper selection of key areas leads to misguided decision and improper management.

Criteria for selecting key areas

The following are some criteria that should be considered in selection key area. A key are:

- should be representative of the stratum in which it is located
- should be located within a single ecological site and plant community
- should contain the key species where the key species concept is used
- should be capable of, and likely to show, a response to management actions. This response should be indicative of the response that is occurring on the stratum

Number of key areas

- Depends on the size of the stratum an on data needs.
- However, the number of areas may ultimately be limited; by funding, and personnel constraints.

Mapping key areas

- Key areas should be accurately delineated on aerial photos and /or maps.
- Mapping provides a permanent record of their location.

1.2.4. Comparison Areas

What is comparison area?

Comparison areas, also known as reference areas or benchmark areas, are additional sampling locations established in rangeland inventory or monitoring programs to isolate the effects of land use from other natural events (especially weather factors) influencing vegetation responses. Therefore, comparison areas are usually chosen at localities with minimal management impacts, such as livestock exclosures or sites distant from water points. In other situations, fence line contrasts reveal useful clues to separate the effects of land use from weather conditions.

Credible interpretations of land use impacts depend upon the selection of comparison areas that are representative of corresponding key areas or critical areas, partially realized by restricting sampling locations to the same range site. Problems of variability within a range site could be overcome by including multiple comparison areas, although this is seldom practical within the scope of time and budgetary constraints associated with most land evaluation programs.

1.2.5. Critical Areas

What is key area?

Critical areas are sampling locations deliberately chosen in rangeland inventory or monitoring programs because of unique values or special concerns such as riparian zones, restricted habitats for threatened or endangered species, or range sites highly susceptible to erosion. Unlike key areas, vegetation responses observed in critical areas are not interpreted to reflect management impacts over the entire management unit. Instead, critical areas are evaluated separately to ensure the fulfillment of specific goals that are associated with resource conservation.

1.2.6. Key species

What does key species mean?

Rangeland inventory or monitoring programs usually concentrate on sampling only a few important species or species groups that serve as indicators of status and/or trend for the entire vegetation. Key species should be selected to satisfy program objectives, such as rare species or important forage plants. This approach permits more efficient sampling and interpretation, because measuring all species is time consuming and often provides greater detail than required. Because most inventory and monitoring programs have typically evaluated the impact of livestock grazing on rangelands, important forage plants have traditionally been selected as key species. Consequently, when the key species concept is commonly applied to determine utilization levels, selection of plants could vary according to dietary preferences associated with the type of animal using the rangeland and time of sampling.

In this situation, the utilization of key species is extrapolated to judge the proper use of other species at the site. Therefore, key species should generally be abundant, productive and palatable components of the vegetation, and moderately sensitive to grazing. However, key species can be selected to meet any management objective. For example, key species may be chosen in relation to their role in watershed protection, or as threatened or endangered species requiring special attention. Furthermore, if the management goal is to improve low range condition, key species may not be abundant in the existing vegetation, but should still possess a seed source and be known as an indicator of improving range condition.

- Key species are generally an important component of a plant community. Key species serve as indicators of change and may or may not be forage species. More than one key species may be selected for a range site, depending on management objectives and data needs example

- In some cases, problem plants (poisonous, encroaching and exotics) may be selected as key species.
- The key species may change from season to season and year to year.

Selecting key species

- Should directly be tied to management objectives
- Species selected will depend upon the plant species in the present plant community, the present ecological status, and the potential natural communities for the specific sites.
- An interdisciplinary team should be used, to insure that various data needs are fulfilled
- Interested publics should also participate.

Considerations in selecting key species

The forage value of key species may be of secondary or no importance. For example, watershed protection may require selection of plants as key species that protect the watershed but are not the best forage species. In some cases, threatened, endangered, or sensitive species that have no particular forage value may be selected as key species. Any forage use of the key species on key areas is assumed to reflect foraging using on the entire range site. Utilization percentages in this situation are an index of the use on key species. Depending on the selected management strategy and /or periods of use, key species may be forage during the growing period, after maturity, or both.

In areas of yearlong grazing use and in areas where there is more than one uses period, several key species may be selected. For example, on area with both spring and summer grazing use, a cool season plant may be the key species during the spring, while a warm season plant may be the key species during the summer. Selection of several key species may be desirable when adjustments in livestock grazing use are anticipated. This is especially true if more than on plant species contributes a major portion of the forage base of the animals using the area.

Key species on depleted rangelands

The key species selected should be present on each study site on which the monitoring and inventory program are being performed. However, on depleted rangelands these species may be sparse. In this situation it may be necessary to conduct monitoring studies on other species. Data gathered on non-key species must be interpreted on the basis of effects on the establishment and subsequent response of the key species. It should also be verified that the site is ecologically capable of producing the key species.

1.2.7. Species groups

What does species groups mean?

Considering each individual species at the site, even to determine species composition, is often a time consuming and inefficient approach to collect data, especially for attributes determined by counting, such as frequency or density. Accuracy can be compromised from species misidentification (particularly for seedlings, grazed, or rare plants), and such detailed information may be unnecessary to satisfy many inventory or monitoring objectives. Many statistical inference procedures are also ineffective when a species is rarely recorded. Instead, many studies focus on close inspection of a few key species that are nominated to meet the goals of the sampling program.

The remaining species of interest can be allocated to broad groups that are based on either morphological characteristics e.g. *Aristida sp.*, or functional features, e.g., perennial forage grasses or succulents. Clear ground rules are needed to ensure that species are consistently designated to their correct group. Season to season fluctuations in vegetation attributes represent the key consideration when deciding what time of year to conduct rangeland inventory or monitoring programs. To prevent seasonal differences from confounding interpretations, comparisons between inventory data from various sites or monitoring data from a single site over a number of years, should be confined to the same season so that key species are at a similar level of maturity. In addition, it is possible to select vegetation attributes that are relatively insensitive to seasonal fluctuations, such as basal cover, to minimize the effects of sampling during different seasons.

4.3. Selection of Rangeland attributes

What are rangeland attributes?

Rangeland inventory and monitoring programs have usually focused on describing vegetation attributes, although soil characteristics are assuming greater importance in recent proposals for evaluating the status of rangeland resources. Vegetation attributes are generally regarded as easier to quantify compared to soil properties, which often rely on subjective assessments. Information on weather conditions, stocking rates, utilization patterns, wildlife, wildfires, and multiple use activities are useful to supplement measured vegetation responses, and to aid in interpreting the results. Photographs also provide a valuable visual record of the overall status of rangeland resources.

No single vegetation attribute is best suited to describe the existing status or to detect trends in rangeland vegetation. Instead, attributes should be selected in light of the objectives of each inventory or monitoring program, the type of vegetation, and the availability of skilled observers. Ideally, attributes should involve rapid and simple sampling methods, to ensure that accurate and precise data can be collected within the budgetary and time constraints associated with many rangeland evaluation plans.

Vegetation attributes commonly measured in rangeland inventory and monitoring programs include:

4.3.1. Biomass

What does vegetation biomass mean?

Biomass is the primary objective of inventories conducted to determine carrying capacity, utilization patterns or range condition. Despite its importance in management applications, few techniques are available to rapidly obtain accurate and precise biomass data for large areas, so that other attributes such as cover are usually recommended for large scale monitoring programs. It is also difficult to isolate fluctuations in biomass created by weather conditions and immediate grazing history from changes induced by active management.

4.3.2. Cover:

What does vegetation cover mean?

A cover is an area of vegetation or other surface features, in relation to the area of ground. It can be expressed in absolute terms, basal area/area of ground or as a percentage. *Cover* is widely adopted for both inventory and monitoring purposes because it is an attribute that provides rapid and repeatable data that is relevant to many practical interpretations regarding land use (e.g., forage availability, wildlife habitat) and resource status (e.g., erosion potential). Basal cover is generally considered a more stable measure than canopy cover to identify herbaceous vegetation change, since it is less influenced by weather fluctuations, time of year, and immediate grazing history.

Types of *cover* as an attribute include;

- ***Ground cover:*** Percent of the soil surface covered by some type of protection (litter, rocks, vegetation, etc.)

- ***Basal area or basal cover:*** Area of plants at or near the ground surface. Most stable cover attribute over time.
- ***Canopy cover****:* A vertical projection of the perimeter of a plant canopy to the ground. Ignores small gaps in canopy.

4.3.3 Density:

What does vegetation density mean?

It is defined as the number of individuals per unit area or unit volume. For example, a species may have an abundance of 10 individuals in a particular area. If the total area is 2.5 ha hectares, then the density of the species would be 40 per hectare (40/ha). Density (D) may provide useful inventory information for large perennial species, particularly trees and shrubs. However, density is rarely measured in monitoring situations, because it can be very time consuming, and there are errors associated with the identification of individual plants.

4.3.4. Frequency

What does frequency mean?

The term frequency indicates the number of samples in which a species occurs. This is expressed as the proportion of the total number of samples taken that contains the species in question. Frequency is regularly used in monitoring programs, because it is a rapid technique that provides precise results. Although a sensitive index of changes in a species over time, additional data must be collected to reveal which other attribute caused the change. Frequency has less relevance in inventory applications, because it does not provide an absolute measure of species abundance.

4.3.5. Species Composition

What does species composition mean?

It refers to the contribution of each plant species to the vegetation. Botanical composition is another term used to describe species composition. Species composition is generally expressed as a percent, so that all species components add up to 100%. Species composition is commonly assessed to describe the character of vegetation during detailed inventory programs. However, accurate determination of species composition can be tedious, because all species must be sampled. Therefore, in long-term or broad scale monitoring situations, it can be more efficient to concentrate on a few key species or species groups, chosen to meet the objectives of the program. In addition to deciding which vegetation attributes to measure, the planning of inventory or monitoring programs must also select which plant species to include in the sampling protocol. Key Species and Species Groups

Activity 4.1

Dear learner, Try to divide into an appropriate group size and take measurements on plant cover, density, frequency, and diversity. At the end of the practical, each group will prepare a report.

4.4. Sampling considerations and concepts

What parameters are you considered in inventory, and monitoring?

Extensive areas are often covered in range inventory or monitoring programs, making it impractical to count every plant or to traverse every meter of land. Therefore, a sample is collected to obtain a subset of data that is assumed to represent the entire site, or population. If the rangeland vegetations were homogeneous, designing a sampling regime would be straight forward. For example, only a few samples would be needed to obtain an accurate description of a well-manicured lawn. However, a diverse assemblage of plant species some of which are abundant while others may be very rare typically characterizes rangelands. Plants are also distributed in a variety of spatial patterns that may be expressed at several different scales in the landscape.

In fact, any factor that affects germination, establishment or mortality will influence the spatial arrangement of plants, including soil type, aspect, water redistribution patterns, grazing distribution (e.g., location of fences and water), and wildlife impacts (e.g., kangaroo rat mounds). Rangeland plant communities also exhibit considerable temporal variation, so that the presence and abundance of a species may fluctuate markedly between seasons and years. Designing effective sampling regimes to accommodate this inherent variability is the real challenge of rangeland inventory or monitoring programs. It is the step that determines the efficiency of sampling, the value of the data, and which statistical models may be applied during data analysis. Much of the terminology and concepts related to sampling is derived from the theory of statistical inference. People often become uncomfortable with statistical theory, but only an elementary understanding is required to understand the general concepts of sampling and data analysis covered here.

4.4.1. Time of sampling

When are you undertake sampling?

Season to season fluctuations in vegetation attributes represent the key consideration when deciding what time of year to conduct rangeland inventory or monitoring programs. To prevent seasonal differences from confounding interpretations, comparisons between inventory data from various sites or monitoring data from a single site over a number of years, should be confined to the same season so that key species are at a similar level of maturity. In addition, it is possible to select vegetation attributes that are relatively insensitive to seasonal fluctuations, such as basal cover, to minimize the effects of sampling during different seasons.

The best time of the year to sample depends upon the objectives of the program and the selection of attributes to be measured. For example, regular monitoring to evaluate stocking rates by determining utilization levels are best conducted at the end of the grazing season. If species composition is identified as a monitored attribute, more accurate data collection is possible by coinciding fieldwork with the period when plants are flowering and identifiable. Other secondary factors may also control the most practical time of sampling. For example, sampling opportunities may be restricted by boggy soils limiting the accessibility to high elevation sites during spring, the availability of skilled labor, or conflicting workplace commitments.

4.4.2. Frequency of Sampling

How many times do you need to take sample for a given parameters?

Data need only be collected on a single occasion for an inventory program, to document rangeland resources and to evaluate their current status. In contrast, monitoring must be conducted on a recurrent basis to detect changes in vegetation attributes. Although it may appear simpler to identify and interpret the causes of vegetation change under an annual sampling regime, such a protocol is rarely undertaken except when monitoring utilization. For example, vegetation changes large enough to assume practical significance often take more than one year to become evident, particularly after allowing for variability arising from weather, and sampling error factors. Consequently, the optimum interval between sampling depends on the longevity of key species. For example, long-lived perennial shrubs such as mesquite (*Prosopis spp*.) need not be monitored as frequently as populations of shorter-lived annuals or biennials such as *Rothrockgrama (Boutelouarothrockii*).

In addition, frequent sampling is usually limited by time and budgetary constraints. Therefore, with the exception of biomass data to evaluate utilization patterns or residual biomass levels, it is not unusual to return to sample sites only once every 3 to 5 years in a long-term monitoring program. More frequent monitoring may be desirable for newly developed schedules, to confirm that the selection of attributes, time of sampling, sampling methods and site selection are suited to the objectives of the program. In other situations, it may be plausible to a) measure a different subset of sites each year so that all sites are sampled at the end of 3 to 5 years, most years, b) measure all sites when changes are noted at a subset of sites, c) when altering stocking rates, or d) during extraordinary seasonal conditions. Photographs may also be considered as a quick and easy alternative to provide additional information for sites in years when sampling of vegetation attributes is not undertaken.

4.4.3. Sample Units

What does sample unit mean?

Sample units are the members of the population from which measurements are taken during sampling. Sample units are distinct and non-overlapping entities, such as quadrats or transect, individual plants, branches within a plant, etc. Characteristics of the sample unit have a significant effect on sample accuracy and sample precision (and therefore sampling costs). Sample unit dimensions may also be manipulated to promote a normal distribution in the collected data that will permit the application of conventional analysis of variance models for statistical analysis.

Sample unit size

What does sample unit size mean?

The optimum sample unit size for rangeland sampling depends on the attribute being described, the size of plants present, and the scale of spatial patterns within the vegetation. Sometimes the size selected in a rangeland inventory or monitoring program is determined by convention or past practices. In fact, it is important to continue using sample units of the same size for repeated measurements. Therefore, sample unit size must be considered carefully in planning stages because of its critical role in determining sample accuracy and sample precision. Sample unit size influences sample accuracy by controlling the likelihood of boundary decisions. The larger sample units have a lower perimeter: area ratio, which reduces possible bias from incorrect boundary decisions.

Sample size, or sampling intensity, refers to the number of sample units that will be measured in the inventory or monitoring program. Sample size is an important consideration during the planning stages of a monitoring program because it is a key way to influence the precision of the collected data. The larger sample sizes improve precision because a greater proportion of the population is being measured. For example, consider a bag of 100 marbles, featuring 8 colors in differing quantities. If we only pull 5 marbles from the bag we don't have a very good idea of colors or quantities, because we haven't even had the opportunity to sample each color (i.e., 8 colors cannot be fully represented by 5 marbles). If we pull 40 marbles from the bag we get a better idea of colors and quantities, and our confidence in the representativeness of our data will continue to increase as more marbles from the population in the bag are studied.

Larger sample sizes are required if the population has a large variance or if a species of interest occurs in low abundance. In both cases, a greater proportion of the population must be sampled to obtain an accurate and precise measure of the vegetation attribute. There are two possible approaches to determine an adequate sample size when designing an inventory or monitoring program. Statistical Techniques and graphing Techniques Sample size is a critical decision in designing an inventory or monitoring program because it is an important way to influence the precision of the sample. Special consideration regarding sample size depends on the vegetation attribute being sampled, and the sampling method selected to collect the data.

Sample unit shape

How does the shape of sample unit determine what you sample?

Sample units used to sample vegetation attributes are generally circular, square or rectangular in shape. In a monitoring program, it is essential to use sample units of the same shape for all subsequent or compared measurements. Sometimes the shape that is selected for a study is determined by convention or past practices, although it is a factor that can significantly affect sample accuracy and sample precision. The shape of sample units influences sample accuracy by controlling the likelihood of bias associated with boundary decisions. Sampling precision is influenced by manipulating sample unit shape in a manner that considers vegetation patterns, so that more variability is encompassed within rather than among sample units.

A general principle is that circular sample units enhance sample accuracy, while elongated types of sample units promote sample precision; leading to the rule of thumb that long, narrow sample units are most suitable in sparse or clumped vegetation, but circular sample units are more convenient in dense vegetation with a more uniform spatial distribution. This rule of thumb is guided by the following considerations:

- Circular sample units have a lower boundary length: area ratio. Fewer boundary decisions are encountered in circular sample units compared to square or rectangular sample units of the same size, improving the accuracy and precision of the sample (Table 4.1).

Table 4.1. The effect of sample unit shape on boundary length

Sample Unit Shape	Area (m^2)	Dimensions (m)	Perimeter (m)	Area: Perimeter Ratio
Circle	10	3.6 (diameter)	11.2	1 : 1.1
Square	10	3.2 X 3.2	12.6	1 : 1.3
Rectangle	10	5.0 X 2.0	14.0	1 : 1.4
Rectangle	10	50.0 X 0.2	100.4	1 : 10.0

Source: FAO, 1998

- Long narrow sample units reduce sample variance. In many vegetation communities, plants feature a patchy spatial pattern. Sampling using a circular sample unit promotes an 'all-or-nothing' situation, where some encompass most of a vegetation patch while others fall in the interspaces between vegetation patches, leading to data with a large sample variance. Under these conditions, it is more desirable to have long narrow sample units, which include both the patch and the interspace within their boundaries.

- Long narrow sample units are subject to greater measurement error. Long narrow sample units are difficult to examine in their entirety. As well as the errors arising from boundary decisions, small plants are more likely to be overlooked in long, narrow sample units. Additionally, techniques requiring a subjective estimation or ranking, such as the comparative yield method to estimate biomass, the dry-weight-rank method to determine species composition, or Daubenmire cover class method to estimate cover, are more difficult to execute in elongated quadrats.

Sample size

How does sample size determine what you sample?

The sample size or sampling intensity refers to the number of sample units that will be measured in the inventory or monitoring program. It is an important consideration during the planning stages of a monitoring program because it is a key way to influence the precision of the collected data. The larger sample sizes improve precision because a greater proportion of the population is being measured. The larger sample sizes are required if the population has a large variance or if a species of interest occurs in low abundance. Sample size is a critical decision in designing an inventory or monitoring program because it is an important way to influence the precision of the sample. Special consideration regarding sample size depends on the vegetation attribute being sampled and the sampling method selected to collect the data.

Activity 4.2

Dear learner, divided into appropriate size groups and take measurements of plant cover, density, frequency, and diversity. At the end of the practical, each group will prepare a report.

Self-Assessment Questions 4.1

Direction I. Write “ True” if the statement correct and “ False” if it is incorrect on the space provided.

------1. Range monitoring is conducted to record changes in resource status usually the response to management programs at a site.

-------2. Monitoring and inventory are two central themes of range management as a tools to assist in making wise decision

-------3. Additional sampling locations established in range monitoring/inventory programs to isolate effect of land use are comparison areas.

-------4. The extent to which plant residues primarily depends on production level of plant community and amount of plant growth removed only.

-------5. Native plant community evolve with in their environment and slowly changes over time as environmental factors, vegetation and the soil.

Direction II. Choose the correct answer from the given alternatives and write the letter of your choice on the space provided.

--------1. The information collected to document and describe the existing resource status

a. Range condition c. Range management

b. Range monitoring d. Range inventory e. All

---------2. Which is the objectives of range monitoring and inventory programs to

a. develop high quality land use plan d. allocate resources to use & user

b. asses impacts of proposed land use actions e. monitor condition in future

c. asses current condition and f. all

---------3. Sampling site selected deliberately in range inventory/monitoring programs to be a representative of entire management unites

a. Range site d. Species composition

b. Range areas e. Soil conservation

c. Key areas

--------4. Which is the criteria that should be considered in selection of key areas

a. Representative of the stratum d. located within a single ecological site

b. Contains the key species e. likely to show mangt action response

c. All

--------5. Vegetation attributes commonly measured in range inventory and monitoring programs

a. Biomass c. Cover

b. Density d. Frequency e. Composition

-------6. The number of sample unites that will be measured in range inventory and monitoring programs

a. Sample unit frequency c. Sample unit size

b. Sample unit shape d. Sample unit intensity e. B and D

4.5. Allocation of sample units and sampling designs

4.5.1. Random sampling

What does random sampling mean?

In random sampling, any member of the population has an equal chance of being selected to contribute to the sample. In practice, this means that the set of potential sample units are identified and then the individuals that are actually sampled are selected using a randomization technique, such as throwing a dice, flipping a coin, or using a random number table. For example, 100 contiguous $1m^2$ quadrats could be identified along a 100 m tape, and then 20 of these quadrats are selected from a random number table and measured. Similarly, 10 potential transects could be systematically identified at 10 m intervals along a 100m baseline, and 3 of these transects selected for sampling using a deck of cards.

Random selection of sample units is an underlying assumption of most statistical inference techniques, because it ensures that the sample unit selection is free from personal bias and not confounded by possible spatial patterns within the vegetation. Therefore, a major advantage of adopting random sampling is that data sets can be compared using conventional statistical inference techniques that estimate the sample mean and it' s precision. However, random sampling is often impractical to apply in its purest sense. For example, randomly located quadrats are often difficult to accurately locate, particularly when an extensive area is sampled, and a large proportion of sampling time is devoted to locating the quadrats.

In addition, a larger sample size is needed to obtain adequate precision under random sampling, because the technique ensures that all the variability of the population is represented in the sample. Therefore, simple random sampling designs usually feature low sampling efficiency. Finally, random selection processes may lead to an uneven distribution of sample units across the site, so that some areas may be poorly represented during sampling. Several designs have been developed to address these disadvantages while maintaining the principles of randomization, including restricted random techniques (arrangement of sample units within blocks or clusters) and stratified sampling.

4.5.2. Systematic sampling

What does systematic sampling mean?

In a systematic sampling design, sample units are selected according to a predetermined methodical pattern, which ensures that each unit of the sample represents an equal portion of the whole population. For example, running transects off a baseline at regular 10m intervals represents a systematic sampling design. Systematic sampling is also commonly used in research situations, when quadrats are located on a grid arrangement throughout the small study area. Methodical selection within the site permits sample units to be located more rapidly and more evenly distributed than is the case with random sampling. Sample units are also selected without personal bias, as long as the systematic arrangement is determined without intent to include or exclude certain portions of the population.

The main drawback of systematic sampling is that typical methods of statistical inference cannot be applied, because the assumption of random selection is not met. Even though the observer may be certain that the sampling units were selected free from personal bias, it is possible that the accuracy of the data is compromised by a regular spatial pattern within the vegetation community. For example, sampling according to a 30m grid in a pecan orchard where trees were planted on 30m spacing could result in estimated cover values of either 0% or 100%, depending on whether the sampling grid coincided with the trees or with the interspaces!

Various interpretations and modifications have been suggested so that data collected under systematic sampling designs represent an unbiased selection of the population, to ensure valid applications of typical statistical analysis methods. For example, a degree of randomization may be incorporated into the sampling design by tossing a coin to decide whether each regularly spaced transect should be run in a left or right perpendicular direction away from the baseline. In other situations, the scale of spatial patterns within the vegetation community may have been previously investigated (particularly for key species), so a contrasting scale could be adopted when planning the systematic sampling design. However, the purist's approach to rangeland inventory and monitoring will insist that only true randomization ensures valid statistical analysis using typical methods. In practice, it remains the responsibility of individual to objectively guarantee the accuracy of the data.

4.5.3. Selected Sampling

What does sampling selection mean?

Selected sampling involves active selection of members of the population that are considered to be most representative of the objectives outlined in the inventory or monitoring program. For example, key areas are often selected for closer attention in utilization studies, because it is not possible to monitor utilization across the entire site. Likewise, in a riparian monitoring program, transects may be subjectively located at several locations considered typical of the riparian zone.

The potential of selected sites to accurately represent the larger area depends upon personal judgment. With experience and skill, people are often able to successfully select representative sites. However, in other cases, personal bias or unrecognized natural factors affecting the area may confound the accuracy of the data from the selected sites. Therefore, extra care must be taken in interpreting the data, in addition to the initial site selection.

Fewer sites are usually chosen in a selected sampling design, because they are assumed to provide a good representation of the population, and no measure of sample variance is required. As a consequence, the overall sampling effort is greatly reduced, and selected sampling is often adopted in monitoring programs where the primary goal is to investigate change over time for extensive areas. However, because the data provides no measure of variability for the area being sampled, sample precision cannot be estimated and statistical inference analysis cannot be applied to describe spatial patterns from the general area. However, it is possible to use statistical inference methods to compare values for each site among the various times that the sample units were measured.

4.5.4. Stratified sampling

What does stratified sampling mean?

Stratified sampling involves dividing the site into sections that are more homogenous than the entire area. Boundaries of the sections should be based on factors that are readily identified and mapped, such as different vegetation types, soil types, topography, range sites, range condition classes or utilization levels. Stratification of the area makes sampling more efficient, because fewer samples are required for a precise estimate of the sample mean and sample variance of a uniform area. Data from each section can be analysed and interpreted separately or combined to describe the entire management unit. This sampling scheme also overcomes the problem of poor distribution of sample units associated with random sampling. In stratified sampling, sample size is usually determined for the entire site, and then sample units are divided among the stratified sections. The number of sample units may be allocated on the basis of the area of each section ('proportional allocation'), or by considering variability within each section so that the attribute is estimated with the same precision for all strata ('optimum allocation').

4.6. Sampling Terminology and Theory

Attributes – are the characteristics of the population we wish to measure during sampling such as; species composition, biomass, cover, density or frequency at a site. Other attributes of vegetation community that we may need to describe include plant vigour, habitat quality, soil condition status, erosion potential, etc. obviously some attributes are easy to measure directly, while others depend on an indirect or subjective assessment of the characteristics

Population- is the set of all individuals possessing the particular attribute we wish to describe. Therefore, the limits to the population are decided by the objectives of the sampling program. For example, if we wished to conduct a national inventory to determine the volume of commercially valuable fodder in a nationally park, the population would comprise all rangeland sites with in the national park. In another situation, a local land management team may want to know the biomass of forage with in a particular pasture, to determine it' s stocking rage over the next 12 months. This time the population is confined to the forage species with in that pasture, excluding the unpalatable or in accessible material that will not be consumed. Because it is usually impractical or impossible to measure all members of the population, a sample is selected and measure to obtain information on the population.

Sample: a sample is that portion of the population, which is actually measured. Sampling is a more practical way to obtain inventory or monitoring information because not all members of the population need to be measured. It permits data to be obtained at less effort and expense, and may enhance its integrity by reducing mistakes associated with the tedium of prolonged repetitive measurements.

For example, it would be an unreasonable undertaking to measure every tree constituting the population to obtain information for an inventory on the volume of commercially valuable timber in a national forest! Instead, data on this attribute may be collected using several smaller areas (perhaps 5 to 10 ha) as samples, and then extrapolated to represent the entire commercial timber resources for the national forest. Likewise, a local bureau of land management is not likely to cut and with all forage plants within a particular pasture to determine the biomass of forage so that the stocking rate for the next 12 months can be estimated. Instead, they are likely to weigh the forage cut from a sample of smaller quadrats (perhaps $1m^2$), and use this information to make some useful conclusions about the forage biomass over the entire pasture.

The key assumption of the sampling process is that sample members make up a representative selection of the entire population. That is, we assume that the information on a particular attribute, which we obtained from the sample reliably, reflects that attribute in the population. Safeguards incorporated into the sampling process to support this assumption are discussed under accuracy, bias, and precision error. Each population has a unique set of parameters, but their actual values are rarely known because of the impracticality of taking a census that includes ever member in the population. Instead, data obtained from sampling is used to infer information regarding the parameters of the population.

Parameter-values that summarize properties of the population. Commonly expressed parameters are the population means (μ) and the population variance (σ^2).Parameter is unique for each population. We need a simple understanding of population parameters in rangeland inventory monitoring for two reasons.

- The objective of a sampling program is to estimate the parameters without measuring every member of the population.
- Statistical techniques to analyse difference between treatment, sites, years etc., are based on comparing parameters form different samples to determine the probability that all data from these different locations and sampling dates are actually derived from the same population.

Statistics: values that summarize properties of the sample are known as statistics. Commonly expressed statistics are the sample mean (χ) and the sample variance (s^2). In sampling, we use statistics derived from the sample data to infer something about the population parameters, since we assume that the sample is representative of the population. The relationship between population parameters and sample statistics is covered in the discussions of sample mean and sample variance.

Sampling distribution- sampling distributions describe general patterns in the spread and frequency of the values in the sample data. This type of sampling distribution generated during sampling depends on the vegetation attribute, spatial patterns of the vegetation, the sampling method and characteristics of sample unit. Sampling distributions have important ramifications on statistical approaches to analyse the data collected in range inventory or monitoring programs. Therefore, specific considerations concerning each vegetation attribute are discussed in statistical analysis of biomass data, statistical analysis of cover data, statistical analysis of density data and statistical analysis of frequency data. There are three common sampling distributions encountered during sampling:

- Binomial distribution
- Normal distribution
- Poisson distribution

Binomial distribution- are special sampling distributions generated when an attribute with only two possible outcomes is being recorded from a series of sample units. The sample units should be independent and selected by random sampling. In rangeland sampling, recording the presence of plants in quadrats to determine frequency produces a binomial distribution. Binomial distributions are also associated with point sampling to determine cover whenever each pin is considered a separate sample unit so that data is collected on a 'hit' basis. Sample data following a binomial distribution cannot be analysed using conventional inferential statistical procedures, which assume that data fits a normal distribution. Procedures specific to the binomial distribution can be found in statistics textbooks.

Normal distribution: sampling distributions generated when an attribute possessing a continuous, and typically unbounded, range of outcomes is recorded from a series of sample units. Sample units should be independent and selected by random sampling. Normal distributions follow a symmetrical form, characterized as a bell-shaped curve. Normal distributions are observed in many biological populations, wherever most individuals represent a average expression of the continuous attribute such as plant height or weight. In rangeland sampling, biomass data generally follows a normal distribution. Data for other attributes, such as cover and density, will also tend toward a normal distribution by selecting an appropriate sample unit size or calculating the parameter from a group of sample units. Sample data following a normal distribution are analysed using conventional inferential statistical procedures, which are founded on established relationships between sample statistics and population parameters

Poisson distribution - it is a special sampling distributions generated when discrete individuals are counted from a series of sample units. Sample units should be independent and selected by random sampling. Poisson distributions are similar to the binomial distribution, except there are more than two alternative outcomes associated with the attribute. In rangeland sampling, counting individual plants in quadrats to determine density produces a Poisson distribution. In these cases, distributions assume a skewed form because most values are zeros or very low and higher counts are infrequently recorded.

Sample data following a Poisson distribution cannot be analysed using conventional inferential statistical procedures, which assume that data fits a normal distribution. Sometimes Poisson-type populations will give data, which tend toward a normal distribution if sample unit size is increased, sample units are defined as a group of quadrats or square-root transformations are applied. Procedures specific to the Poisson model can be found in most statistics textbooks.

Sample mean- The sample mean (χ) is the average of a set of values that are sampled from a population. Because vegetation attributes usually exhibit a normal distribution, a greater proportion of the data will lie close to the mean. The sample mean is computed by adding all values in a sample data set and dividing by the number of values in the data set.

Population mean- the population mean (μ) is calculated in the same manner. However, because we usually are not able to collect data on all members of the population, we can use the sample mean to estimate the population mean, based on the assumption that they are equal. This relationship between the sample mean and the population mean will be valid whenever the attribute being sampled exhibits a normal distribution, and the sampling procedure is free of bias. Safeguards incorporated into the sampling process to protect against bias are discussed under Accuracy and Bias.

Sample variance -the sample variance (s^2) is a measure of dispersal that reflects the spread of data around the sample mean. The sample variance is calculated as. This equation indicates that the variance gives us a measure of dispersal by considering the average absolute difference between each value in the data set and the sample mean. We rarely have the need to directly calculate the population variance (μ^2), because it is unusual to measure all members of the population. However, we can estimate the population variance from our sample data, from the assumption that $\mu^2 = s^2$

Standard error -The standard error (ε) is a measure of the variability among the sample means (χ) of repeated samples taken from the same population. The standard error is a measure of precision, and reflects how certain we are in the results from our sampling. A small standard error indicates that we expect to get the same result from repeated samples, whereas a large standard error suggests that repeated samples produce highly divergent results. The standard error is calculated as If we sample a highly variable population (i.e., the value of s in the formula is large) we would expect a large standard error, which demonstrates a low level of repeatability among samples and indicates we should be cautious about how well our sample actually represents the population. By including more members of the population in each sample (i.e., increasing the value of n in the formula), we should reduce the standard error and improve the repeatability among sample

Confidence interval-The confidence interval gives a range cantered around the sample mean (χ) and it indicates how closely we believe our sample mean is representing the population mean (μ). A large confidence interval suggests that the sample does not provide a precise representation of the population mean, whereas a narrow confidence interval demonstrates a greater degree of precision. The formula used to calculate the confidence interval of a sample is. All confidence intervals are expressed according to a particular probability (also referred to as level of confidence) that the interval correctly includes the population mean. This caveat is necessary because the population parameters remain unknown, but are estimated by theoretical inferences from the sample statistics.

The other factor influencing confidence interval width is the standard error (ε), which indicates variability of the population and the degree to which it is mediated by sample size. Confidence intervals are used in statistical analysis to describe the probability that two sample means are from the same population, provided that the data sets exhibit a normal distribution. If there is overlap between the confidence intervals for two means being compared, then it is concluded that these values are not significantly different with a probability equivalent to the probability used to establish the t-value.

Accuracy and bias-The accuracy of a sample reflects how closely the sample mean (χ) represents the true population mean (μ). Sample accuracy is jeopardized by systematic factors associated with the placement or measurement of sample units, that lead to cumulative errors or biases in the sample mean. These may be caused by inherent flaws in our sampling procedures or by personal prejudices during data collection. Sample accuracy cannot be assessed or corrected after the data is collected, because the true population mean remains unknown (if it were known, we would not be sampling). The best way to ensure accurate data is to incorporate safeguards into the sampling process that protect against bias. These safeguards include:

- Random Sampling and
- Ground Rules

Precision and error -Precision of a sample can be described as the variation among all the samples used to estimate the population parameters. In this respect, it is analogous to the sample variance, and is reflected in the width of the confidence interval of a sample. Precision is affected by various compensating 'errors' associated with inherent variability of the population, as well as random measurement errors, such as possible inconsistent assessments when making estimates, for example, the designation of classes in the Daubenmire cover class method to determine cover, or the designation of ranks in the comparative yield method to determine biomass.

Precision is an important factor to consider when designing the inventory or monitoring program because the sample variance is the foundation of subsequent statistical analysis. Therefore, although sampling precision can be quantified from the collected data, it is used as an expression of the confidence we have in our collected data. Highly variable samples have a low precision, meaning we are unsure how well our particular sample represents the population.

Ground rules-Ground rules are guidelines developed to minimize the subjectivity of sampling. Ground rules should be developed before fieldwork commences, and should be clearly included in the sampling protocol. Ground rules are especially important to maintain sampling accuracy and precision when a number of different people are involved in data collection, or when data is collected over a number of years.

Allocation of the sample units- sampling design- Decisions relating to the arrangement of sample units within the site have a large influence on sample precision, sample efficiency, and statistical models used to analyse the data. These decisions are an important component of designing the inventory or monitoring program before the data is actually collected. In vegetation where distinct boundaries of spatial patterns can be identified, sampling precision will be improved by stratified sampling. Under this approach, it is important to ensure that the sample unit is confined within the boundaries of the subunit.

For example, when collecting data to determine range condition of a sandy loam upland range site, care must be taken that the transect does not extend into the adjoining loamy upland range site. Vegetation often exhibits an identifiable gradient according to slope, soil depth or distance from water, where the effect of orientation of sample units on sample precision becomes increasingly pertinent. In the situations where the gradient is too subtle to create distinct sampling areas, the sampling precision will be enhanced by orienting the quadrat or transect so it intersects across the gradient, with the aim of encompassing the range of variability within each sample unit.

Summary

In general any ecological studies aim at investigating the patterns of nature, especially on how communities interact with each other and the environmental complex. The study beyond generating a new knowledge on the pattern of distribution and interaction of organisms in nature, it could also serve as a tool for conservation measures and policy decisions. If we want to know what kind of plants and animals are in a particular habitat and how many there are of each species, it is usually impossible to go and count each and every one present. This problem is usually solved by taking a number of samples from around the habitat, making the necessary assumption that these samples are representative of the habitat in general. In order to be reasonably sure that the results from the samples do represent the habitat as closely as possible, careful planning beforehand is essential.

Depending on the purpose of our study, we have two classes of data in ecology these are: species data and environment data. Species data include characteristics of individual species in a community such as: relative importance of species (abundance, biomass, and cover) frequency, height, width, degree of herbivory and the like. To record these types of data we usually use quadrats (relevee’ or stand) for plants and less mobile animals. Transects also could be used for both plants and animals. Environment data include all the physical and chemical nature of the habitat surrounding the organism such as soil, water and atmospheric temperature, moisture, soil pH, landform (topography), land inclination, elevation, geographic position and the like.

The species and environmental data could be recorded using different strategies however; the conventional method for larger areas is using samples. If we are using quadrats, they are recorded at each quadrat. All the attributes of each species and also the physical factors are recorded at each quadrat.

Samples are usually taken using a standard sampling unit of some kind. This ensures that all of the samples represent the same area or volume of the habitat each time. The usual sampling unit is a quadrat. Quadrats usually consist of a square frame made from wood or metals. If the quadrat size is larger, we can use strings (rope) to delineate the sampling area. The purpose of using a quadrat is to enable comparable samples to be obtained from areas of consistent size and shape. Rectangular quadrats and even circular quadrats have been used in some surveys. It does not really matter what shape of quadrat is used, provided it is a standard sampling unit and its shape and measurements are stated in any write-up. It may however be better to stick to the traditional square frame unless there are very good reasons not to, because this yields data that is more readily comparable to other published research.

Further Reading

Crowder, L.V. and H. R. Chheda. 1982. *Tropical Grassland Husbandry*. Longman, London.

Kent, M. and P. Coker. 1992. *Vegetation description and analysis: A practical approach.* John Wiley & Sons, Chichester.

UNIT 5

PARTICIPATORY RANGELAND ATTRIBUTES MEASUREMENT TECHNIQUES

INTRODUCTION

Dear learner, in this unit you will deal with different techniques to measure rangeland attributes. Pastoralists and agro-pastoralists should be participated during taking data from the rangelands.

Objectives

At the end of this unit, you should be able to:

- Define terminologies
- Identify the techniques of rangeland vegetation measurements
- Describe the current rangeland conditions of the country
- Explain the direction of the change in Ethiopian rangelands
- List and explain about methods of biomass determination

Range condition, range trend and biomass concepts will discussed well in this unit. Range condition and range trend are long-time concepts, each with several definitions, numerous procedures for application, and as many shades of meaning as individuals who use them.

Do you know the techniques of measurement of rangeland attributes?

5.1. Definition of Terminologies

- ***Rangeland condition:*** is the present state of health of the rangeland in relation to what it could be with a given set of environmental and managerial factors. Range condition measures range deterioration and improvement.
- ***Rangeland trend:*** states the direction of change in range condition.
- ***Biomass*****:** the total mass of the plants (above and below ground).

5.2. Rangeland Condition

Dear learners, what do you think about Ethiopian rangeland condition?

It evaluates present rangeland status in proportion to the production potential. Range condition is measured by the extent to which it departs from climax. It is used as a guide to ensure sustainable land use, to determine carrying capacity and adjust stocking rates, to identify potential responses to range improvement programs such as bush control or reseeding, and to evaluate the best locations of fences and water facilities to improve utilization within a rangeland. The quality of a rangeland to support various levels of productivity in accordance with management objectives and land use-planning principles following the application of management action.

It relates to soil quality, present state of vegetation in relation to the potential plant community for that site and the relative degree to which vegetation in a plant community resembles that of the desired community for that site. Through designing condition surveys, understand long-term impacts of management on range resources. Information from range condition assessment is used as a guide to ensure sustainable land use, to determine carrying capacity and adjust stocking rates, to identify potential responses to range improvement programs such as brush control or reseeding, and to evaluate the best locations of fences and water facilities to improve utilization within a pasture. Generally, the value and use of assessing rangeland condition can be any one of the following;

- Provide a preliminary evaluation of soil and/or site stability, hydrologic function and integrity of the biotic community (at the ecological site level).
- Help landowners identify areas that are potentially at risk of degradation
- Provide early warnings of potential problems and opportunities.
- Used to communicate fundamental ecological concepts to audiences in the field
- Improve communication among interested groups by focusing discussion on critical ecosystem properties and processes.
- Select monitoring sites in the development of monitoring programs.
- Help understand and communicate rangeland health issues.

Range condition is the present state of health of the range in relation to what it could be with a given set of environmental and managerial factors. It is the present state of vegetation of a range site in relation to the climax (natural potential) plant community, or the degree of closeness of the present plant community to the climax vegetation for that site. In general, condition implies the health state of a given land escape and its vegetation cover following the application of different management actions. It resemblance of vegetation to the one desired.

rangelands are in good or excellent condition, maintaining them in a stable condition may be the best management strategy. However, if they are in poor or fair condition, management aimed at " improvement" may be indicated. Generally, four or five condition classes are recognized. These are excellent, good, fair and poor sometimes a fifth category very poor is added. The four classes of range condition are based on production percentages of decreaser and increaser plants as compared to the original vegetation. Rangeland condition can also be assessed using multiple condition parameters such as grass species composition, herbaceous basal cover, number of grass seedlings, grass age distribution, soil physical condition and woody density and cover.

5.2.2. Uses and applications of rangeland condition

The information from range condition assessment is used as a guide to ensure sustainable land use, to determine carrying capacity and adjust stocking rates, to identify potential responses to range improvement programs such as brush control or reseeding, and to evaluate the best locations of fences and water facilities to improve utilization within a pasture. Range condition classification provides an indication of management inputs necessary. If ranges are in good or excellent condition, maintaining them in a stable condition may be the best management strategy. However, if they are in poor or fair condition, management that is aimed at " improvement" may be indicated.

Generally, the value and use of assessing rangeland condition can be any one of the following;

- Provide a preliminary evaluation of soil/site stability, hydrologic function, and integrity of the biotic community (at the ecological site level).
- Help landowners identify areas that are potentially at risk of degradation.
- Provide early warnings of potential problems and opportunities.
- Used to communicate fundamental ecological concepts to a wide variety of audiences in the field.
- Improve communication among interested groups by focusing discussion on critical ecosystem properties and processes.
- Select monitoring sites in the development of monitoring programs.
- Help understand and communicate rangeland health issues.

5.2.3. Assessing rangeland condition

Dear learner, how can you assess rangeland condition?

Assessment of rangeland condition can be done by relating the compositional, structural and utilization characteristics of those vegetation communities that do happen to occur on a range site with what can be determined of the site’ s land use history and supplementing this with information obtained from local pastoralists (and other sources) about the relative values of plant species /communities. For instance, comparisons can be made of soils, vegetation composition and structure and general levels of utilization at different points along land use impact gradients. To know the previous and future condition of the rangelands, it is possible to compare the current state with:

- Protected areas, such as national parks, game reserves and fenced enclosures where use is minimal,
- On fallowed fields of differing ages and degrees of protection from grazing and,
- Ranch paddocks and
- Moderately grazed areas and enclosures.

In order to develop adequate criteria for assessing range condition it is necessary to know about:

- The various types of vegetation communities and plant species that may occur on a range site,
- The relative values of the vegetation and/or its component species for the type of land use concerned,
- Level of degradation and resource depletion in the rangeland.

Therefore, an initial and critical step in evaluating range condition is to classify range sites to determine site potential. This is because of the fact that different rangeland sites will have different range management requirements and responses. Hence, before range condition can be assessed the range sites must be identified and located. Similarly, before the application of range condition classes or ratings to the whole rangeland, the range areas are broken into smaller less variable land units termed as ecological sites or range sites or habitat types. An ecological site is a distinct land unit with specific physical and biological characteristics such as topography, soils, etc that differs from other sites in its vegetation types and response to management (grazing, seeding, fire, etc). A rangeland site is recognized on the basis of its productivity and the dominant kinds and proportion of species it contains.

Ideally, each range site should have the following characteristics;

- A rangeland site should respond in the same manner to management and to climatic variation,
- A range site should have a maximum possible internal uniformity in terms of vegetation composition, productivity, topography and etc.
- For practical purposes, the scale of range sites should be in hectares and square kilometres in contrast to research sites, which should be on the scale of square metres
- Every range site has a definite set of environmental factors including soil type, mean annual precipitation, temperature variation and wind.
- A rangeland site has distinct values in terms of in composition and proportion of the species groups in the community
- A rangeland site has a clear difference with other rangeland sites in soil characteristics, climate (rainfall), and topography leading to significant difference in production.
- A rangeland site has a clear difference with other rangeland sites land use potential and subsequent hazards (example hillsides, riverbanks, etc)

These factors cannot be controlled but they must be known in order to define the site potential. Vegetation changes occur in response to many factors. The manager must be able to distinguish between the consequences of overgrazing, those variations in environment in order to understand what can be corrected, and what must be endured. The nature and definition of excellent range conditions presents major difficulties in application to many range sites. Widespread understanding of rangeland deterioration requires that excellent range condition must be reconstructed deductively. In most cases, this suggests reconstructing climax vegetation. Similarities between excellent condition grasslands and climax grasslands in many rangelands of the world do exist but only in an approximate fashion. Excellent range conditions in desert, chaparral, woodland and forest types may have little relationship to climax.

Activity 5.3

Dear learner; make a group of five and discuss about the current status and constraints of a given rangelands in nearby locality by looking at vegetation in-protected areas such as national parks, enclosures where use is minimal, ranch paddocks, on fallowed fields and try to discuss about the current condition.

on the state of knowledge, the standard will then be described in general or in specific terms. The more exactly it is described in terms of botanical composition, the more the rating of condition will also depend on botanical analysis and the greater will be the need to qualify the rating by reference to specific animal species. It can be quite feasible for an area to be rated as good for camels and goats but only fair for cattle, when full weight is given to the composition and feeding value of the vegetation.

5.2.4. Criteria for condition assessment

Dear learners, can you list criteria to assess rangeland condition?

The two most important factors that drive the dynamics of the vegetation to various levels (stages) are grazing and drought. Light grazing coupled with higher rainfall accelerates the successional tendency towards the climax end point and there by improve the range condition towards the ‘ excellent’ condition class. There are also other factors that could drive the vegetation towards excellent (fire). Heavy grazing and drought act in opposite direction and result in a poor range condition. Depending on which factors are the actors, all possible stages of the vegetation ranging from poor, heavily grazed, early succession to excellent, no grazing, and climax could be arrayed along a single continuum of this succession model.

The succession model thereof tries to adjust stocking rate to fit the different condition states of the vegetation by seeking a balance between herbivore numbers and vegetation abundance. Different objectives such as production per unit land and per head are achieved by combining different levels of stocking rates to the condition state of the vegetation. There are some important criteria that are considered in assessing the condition of any rangeland. These criteria are measured and interpreted to give some meaningful implication about the condition of a rangeland. In most instances, criteria for rangeland condition assessment and monitoring focus on vegetation as vegetation are the most reliable indicators of rangeland productivity and ecological change.

- ***Botanical composition***: the proportions and contribution of each type of plants is compared. According to these criteria, the higher the proportion of the most desirable plants, the better will be the condition of the rangeland. However, there is some times difficulty in interpreting results from these criteria. This is mainly because there is always disparity of objective and interest between different stakeholders. For example, a higher proportion of woody species can be a good condition from a forester' s point of view while the same condition could be considered bush encroachment by a range manager.

- ***Soil erosion***: soil erosion is almost a universal indicator or criteria for assessing rangeland condition, for most people assessing rangeland condition, the higher the extent and risk of erosion, the lower will be the rangeland condition.
- ***Soil stability and fertility***: depth of soil, extent of erosion, structure, rainfall acceptance, microbial activity and nutrient status
- ***Ground cover:*** this vegetation attribute is very power full, that it can provide information on different other aspects of the rangeland, such as erosion, ability to burn etc.
- ***Shrub and tree cover***: density, species composition, height, vigor and age.
- ***Forage value:*** bulk, nutritive value, seasonal variation, potential productivity, preference by animals, and relative palatability. Nutritive value, (consult the animal nutrition lab technician for common procedures of measuring forage nutritive value).

Conceptually, similar indicators or criteria of rangeland health (condition) are also given by (USDA, 2005), and these are in general termed as ecological processes include the ***water cycle*** (the capture, storage, and safe release of precipitation), ***energy flow*** (conversion of sunlight to plant and then animal matter), and ***nutrient cycle*** (the cycle of nutrients through the physical and biotic components of the environment). Ecological processes functioning within a normal range of variation support specific plant and animal communities. Direct measures of site integrity and status of ecological processes are difficult or expensive to measure due to the complexity of the processes and their interrelationships.

Therefore, biological and physical components are often used as indicators of the functional status of ecological processes and site integrity. The product of this qualitative assessment is not a single rating of rangeland health, but an assessment of three components called attributes. These attributes include:

- ***Soil/Site Stability*****:** The capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.
- ***Hydrologic Function:*** The capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.
- ***Biotic Integrity*****:** The capacity of the biotic community to support ecological processes within the normal range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants, animals, and microorganisms occurring both above and below ground.

5.2.5. Approaches and methods of rangeland condition assessment

What methods used in rangeland condition assessment?

For successful rangeland condition assessment, the technique must be simple and fast to execute, ecologically meaningful and scientifically sound. Therefore, the choice of the method to use should depend on the local conditions and it is preferable to use different techniques for different objectives. In general, there are two basic approaches to rangeland condition rating, i.e., ecological and the other is based on production (agronomic). Both approaches depend on assessment in relation to the potential or capability of the ecological site and on the amount and composition of the vegetation. Moreover, the techniques have a common factor, namely the creation of a basis from which grazing capacity can be calculated and attempt to provide a measure of monitoring condition trends with time.

Agronomic (site potential) approach

What does agronomic approach?

This approach is condition classification or rating approach based on the site potential of an area in terms of forage for animals. This approach presupposes knowledge of the potential of the site for forage production also called the genetic potential. The approach rates a given site in terms of current forage production and its potential under sound management practices. The different forage types are differentiated into desirable (or decreasers) less desirable (increasers) and undesirable (invaders) groups and rating is based on the proportion of these groups.

These ratings are:

- Excellent condition range that has the capability (potential) to produce 90 to 100% of all the forage possible under sound and potential management
- Good condition range productivity = 70-90%
- Fair condition = 50-70%
- Poor condition = 25-50%
- Very poor condition = < 25%

Similarly, the agronomic or the site potential approach also measures condition of rangeland in terms of the palatability classes of the existing vegetating. The use of palatability classes has been widely used in the United States and South Africa. Species are allocated palatability ratings, which signify their forage production potential. Three palatability classes were developed for the purposes of classifying grassland species:

- Class I - highly palatable,
- Class II - intermediate and
- Class III - unpalatable.

Multipliers, i.e., weightings of 3, 2 and 1 are used for classes I, II and III respectively, to derive a palatability composition rating for each sample site. It is calculated as the sum of the products of the relative abundance of each species and its weightings, and is expressed as a percentage of the maximum palatability composition (viz 300) to produce a scale ranging from 33.3 (all species in class III) to 100 (all species in class I). These palatability composition (PC) values are converted to weighted palatability composition (WPC) values by means of the formula developed by (Barnes et al. 1984), namely:

$$\mathbf{WPC = (PC - 33.3) \times 100 \div 66.7}$$

In addition to the forage production potential and proportion of palatable and desirable plants, the agronomic or site potential approach uses other criteria like;

- Percentage composition of desirable species, density of plants,
- Vigor (which is the health and thriftiness of plants),
- Litter accumulation and decomposition rate,
- Degree of soil erosion, which all can be used in different combination in different range areas.

In short, condition rating according to the site potential or agronomic approach is based on the current forage production of a site in relation to its potential under sound management. Therefore, any criteria with an implication in forage production can be used.

Ecological (climax) approach

What do you think about the Ecological approach?

The ecological approach requires the knowledge of the climax vegetation and succession. Condition classes are assigned according to the percentage of the climax vegetation.

These condition classes are based on similarity of the current vegetation with the climax and stable community that could occupy a site without mismanagement or human influence. This vegetation also is called potential natural vegetation or community. The identification of climax and stable vegetation for rangeland condition assessment is based on relict vegetation and soils, evaluation of vegetation changes attributed to light grazing pressure, review of repeat photos and historical accounts. Observations, measurements, and evaluation of climax contain a large measure of personal opinion.

Criteria used to judge stability are one or more but never all of the following:

- Species composition; this changes very little in stable communities. An individual that dies is likely to be replaced by another of the same kind (not by an individual of a different species).
- Dominant species do not change. Example Acacia/grass continues to be Acacia/grass if it is climax vegetation for the area.
- Longevity of the dominant species increases with an increase in the successional tendency.
- Dispersal mechanisms tend to be adapted to movement by animals rather than by wind and to vegetative (perennials) continuations rather than by the seed (annuals).
- Biomass quantities remain relatively unchanged (despite the climatic fluctuations)
- Net production is low in the climax as maintenance (as opposed to reproduction) takes much of the energy (r and k strategy).

Based on the above criteria, it is possible to evaluate whether the current vegetation is climax or not. Condition classes could then be rated for each site depending on its proportion of climax vegetation. According to this approach, or based on the similarity of the rangeland plant community in question with the climax vegetation, the following condition classes are identified.

Table 5.1. Condition classes based on the similarity with the climax vegetation

Range condition	Percent similarity with climax
Excellent	76-100%
Good	51-75%
Fair	26-50%
Poor	0-25%

Source: Arizona Grazing Lands Conservation Association, 2004

Percent similarity to climax is calculated by the formula: $\mathbf{2W/(a+b)}$

Where a = the sum of species values for present vegetation,

b = the sum of species values for the climax, and

W = the sum of values common to a and b.

Table 5.2. Calculation of percent similarity to climax and determination of condition class

Species	Present vegetation (a)	Climax vegetation (b)	Allowable (W)
A	200	500	200
B	400	300	300
C	50	100	50
D	200	100	100
Total	850	1000	650

The **%**similarity is (2*650)/ (850+1000) = 0.7 = 70%

Therefore, the condition class is (**Good**)

There are many other methods with similar basic principle with the ecological or climax approach and include benchmark, ecological index method, the key species, weighted key species and the degradation gradient techniques. The general principle of this approach is to compare the different ecological characteristics of the existing population with the ideal climax condition in mind. In general, either it is the agronomic or the ecological approach that is being in use, condition of a rangeland is considered to be below the normal. If there is observation of the following conditions; desirable species are replaced by poor species; reduced plant cover exposes bare soil surfaces; erosion accelerates; production of forage and animals decreases, and any combination of these effects occurs.

Pros and cons of different approaches of condition assessment

The above discussed approaches of condition assessment; even if they are the most popular and most used approaches, they have got some practical and theoretical limitations for their application. The agronomic and the ecological and other evaluating approaches are all dependent on the secondary succession theory.

This theory/model has many drawbacks when tried to use it as a basis of condition evaluation for arid and semi-arid rangelands. These include linear, continuum and predictive assumption of the climax or potential of the site. The model assumes that all possible condition classes could be arranged in a continuum and linear way. The achievement of any of the condition classes depends on the degree of the grazing pressure as manipulated by the manager/ rancher. Besides, drought could defer the successional tendency of the vegetation to which, by implication, the manager responds by reducing the grazing pressure.

Excellent, good, fair and poor may not have relevance with respect to management objectives. Basing range condition standards on ecological criteria does not imply suitability for a particular use. For example from a rancher point of view, bush encroachment is a poor condition. However, the same condition can be a better class for a forester. In other words, the method does not allow for a realistic evaluation of rangelands invaded by exotic species

- In some cases livestock grazing or wildlife objectives may be maximized at fair or good condition classes.
- Determining climax is very difficult. In most ecological communities all over the world, the ecological change is very great that there may not be any form of indication of the climax vegetation.

- It is also the assumption of this model that other measures such as complete removal of animals (enclosures) can also improve the condition of the vegetation towards the climax end point. However, many studies have already witnessed that up to 50 years of protection did not result in the reappearance of species that existed before the induction of heavy grazing.
- Successional pathways following removal of grazing may take a direction different from retrogression. The system may cross a threshold by heavy grazing beyond which it would be difficult to return the system to its original position in economically justifiable way. In this case a result different from that predicted by the model could be obtained.

The palatable species may be favored by removing when the beginning of the growing season coincides with their active growth phase. Simple destocking without considering this will not restore the palatable species.

5.3. Rangeland Trend

Dear learner, can you define rangeland trend by your own words?

Activity 5.4

Dear Learner; based on the information is gathered on the land use history of a given rangeland found in your locality on the relative values of plant species and communities for specific uses through discussion with administrators, pastoralists, or agro pastorals; try to state their criteria and approach of condition assessment.

however, difficulty in measurement and quantification of ecosystem changes cause arguments.

Trend is a rating of the direction of change that may be occurring on a site. The plant community and the associated components of the ecosystem may be either moving toward or away from the historic climax plant community or some other desired plant community or vegetation state. At times, it can be difficult to determine the direction of change. The kind of trend (rangeland trend or planned trend) being evaluated must be determined. This rating indicates the direction of change in the plant community on a site. It provides information necessary for the operational level of management to ensure that the direction of change will enhance the site and meet the objectives of the manager. The present plant community is a result of a sustained trend over a period of time.

Trend is an important and required part of a rangeland resource inventory and monitoring process. It is significant when planning the use, management, and treatment needed to maintain or improve the resource. The trend should be considered when making adjustments in grazing management. Repeated measurements with a year or more time interval between them can quantify trend; but with many problems, the range professional must assess trend immediately or during the first examination. In those situations, his criteria become qualitative, especially subject to uncontrollable environmental variation. It is therefore important and advisable to use less accurate indicators than repeated measurements must be used. Quite obviously, measurement of range trend and its evaluation have much in common with the study of plant succession.

Monitoring information can usually be used to exploit information about the trend in the condition of rangelands. Trend in general sense can therefore be defined as the direction of change in ecological status or resource value rating observed over time. Trend in ecological status can be described as toward or away from the potential natural community, or as not apparent. Trend in a resource value rating is usually described as up, down or not apparent. Trends in resource value ratings for several uses on the same site at a given time may be in different directions, and there is no necessary correlation between trends in resource value ratings and trend in ecological.

5.3.1. Types of rangeland trend

According to the objective and method of assessment, there are two types of rangeland trend namely; rangeland trend and planned trend.

Rangeland trend

What is rangeland trend?

Rangeland trend is defined as the direction of change in an existing plant community relative to the historic climax plant community. It can be determined as apparent trend or measured trend.

- ***Apparent trend*** is a point in time determination of the direction of change.
- ***Measured trend*** requires measurements of the trend indicators over a period of time. Rangeland trend is monitored on all rangeland ecological sites. It is described as:
    - ***Toward***: Moving towards the historic climax plant community.
    - ***Not apparent***: No change detectable.
    - ***Away from***: moving away from the historic climax plant community.

Planned trend

What is planed trend?

Planned trend is defined as the change in plant composition within an ecological site from one plant community type to another relative to management objectives and to protecting the soil, water, air, plant, and animal resources. It is described as:

- Positive: Moving towards the desired plant community or objective.
- Not apparent: Change not detectable.
- Negative: Moving away from the desired plant community or objective.

Planned trend provides feedback to the manager and grazing land specialist about how well the management plan and prescribed grazing are working on a site-by-site basis. It can provide an early opportunity to make adjustments to the grazing duration and stocking levels in the conservation plan. Planned trend is monitored on all native and naturalized grazing land plant communities. It may be determined on any ecological site where a plant community other than the historic climax plant community is the desired objective.

The ratings of range trend for any of the two types of trends are sometimes described as ‘ up-ward’ or positive, ‘ down-ward’ or negative trend and ‘ stable’ or zero trend. According to Clements’ s view of succession, upward trend corresponds to successional stages toward climax and downward trend corresponds to retrogression or away from climax. The most important technique to measure rangeland trend is to use exclosures. Enclosures separate climatic effects from those caused by grazing. For periodic monitoring of ecological changes taking place in soil improvement and natural habitat of fauna and flora, enclosures are erected in range ecological zones.

Each enclosure usually cover an area of 50*100 m. three permanent transects are usually laid out inside the fence and 3 transects of the same length are marked outside the enclosure. Transects are the beginning point marked with an aluminum cap set in a concrete pier at about 4 inches above the soil surface or using wooden pegs. In hilly areas, transects are laid out in north-south direction. The location of the marker and the transects are stem diameter at one meter height, crown diameter and height are estimated for each tree. An estimate of vegetation condition and trend are made for the immediate area of the transect. Soil surface is described with soil erosion characteristic condition and trend noted.

Activity 5.5

Dear learner; based on the criteria for assessing range condition and the finding of the Activity 4.2 above, and try to analyse the trend of rangeland on level of degradation and resource depletion.

5.3.2. Factors used to indicate rangeland trend

What factors do you consider in rangeland trend indication?

Except on a research, basis and where management of land continues on a stable basis allowing repeated measurement, range trend assessments depend upon evaluation of the general health of individual plants, the vegetation, and the soil. Health in these contexts is difficult to measure, and no completely satisfactory procedures have been found to determine range trend on the basis of one field examination. Perhaps the most useful factor is reproduction of the desirable species. Presence of young, medium-sized, and large grass plants indicates that the species is regenerating and that the stand is increasing in density presumably, then, the trend is improving.

On the other hand, the dead centers in bunch grasses, dead stubble, and lack of tillering suggest that the plants are dying and the trend is downward (the case of the *Doberaglabra* plant in the Kala rangelands in Afar). Plant parts may be shorter, narrower, and fewer than expected, also indicating downward trend. Measurements of size, number, and dead areas in plants are relatively easy, but interpretation of general health requires experience and comparison of areas that have been subjected to various grazing pressures. In developing regions, the background information for these interpretations is difficult to obtain. Determination of trend necessitates evaluation of;

- Plant establishment,
- Vigor of growth,
- Changes in plant residue,
- Directional change in botanical composition, and
- Soil surface conditions.

It is well to keep in mind that numbers and sizes of plant parts may be as much a result of a single rain as they are the result of past grazing pressure. However, vigor must be good, regardless of cause, before range condition can change. Poor condition ranges must have some plants in good vigor in order to improve. The relative importance of the trend factors described varies in accordance with differences in vegetation, soils, and climate. Evaluating any one of these factors on an ecological site may indicate whether the plant community is improving or declining. A more accurate evaluation of trend, however, can be ascertained if all or several of the factors are considered in their proper relation to each other.

Changes in plant composition

What does plant composition mean?

Native plant communities evolve within their environment and slowly change over time as environmental factors change. Major short-term changes in the plant composition, however, do not normally occur unless induced by significant disturbances. Disturbances, such as continued close grazing by livestock, severe or prolonged drought, abnormally high precipitation, exotic species invasion, or unnatural burning frequencies, can cause major changes in plant communities. If the plant community is changing as a result of prolonged grazing, the perennial species most sensitive to damage by grazing decrease.

This may lead to a relative increase in species of lower forage value or successional stages, or both.

When improved management has occurred in areas where the plant cover has been severely depleted, increases in low-quality plants may indicate improvement since these plants may be the first to respond. When disturbances that caused a decline in plant community are removed, the present plant community may react in one of several ways. It may appear to remain in a steady or static state while it moves along one of several transition pathways leading to one of several identifiable plant communities including the historic climax plant community.

Original species that have declined in amount because of past misuse will often increase over time. For this to occur, seed or vegetative parts must still be available, growing conditions be similar (e.g., soil profile, hydrologic characteristics, microclimate), and space for re-establishment must be available and must not have been displaced by other species; i.e., exotic annual and perennial grasses, forbs, shrubs, or trees. Once established, certain woody and some other long-lived perennial plants may persist and may require high-energy expenditures, such as prescribed burning, herbicide application, mechanical treatment, or other applications of supporting practices if the decision maker desires to remove them.

The invasion of plants on the site indicates a major change in the present plant community. Some invaders, particularly annuals, may flourish temporarily in favorable years, even when existing plant community is moving towards management objectives. A significant, though temporary, increase in annuals and short-lived perennials may also occur during a series of wet years even though general trend is toward objectives. Changes in plant composition from one plant community type to another generally follow a pattern. Although all changes in amounts of species on a site are not always predictable, general successional patterns for specific sites, plant species, climates, and rangeland uses often can be predicted. These successional changes in plant composition are generally not linear and vary because of localized climatic history and past use patterns.

Abundance of seedlings and young plants

How does seedling abundance indicate range trend?

Changes in a plant community depend mainly on successful reproduction of the individual species within the community. Young seedlings, plants of various ages, and tillers, rhizomes, and stolon’ s, evidence this reproduction. The extent to which any of these types of reproduction occurs varies according to the growth habits of the individual species, site characteristics, current growing conditions, and use to which the plant is subjected. In some plant communities, reproduction is often largely vegetative so the mere absence of seedlings does not always indicate a change in plant community. A significant number of seedlings and young plants of species indigenous to the site, however, usually indicates a positive trend. Variations in seedling recruitment resulting from abnormal weather patterns should be recognized.

Plant residue

What is Plant residue mean?

The extent to which plant residue accumulates depends primarily on the production level of the plant community; the amount of plant growth removed by grazing, haying, fire, insects, wind, or water; and the decomposition rate of the plant biomass on the site. In hot and humid climates, the rate of decomposition of plant residue may be so great that little or no net accumulation occurs. Conversely, in cold climates decomposition is generally slow.

When using plant residue to judge trend in plant community, careful consideration should be given to the level of accumulation that can be expected for the specific ecological site, plant species, and climate. Excessive grazing, below-normal production, recent fires, and abnormal losses caused by wind or water erosion may result in an accumulation of plant residue below that considered reasonable for the site. In the absence of these factors, progressive accumulation of plant residue generally indicates positive changes in the plant community. Residue may accumulate rapidly for some kinds of plants, especially woody species or annuals. When the amount characteristic for the historic climax plant community is exceeded, such accumulations of residue are not necessarily an indication of an improving plant community.

Plant vigor

What is Plant vigor mean?

Plant vigor is reflected primarily by the size of a plant and its parts in relation to its age and the environment in which it is growing. Many plants that form bunches or tufts when vigorous may assume a sod form if their vigor is reduced. Length of rhizomes or stolons is also a good indication of the vigor of a parent plant; these parts are usually fewer and shorter if a plant is in a weakened status. Periodic drought is common in many rangeland environments and will lower the apparent vigor and annual productivity of ecological sites while often retaining their current plant community. Cryptogams develop new growth during growing periods that adds to the total structure and biomass of the plant. When considerable amounts of live *cryptogamic* material are destroyed, several years may be required for these plants to fully replace lost tissue.

Condition of the soil surface

What does soil surface condition mean?

Unfavorable conditions of the soil surface may significantly affect trend. Compaction, splash erosion, and crusting may occur if plants or plant residue are lacking on the soil surface. Compaction and crusting impede water intake, inhibit seedling establishment and vegetation propagation, and induce higher soil surface temperature. These conditions often increase rates of water runoff and soil loss, reduce effective soil moisture, and generally result in unfavorable plant, soil, and water relationships. Improvement in the plant covers following good management is delayed if such soil conditions exist.

A rangeland with fewer and fewer desirable forage plants, increasing erosion of bare soil and increased weedy and undesirable species indicate downward trend. A rangeland with reproduction of the desirable species, young, medium sized and large plants indicate that the species is regenerating (improving trend).

Self-Assessment Questions 5.2

Direction II. Choose the correct answer from the given alternatives and write the letter of your choice on the space provided.

-------1. Health state of a given land escape and vegetation cover following the application of different management actions

a. Range condition d. Range trend

b. Range improvement
c. Range deterioration
e. Range assessment

---------2. Which condition rating on site potential of area in terms of forage to animal matched incorrectly

a. Excellent condition 90-100%
b. Fair condition 50-70%
c. Very poor condition <25%
d. Good condition 60-90%
e. Poor condition 25-50%

Direction III: Match the words/phrases listed under the column " B" with their appropriate terms listed under the column " A" on the space provided

A	B
-----1. Attributes	a. 2W/(a+b)
-----2. Sample Variance	b. range trend
-----3. Sample	c. positive, not apparent
-----4. Percent similarity	d. characteristics of population
-----5. Direction of change	e. proportion of population
	f. $(X - X^\wedge) / (n - 1)$

IV. Short answers

1. What are two basic approaches in range condition rating?

a. ……………………………………………………………….

b. ……………………………………………………………..

5.4. Determining (Measuring) Biomass

Estimates or actual measurements of the production or yield of the grass layer are often required for purposes of evaluating the productivity of the grass layer and for calculating the grazing capacity for grazer herbivore species. Biomass is a commonly measured vegetation attribute that refers to the weight of plant material within a given area. Other general terms, such as 'yield' or 'production', are sometimes used interchangeably with biomass. Units to express biomass should be selected so that actual plant weight is easy to visualize, such as kg/ha or g/m^2 according to vegetation abundance and objectives of the inventory or monitoring program. Biomass data may be collected on an individual species basis, as species groups, or as a total weight for the vegetation. Species composition may also be calculated as the contribution (percent by weight) that each species makes to the total biomass. Biomass is an attribute that is time consuming and laborious to collect, but easy to interpret. Biomass is regarded as an important indicator of ecological and management processes in the vegetation.

- ***Ecological indicators* -** biomass is a measure of species dominance within the vegetation, since the demand for resources by each species is largely determined by plant size. Biomass also reflects the amount of energy stored in the vegetation, which can indicate the potential productivity at the site.

- ***Management indicators* -** biomass provides a variety of indicators for rangeland management. For example, it is a valuable tool to assess range condition, the carrying capacity of an area, or to make short-term stocking rate adjustments according to the amount of forage reserves and residual biomass. Other terminology related to biomass includes;

- ***Browse*:** it is the biomass from trees, shrubs, and woody vines that is available for consumption by livestock and wildlife. It includes leaves and small twigs, but excludes branches and trunks that would not be consumed. Browse is also generally restricted to species or parts of plants deemed palatable to animals, but this issue is confused by the subjective nature of palatability and alternative forage sources.

- ***Productivity***: it refers to the biomass produced at a site over a given period of time. Most vegetation assessments are actually limited to estimating net aboveground primary productivity, by ignoring contributions from consumers (livestock, wildlife, microbial populations, etc.). It also circumvents complicated measurements to account for plant respiration and belowground contributions. Productivity is used to indicate energy and nutrient dynamics in the vegetation. Comparisons of productivity from different areas provide an indication of site potential, but in most rangeland areas, moisture availability has greatest effect on year-to-year fluctuations in productivity. Sampling date is a critical consideration to obtain reliable estimates of productivity.

- ***Residual Biomass***: residual biomass refers to the weight of vegetation remaining after grazing is concluded. Residual biomass has important rangeland management ramifications because it acts as the source of future plant growth and as soil protection. For these reasons, residual biomass is a useful goal upon which to interpret utilization and base decisions concerning stocking rates. Residual biomass can be directly sampled using any of the methods to determine biomass.

- ***Standing crop*****:** is the total aboveground plant biomass on the site at a particular point in time. Standing crop includes current year's production together with that produced in previous years. Standing crop at a site fluctuates within and among years, depending on seasonal conditions and utilization by grazing animals. One common objective of rangeland monitoring is to try to determine peak standing crop or the greatest level of biomass at the site during the year. In environments with clearly defined seasons, peak standing crop coincides with the end of the growing season, such as in spring season or early dry season in east African rangelands and early fall following the monsoon rainfall in southern Arizona. Information regarding the peak standing crop is taken as an indicator of yearly productivity and used to estimate carrying capacity.

- ***Current year’ s growth***: Current year's growth is the aboveground biomass produced during the previous 12 months. In environments with distinctive seasons, current year's growth is best approximated at the end of the summer growing season. *For grasses, the biomass with a grayish hue is rejected as older than the current year's growth*. For evergreen woody species, supple twigs and associated leaves are usually included as recent growth. Obviously, these judgments are subjective, and ground rules that present clear guidelines on the separation of old growth are required to maintain consistency among different observers. In situations where climatic conditions promote year-long plant production, or where utilization by grazing animals has already removed some biomass, current year's growth is difficult to determine from data collected at a single time.

5.4.1. Special considerations in measuring biomass

What do you consider in measuring biomass?

The following critical issues should be considered when designing sampling protocols to determine biomass.

- ***Biomass Property:*** Biomass is a general term that encompasses many special attributes. For example, inventory or monitoring programs focusing on grazing applications may only want to estimate available forage, whereas those addressing ecological perspectives may need to estimate productivity. In some instances, the objectives of the sampling program could be tied to current year's production, while at other times an estimate of dead or alive biomass is most relevant. The decision of exactly what to measure depends on sampling objectives and availability of resources, and should be clearly supported by ground rules.

- ***Dry Matter Content*:** Biomass is usually determined on a dry matter basis, which is the weight of plant material after the moisture within the plant material has been extracted. Moisture content varies; among species, during the year, according to the stage of growth, growth forms (herbaceous, woody, succulent), soil moisture levels, and atmospheric humidity. Standardizing weights on a dry matter basis facilitates comparisons of biomass among sites and over time by eliminating these other confounding factors. Dry matter content is determined by drying a sample in an oven, usually at 60°C, until a constant weight is obtained. Since moisture levels differ among species, samples of individual species may have to be dried separately. Methods to determine biomass usually demand a subjective correction for moisture content in the field during data collection. With training and experience, observers are mostly able to adequately correct green plant weight to a dry matter basis. However, some situations including the presence of succulents (e.g., *Opuntia spp*.), fresh growth, or quadrats containing mixtures of woody and herbaceous plants always present a challenge to accurately estimate for dry matter content.

- ***Sampling Date***: Due to the constraints of time and labor, it is unusual to conduct biomass sampling at a site more frequently than once a year. However, total standing crop fluctuates during the year due to; physical decomposition, utilization by domestic and wild herbivores, and consumption by insects. Furthermore, species composition and species biomass also vary within the year according to the contrasting growth requirements of warm season and cool season plants, making it difficult to obtain a realistic determination of productivity from a single sampling period. Therefore, the time of sampling for a yearly measurement must consider the biomass property to sample, and growth dynamics of key species at the site.

- ***Separation of Dead and Live Material***: The actual components of aboveground biomass that are considered during sampling depend upon the biomass property to sample. Biomass categories that may be identified include: Living, actively growing material, recent dead - current year's growth, which is no longer actively growing, Old dead - produced during previous growing seasons, and Litter - detached plant material lying on the soil surface. The accuracy and precision of data, whether acquired by harvesting to determine biomass or estimation approaches to determine biomass, are prejudiced by the observer's ability to identify current year's growth, and the level of care devoted to conscientiously and consistently separating components during sampling.

Other ground rules may be needed to describe the treatment of litter, flowers, fruit, etc. The following are terms used to describe different components of standing crop

- ***Biomass***: Total live plant material above and below ground
- ***Phytomass***: The above ground standing live and dead (attached) plant material
- ***Necromass***: The above ground dead plant material not attached to the plant.

5.4.2. Techniques of biomass determination

What techniques do you consider in determining biomass?

The methods utilized for calculating herbage yields can be grouped into categories as follows;

- **Agronomic methods** in which the yield of herbage is determined by; *Direct methods*: which involve techniques that weigh or estimate the actual biomass of plants in quadrats. Cutting and weighing samples from known areas and at appropriate intervals of time, and Weight estimates based on visual observations. *Indirect methods* are based on developing a relationship between plant weight and an easier-to-measure attribute such as plant height, rainfall, or cover, use of electronic equipment' s, photography. The most suitable approach to determine biomass in an inventory or monitoring program depends on; the type of vegetation, skills of observers, sample size requirements, and time and budgetary constraints.

- **Animal production methods**: are methods that measure the animal productivity rather that the plant yield. In this method the common attributes measure, are animal production and the quantity of herbage consumed, and digested by the grazing animal. This method involves highly sophisticated techniques like esophageal fistulation of an animal. This technique is therefore, too esoteric to be discussed at this level.

Direct methods to determine biomass

In the direct method of determination of biomass, biomass sampling is usually conducted using a sample unit with defined boundaries, for example, some type of quadrat, so that biomass can be expressed relative to a known area. With these techniques, the quadrats are directly evaluated to assess biomass. This type of sampling is best suited to areas dominated by herbaceous or shorter shrub species that can be accommodated in relatively small quadrats. The most common direct methods of determining biomass are:

- Harvesting to Determine Biomass
- Estimation Approaches to Determine Biomass
- The cage method for determining herbage yield and consumption

Harvesting to determine biomass

Direct harvesting of vegetation from quadrats of a known size is the most straightforward approach to determine biomass at a site. A wide variety of mechanized clippers, lawn mowers, vacuum collectors, etc have been invented in attempts to making the task less onerous, but plant material is usually painstakingly gathered using clippers. Data are usually collected from many quadrats located along a transect so that the transect is the sample unit. Therefore, data must be collected from several transects to determine the precision of the sample, for statistical analysis of biomass data.

When samples are carefully collected, harvesting is regarded as the most accurate method to determine biomass. However, clear ground rules are needed to ensure consistency between observers. Ground rules are guidelines developed to minimize the subjectivity of sampling. Ground rules should be developed before fieldwork commences, and should be clearly included in the sampling protocol. Ground rules are especially important to maintain sampling accuracy and precision when a number of different people involved in data collection, or when data is collected over a number of years. Some important aspects that require clear ground rules are;

- ***Boundary decisions:*** these are especially important because sampling should incorporate quadrat volume, leading to potential errors in judgment regarding its vertical boundaries.
- ***Clipping height:*** clipping at ground level is recommended for best repeatability, but clipping at a grazed-height gives a more pertinent measure of forage biomass. Clipping height is most sensitive when a greater proportion of the plant biomass occurs close to the ground such as in herbs or prostrate shrub species.
- ***Separation of dead and live material:*** depending on the biomass property to sample, biomass is removed from most samples before weighing.
- ***Species groups:*** identification and separation of species, whether occurring in the field or in the laboratory, needs to be conscientiously and consistently performed between observers. In harvesting technique to determine biomass, because each quadrat represents only a very small area of the entire site, sample variance is generally high, and many quadrats must be clipped to obtain a sample size that adequately represents the amount of biomass on the site. Therefore, clipping is very time consuming and not practical for inventory or monitoring purposes over extensive areas. Likewise, the method is destructive and not suited to permanent quadrats. Other disadvantages of direct harvest method include; it is labor intensive and time consuming, specialized apparatus like a dry oven and an accurate scale is required, and it is a destructive technique that results in the removal of plant material. In these situations, estimation approaches to determine biomass or indirect methods to determine biomass are often adopted.

Cage method for determining herbage yield and consumption

Agronomic measurement of herbage yield on permanently grazed pastures is usually accomplished by harvesting areas protected by cages. Cages are randomly distributed throughout the pasture and the herbage within the cage clipped from time to time during the year. A comparable nearby area is harvested outside the cage at the same time. This allows the determination of herbage consumed by the so-called difference or cage difference method. It is assumed that consumption equals the herbage yield from the caged area minus the yield of the outside area. The cage is moved to another area after clipping to avoid the modified environmental effects within the cage. There are however, some criticisms of this technique wind velocity and transpiration are lower and humidity higher in the caged area than outside. This may lead to an increased yield of 10 per cent or more. Furthermore, soil compaction and trampling of grazing animals may reduce herbage yields as compared to the ungrazed (caged) area.

A system of calculation herbage yields that accounted for plant growth during the grazing period was proposed. It is observed in many experiments that yield as determined by the cage method tends to overestimate forage consumption of the grazing animal. A system was proposed that made allowance for differences in growth of pasture plants in protected and unprotected areas. The following formula was employed to make adjustment for growth:

$$\text{Amount of herbage consumed} = (c - f \frac{(\log d - \log f)}{(\log c - \log f)}$$

Where

- c is the quantify of herbage present at the beginning of grazing;
- d is the quantity within the caged area at the end of grazing and
- f is the uneaten quantity outside the caged area at the end of grazing.

This formula was designed for long rotational grazing periods in the temperate zone, but would have application to seasonal grazing or sampling periods in the tropics. The total herbage produced per hectare could be calculated by knowing the amount on offer at the beginning of the grazing period, that consumed by grazing animals and that uneaten at the end of the grazing period. The size of cages has varied with different trials, and includes dimensions of 0.91 x 0.91m, 1.2 x 1.2 and 1.21 x 2.73m with a height of 0.45 or 0.60m. They are usually constructed of heavy wire or small metal rods. Considerable difficulty is encountered in maintaining the position of the cage, even though pegged down with metal or wooden stakes. Grazing animals frequently push against them in an effort to obtain the lush herbage inside.

Information about the number of cages to use per hectare is limited. A study in North Carolina showed that 12-13 per hectare of yields or botanical composition accurately and more than 24 would be needed to obtain reliable results. In studying temperate zone pastures, Davis and Bell (1958) used 25 cages/ha of 1.2 x 1.2m in continuously grazed pastures and Naylor (Carter, 1962) recommended 127 and 32 cages/ha of the same size to obtain coefficients of variation of 10 and 20 percent, respectively. These large numbers involve considerably more expense and labor than most investigators wish to invest and usually they use from 12 to 15 cages/ha.

Practical works

- Quantify the rangeland vegetation attributes (like: cover, density, frequency, dominance and etc.)
- Assess the condition of your nearby rangelands based on vegetation availability
- Observe the rangeland trend
- Plant sampling and taking to the herbarium and involving in identification
- Measure the productivity of a specific rangeland based on biomass measurement

Activity 5.1

Dear learner, please go to field, specify area of rangeland, and try to assess rangeland condition, rangeland trend and biomass of the pasture?

Summary

Rangeland condition can also be assessed using multiple condition parameters such as grass species composition, herbaceous basal cover, number of grass seedlings, grass age distribution, soil physical condition and woody density and cover. Rangeland trend is the direction of the change over time in reference of climax. Biomass is the weight of organic matter per unit area. It is the measure of the whole plant parts above the soil surface. It is usually done based on unit area of measurement, which is square centimeter or square meter. Direct harvesting is considered the most reliable method of determining above ground biomass.

Self-Assessment Question 5.2

Direction I. Write " True" if the statement is correct and " False" if it is incorrect on the space provided.

----------1. The direction of the change for rangelands called rangeland condition.

----------2. If palatable and infant, young, old plants found in the rangelands then we can say that the rangeland is in progressive state.

--------3. By measuring the biomass of plants in rangelands, we can estimate the productivity of the specific pastureland.

Further Readings

To supplement on this unit you can refer:

Harold F. Heady R. Dennis Child. (1994). Rangeland ecology and management. United States of America by West view Press, 5500 Central Avenue, Boulder, Colorado 80301-2877, and in the United Kingdom.

L.‘ tMannetje, R.M. Jones (Ed). (2000). Field and Laboratory Methods for Grassland and Animal Production Research. Department of Plant Sciences, Wageningen University, Wageningen, the Netherlands and CSIRO, Tropical Agriculture, St Lucia, Australia.

UNIT 6

BUSH ENCROACHMENT AND INVASION IN ETHIOPIAN RANGELANDS

INTRODUCTION

Dear learner, in this unit you will deal with concept of weeds and bushes, different types of bushes and bush encroachment. How pastoralists and agro-pastoralists bush control techniques in rangelands, the ecological and economic effect of bush encroachment, and its management and possible cause of bush encroachment.

What is bush and bush encroachment in rangeland?

Objectives

At the end of this unit, you should be able to:

- Define terminologies bush, weed and bush encroachment
- Understand and apply rangeland bush encroachment control mechanisms
- List different impacts of rangeland bush encroachment
- Identify cost effective and preferable bush encroachment control mechanisms

6.1. The concept of bush encroachment and invasion

Rangeland productivity is threatened by land degradation mostly characterized by soil erosion and invasion by alien plant species. Plant invasion is considered a threat to rangelands because of the suppression of productivity of herbaceous plant species due to the increase of bush cover. Bush encroachment refers to the spread of plant species into an area where previously it did not occur. Invasion on the other hand, refers to the introduction and spread of an exotic plant species into an area where previously did not occur. Thus, bush encroachment could occur even with indigenous species and it is more defined by plant density than species themselves. Invasion on other hand, although it includes plant density, it focuses on the exoticism of species in question and therefore, more species specific.

Increase in woody cover in savanna and grassland ecosystem has been called woody plant profiration, vegetation thickening, bush encroachment, shrub encroachment, woody weed invasion or regrowth and is widespread in arid or semiarid savanna and grasslands in North and South America, Africa, South East Asia and Australia (Houghton *et al.*, 2000). Bush encroachment can be defined as " the invasion and/or thickening of aggressive undesired woody species resulting in an imbalance of the grass - bush ratio, a decrease in biodiversity, and a decrease in carrying capacity" (Lechmere-Oertel *et al.*, 2005). Changes in natural vegetation dominated by the grass layer leading to dominance by woody cover, and increase in unpalatable forbs are considered as a threat to range conditions in Borana rangeland (Coppock, 1994).

Moreover, encroachment focuses on the woodiness of the species, invasion is not limited to woody species but includes the alien herbaceous species; thus, there are grasses that are classified as invaders. Other than, suppression of herbaceous by encroaching species, the higher bush density in rangelands reduces land accessibility by livestock and subsequently affects the utilization of rangelands. Furthermore, due to competition for light, water and nutrients between native and invading species, the grazing capacity of rangelands declines and plant biodiversity becomes compromised. Therefore, invasions are considered one of the largest threats to the ecosystems of the earth, and the services that they provide to humanity. These species are characterized by rapid spread and they displace the native vegetation and disrupt important ecosystem processes and leads to serious environmental impacts.

There are a number of sources for invading species, however, in natural ecosystems such as rangelands some alien tree species used in commercial forestry and agroforestry cause major problems as invaders. The effects of bush encroachment such as an increase in woody vegetation density and cover and reduction of biomass production in rangelands have been widely reported. Invader species can be found in different ecosystems, however, in Ethiopia, they are a significant environmental problem in terrestrial and freshwater ecosystems. Bush encroachment and invasion on rangeland therefore, have negative effects on rangeland biological and economic value. Thus, bush encroachment and invasion results in rangeland degradation, which leads to declination of rangeland functional capacity and subsequently on the increased food insecurity and poverty.

Introduction of woody plant cover in grasslands and their increase in savanna ecosystems is an indication of rangeland degradation. The earlier assertion is aligned with the definition of rangeland degradation, which states the reduction or loss of biological and economic productivity arising from inappropriate land use practices. Therefore, if bush encroachment in rangeland is left unchecked, it progresses within grassland ecosystems until a closed canopy woodland thicket occurs, which influences vegetation species composition and in turn threaten the sustainability of livestock production, wildlife habitat and grassland birds. Thus, the increase in vegetation cover of encroaching species can significantly reduce grass productivity through competition, shading and allelopathic effects.

6.2. Effects of bush encroachment and invasion on rangelands

Do you know the consequence of bush encroachment on rangelands?

6.2.1. Ecological impact

What are the ecological impacts of bush encroachment?

It is important to establish an understanding of ecological effects of bush encroachment on rangeland ecosystems prior to embarking on any bush encroachment intervention. Thus, the degree of invasion should be quantified to help justify the need for, and determine the type of intervention. It is fundamental to characterize invasion and these could be in terms of identification of invading species (morphology, phenology, anatomy, physiology, mode of spread), plant population density, spatial localization (along the landscape, vegetation types, soil type, water distribution), seasonal distribution, their impact on the ecosystem stability (soil cover and biodiversity) and productivity (primary and secondary).

The global reviews of plant invasions suggest that the most damaging species transform ecosystems by using excessive amounts of resources notably, water, light, and oxygen. Invading species achieve these by adding resources such as nitrogen, promoting or suppressing fire, stabilizing sand movement, and/or promoting erosion, accumulating litter and accumulating or redistributing salt. Such changes potentially alter the flow, availability, or quality of nutrient resources in biogeochemical cycles. They further modify tropic resources within the food web and alter physical resources such as living space or habitat, sediment, light and water. In addition, invaders are most likely to have substantial effects on ecosystems by rapidly changing the disturbance regime. Thus, dense stands of alien trees and shrubs in rangelands can rapidly reduce abundance and diversity of native plants.

Different invading species have similar or specific effects on rangeland ecosystem dynamics. According to Coppock (1994), cited from roughly 15 species of woody plants are thought to be encroachers in the Borana plateau. Of these, *Acacia drepanolobium* and *A. brevispica* are the most important. Forty percent of the Borana rangelands were estimated to be bush encroached (Oba, 1998). According to Beruk and Tafesse (2000), with reference to the Afar region indicated that an increase of *Acacia seyal, A. mellifera*, *A. Senegal*. *Prosopis juliflora* are also very serious problems. These impacts include reduction of surface stream flow, loss of biodiversity, increase in fire hazard, and increases in soil erosion, destabilization of riverbanks, and loss of recreational opportunities, aesthetic costs, and nitrogen pollution and subsequently loss of grazing potential.

An increase in the height and biomass of vegetation increase the rainfall interception and transpiration, and decreases stream flow. Alien trees and shrubs increase above ground biomass and evapotranspiration and thereby decrease both surface water runoff and ground water recharge. The increased biomass and evapotranspiration rates associated with invasive alien plants arise because of their greater height, root depth and senescence, compared to the native species that they replace. Invasive plants may influence native ecosystems by exerting resource competition on native plants to altering fire dynamics. Thus, the increased biomass that accompanies plant invasions also result in more intense fires due to an accumulation of fuel loads. On other hand, the dense stands of invasive trees hamper access for fire management, which makes it difficult for fire control in rangelands.

The increase in fire intensity due to accumulation of sufficient fuel load subsequently damages vegetation and soil, which in turn leads to excessive soil erosion due to soil water repellency caused by fire. Therefore, it suffices to indicate that the alien invasive plants reduce the functional capacity of rangeland ecosystems such as support for livestock and wildlife. This is among others due to competition between invasive plants and grasses that are important for grazing. This competition leads to reduction on performance of a number of ecosystem functions such as grass cover, which subsequently contributes to loss of grazing potential. There is also a significant loss of biodiversity due to competition, resulting from the displacement of species-rich indigenous plant communities by single species stands, and disruption of important ecosystem processes.

6.2.2. Economic impacts

How does bush encroachment causes economic loss?

Rangelands contribute to the economy of Southern Africa in a number of ways. They provide agricultural commodities that can be valued in the market such as wool, meat, milk etc. These are the major source of forage for grazing animal, which in turn influence animal production. Rangelands further provide benefits that are not directly related to the agricultural sector, such as wildlife habitat, however, have an impact on the economy through activities that make use of them. Increases in the density of woody plants worldwide are a major threat to livestock production, and rangeland biodiversity.

Invasive species pose problems for managers of rangelands because they reduce the land' s usefulness for grazing activities. In addition, they interfere with other non-agricultural functions that rangelands provide, such as acreage of wildlife habitat and watershed quality. Therefore, in order to realize the impact of invasion on rangelands, it is important to understand the total economic loss that invasive plant infestations create on the economy in relation to both its agricultural and non-agricultural products of the ecosystems.

Economic impact of invasive species could be defined as the product of a species' range, abundance and per capita. Although the invasive plants have an ecological implication, they also have some economic implications; these could be either positive or negative. It has significant negative impacts on water resources, biodiversity, and the stability and integrity of riparian ecosystems. These two features, a commercial value on the one hand, and an invasive, damaging ability on the other, give rise to a classic conflict of interests, where the benefits accrue to a number of people, while the society at large bears the external costs. Furthermore, there are larger reductions of water resulting from the presence and densities of invasive plants.

6.3. Management of rangelands bush encroachment and invasion

Why range management is for bush encroachment and invasion?

6.3.1. Bush encroachment control

How you control bush encroachment in a rangeland?

Bush encroachment forms dense infestation that rapidly deplete soil moisture, preventing the establishment of other species. As it displaces native vegetation, it reduces wildlife habitat and ecosystem diversity and suppresses production of nutritious, palatable forage for wildlife and livestock, which leads to a reduction in grazing and wildlife carrying capacity. Soil and water conservation benefits of the rangelands decline; watershed quality declines in areas where the weeds have advanced. Bush encroachment is considered a threat to forage production, which is the feed for the grazing livestock.

The threat to the pastoral economy by bush encroachment and invasion is often the main reason for the control of bush encroachment. Bush encroachment control is a disturbance that reduces the threat of bush encroachment by disrupting the invasive woody plant community structure through transformation of biotic environments and habitat conditions in which colonization of the disturbed microhabitat takes place. Bush control methods shift the rangeland vegetation from dominance by woody vegetation to dominance by herbaceous vegetation. This control of the bush is aimed at creating suitable habitat for grazers. Thus, forage production of herbaceous vegetation increases with reduction of woody species.

The principle of bush encroachment control is based on the ability of the control method to shift the competition between desired and undesired species. Encroaching species have the higher competitive ability over the native species, which is why they colonize. They build up this competitive advantage by modifying the environment in such a way that growing conditions will suit their needs through a number of ways. These include release of chemical substances that suppresses germination and growth of their competitors (allelopathy) and modification of soil fertility in the case of Acacias through higher nitrogen inputs, which in turn favors their growth.

Encroaching species impose competition for light and through shading and subsequently growth for native species becomes negatively affected. There is also a competition for soil moisture and soil nutrient; in this manner, most of the invasive plants win because of their deeper root systems. Other invasive species produce large numbers of seeds, which normally are dispersed faster, have a shorter dormant time before germination, and colonize. Invasive plants use one or a combination of these mechanisms for survival. Therefore, bush encroachment control reduces the ability of invasive plants to exhibit these survival mechanisms.

The use of selective herbicides is aimed at reducing the competitive ability of invasive species through killing them and, in that, species that are not affected by this herbicide gain an advantage. Mechanical methods such as hand clearing targets unwanted plants and create a competitive space for desired plants, thus, without this clearing the invasive species are more competitive. Use of fire to control invasive woody plants is justified by the fact that when woody plants are burned they do not recover or they take a longer time to recover which gives the herbaceous species time to grow with minimal or no competition. In the biological control method, use of herbivores such as goats to selectively-browse on the encroaching species or use of invertebrates that feed on the seed of invading species also reduces the competition against native plants.

6.3.2. Bush encroachment management methods

What is bush and bush encroachment management?

Rangeland management practices

What are rangeland practices for bush and bush encroachment?

Grazing management entails management of livestock and vegetation resources. The main livestock decisions made by farmers both in communal areas are concerned with livestock type, number and seasonal pattern of movement. Commercial and communal livestock farming are generally regarded as the rangeland management systems and they are distinct in grazing management practices. Thus, communal grazing areas generally characterized by continuous grazing, which is perceived by most of the scientists to be the root cause of the often-reported land degradation in this system. These would be done in rotation to give vegetation in grazed areas time to recover such that the rested areas can be grazed again.

Understanding the dynamics of bush encroachment in relation to rangeland management systems over a broad range of environments is essential for sustainable management of rangeland ecosystems. Although rangelands are complex ecosystems varying at multiple scales in time and space, most management usually intends to maintain or enhance livestock production by reducing plant community variability. This usually accomplished by promoting spatially uniform dominance of a few productive forage species. Although it is believed that improper grazing practices leading to overgrazing are responsible for bush encroachment, it is not attributed to heavy grazing alone but is strongly influenced by seasonality, which is a characteristic of arid and semi-arid environments.

In combination with seasonality, the ban on fire and exclusion of browsing animals such as goats and camels may also contribute to the invasion of bush encroachment. Rangeland management practices, particularly fire suppression and overgrazing, have been reported to increase the proportion of some native species, which can reduce overall forage quality or quantity. Effective rangeland management requires sound ecological data about the land being managed however; obtaining such data is not sufficient to ensure the implementation of restoration practices by land users. Thus, rational decisions at the farm or community, regional and national levels, depend on researchers providing not only ecologically sound but also economical, effective alternatives for land use.

Chemical or Herbicides

How chemicals for bush and bush encroachment in rangeland?

Chemical control methods are usually expensive to apply and should be considered only under specific circumstances. Thus, their nature are suited primarily to the initial thinning of bush at high density, where there is poor fuel load to support fire, where trees are above the browse line, where the bush is unacceptable to animals and where the herbicide is intended to selectively kill a specific plant. However, herbicides can sometimes be used in follow up operations such as after fire where there is a need for pre-emergence herbicide application intended to kill the seedlings of a target plant in soil.

Herbicides have been applied extensively on rangelands to reduce forbs that were considered undesirable, which have been assumed to lead to an increase in grass production and ultimately to an improvement in livestock performance. Herbicides are the primary method of weed control in most rangeland systems. Herbicides vary in their chemical properties, that make them vary more with their mode of action under different climatic and soil conditions, and they further vary in their methods of application and their effect on the ecosystems.

There are two broad groups of herbicides used in rangelands. The first type is composed of the herbicides that are applied on the soil surface and are absorbed by the roots; these are the herbicides that are based on *tebuthiuron, ethidimuron or bromacil* as their active ingredient. The other group of herbicides is sprayed onto the plant and absorbed directly by the foliage and other aboveground plant parts have *picloram* as the active ingredient. The second group may also have ingredients such as 2, 4-D and 2, 4, 5-T.

Mechanical methods

What are mechanical bush encroachment method?

Mechanical control options include the physical felling or uprooting of plants often in combination with burning. Mechanical control is labor-intensive and thus expensive to use in extensive and dense infestations or in remote or rugged areas.

Rangeland burning

How bush and bush encroachment controlled through rangeland burning?

Fire is regarded as the natural factor of the southern African environment; it is thought to have occurred from time immemorial, and therefore, it is part of ecosystems. Rangeland burning is an important ecological management tool in the maintenance and productivity of grasslands. The burning in rangelands is practiced for a number of reasons; one of these reasons is to control bush encroachment. To use fire effectively in rangelands, it is important to understand how it behaves and to develop an insight into the way in which various factors influence such behavior. Fire intensity is one of the important components of the fire regime. Fire regime can be defined as season and frequency of burning together with type and intensity of fire.

The effect of fire on natural ecosystems arises from a response of living organisms to the release of heat energy generated by the combustion of plant material. Thus, it is an oxidation process involving a chain reaction during which the solar energy originally converted into carbon compounds by photosynthesis is released as heat during fire. The effect of fire on vegetation, therefore, depends upon the amount of heat energy, and upon the rate and vertical level at which it is released. The rate of fire is measured in terms of time taken to burn a given unit area, it is affected by a number of factors including fuel load and moisture. The vertical level at which heat energy is released during fire determines the height at which plants will be burned. The plant (tree) height is one of the important factors determining the effect of fire on bushes, thus, as the bushes become taller, the fire intensity required to cause a top kill of the stems and braches become critical. Thus, as the plant height increases, the bushes become resistant to fire.

Manual/Physical cutting/Clearing

How does manual method for bush encroachment in rangeland?

Manual and mechanical techniques such as pulling, cutting and otherwise damaging plants, are used to control some invasive plants, particularly if the population is relatively small. These techniques can be extremely specific, and therefore, minimizing damage to desirable plants. However, manual techniques are generally labor and time intensive. These techniques are effective if the treatments are administered several times to prevent the weed from reestablishing. In the process, laborers and machines may severely trample vegetation and disturb the soil thus, providing prime conditions for reinvasion by the same or other invasive species.

Bush encroachment reduces grass growth in rangeland as discussed in the previous sections and that results in reduced biomass production, which subsequently affects forage production. The approach that has been used to address the negative impacts of invading species has been predominantly physical by clearing alien plants. Clearing of the bush in encroached areas results in an increased dry matter yield and basal cover of herbaceous vegetation, which are good indicators for rangeland health if the functional characteristic of such an ecosystem is forage production.

Furthermore, species richness of herbaceous plants and relative abundance of few of the species among the initial population that is intolerant of bush cover increase with tree cutting. As a result, the reduction of bush cover can restore herbaceous plant productivity and biodiversity in rangelands. However, there are herbaceous species that have a positive relationship with certain trees and removal of such trees negatively leads to reduction of herbaceous species. This decline indicates the shifts in the microenvironment due to the removal of ecologically important trees, thus exposing sensitive herbaceous species to increased light intensity.

Biological control of encroaching and invasive species

What is biological bush and bush encroachment control in a rangeland?

Biological control has been defined as the use of living organisms to reduce the vigor, reproductive capacity or effects of weeds. Biological control (bio-control) involves the deliberate introduction of invertebrates or diseases, and is aimed at reducing the effects of ecological release. Bio-control is aimed at arriving at a situation where the plant is returned to the status of a non-invasive naturalized alien, that is an alien plant that is able to survive, and even reproduce but does not invade aggressively in its new habitat.

Biological control could be regarded as the only sustainable mechanism to prevent the spread of invasive alien species in the long term.

Bio-control is potentially very cost-effective, and environmentally kindly. Despite concerns to the contrary, the modern practice of using carefully screened and host-specific bio-control agents is safe and " host shifts" have not occurred in the over 350 recorded cases where weed bio-control agents have been used worldwide. Even though there are some inconsistencies in terms of when bio-control practices were established, at least there is an agreement in that bio-control agents have been released against 47 weed species. Although physical methods of controlling the alien species are mostly used, biological control using species-specific invertebrates and pathogens from plant' s country of origin is also a control option; however, there has been a considerable resistance to its use.

The seed-feeding weevil is one of the agents that have been released against *Acacia mearnsii* in areas where the wattle is not grown commercially. Nevertheless, plant-attacking agents could potentially be used; however, these compared with seed attacking agents such as weevils could kill the target plant and therefore, impact severely on commercial prospects. The impact of biological control agents on controlling invasive species vary with species controlled, biological agents introduced, mode of operation of agents and many other factors.

6.3.3. Integrated bush encroachment and invasion management

What are integrated bush and bush encroachment control methods?

Integrated weed control usually involves a combination of at least three of the primary elements of control; mechanical, chemical and biological. Integrated weed management (IWM) could be defined as a system for the planning and implementation of programs, using an interdisciplinary approach, to select a method for controlling undesirable plant species or group of species using all available methods. These methods generally vary between preventative and restorative domains. The success of preventative encroachment measures mostly depends on the understanding of the causes of encroachment and identification of barriers for natural recovery.

Restorative measures depend on range ecosystem structure and functional characteristics to be restored. Integrated bush encroachment control is a multidisciplinary, ecological approach to managing unwanted plant species in rangeland ecosystems. However, it is important to note that the decision to use a certain method to control the bush encroachment is informed by the cost of using that method against the benefit. Bush encroachment control methods are management systems that might have varied policy implications for bush control. Therefore, understanding the potential role of different bush-encroachment control method for promoting herbaceous species composition requires recognition of the objectives of resource users and policymakers.

The failure to recognize the long-term intended ecosystem status could lead to a subsequent failure to achieve bush encroachment control objectives and that could further lead to land use practice and policy controversy. Thus, the resource users are interested in livestock production through increased plant productivity, while the goal of policymakers is environmental preservation. Thus, the land use practice imperatives and policy directives should be harmonized to permit both forage production and biodiversity conservation functional characteristics of the ecosystem to thrive.

Activity 6.1

Dear learner; take a short trip to the rangeland found in nearby your locality, discuss in detail about the types of bushes with the local pastoralists and look into detail based on the information gathered about the major control techniques they use.

6.4. Encroacher Bushes of Concern in Ethiopian Rangelands

What are major bush encroacher in Ethiopian rangeland?

Besides, the invading of bushes and shrubs, plants of similar importance are some undesirable herbs and annual shrubs. Because of many interacting factors, particularly drought and overgrazing, other undesirable plants are invading most of Ethiopian rangelands. Those invader plants of concern are *Perthineum*, *Calotropis procera*, *Tribulis terristeris*, *Solanum* species, *Sida ovata*, *Cryptostegia grandiflora* (Halimero), Brucae antidysenterica (Hatew), *Datura stramineum* (Ate-faris), *Amaranchus* and *Acharantus Aspara* (Dergu). These plants are generally indicators of range rangeland deterioration and must be controlled. The following are pictures of some of the invader plants taken from different localities in Ethiopia.

Fig. 4.1. Parthinium a threat in Ethiopian rangelands (Dr. Abule E)

Fig. 4.2. *C. procera* an invader newly constructed roads (Dr. Abule E)

Calotropis procera favours open habitats with little competition. It is mostly found in overgrazed pastures, rangelands or land disturbed by road making. Other common habitats are beachfront dunes, roadsides and disturbed urban lots. Competition with tall weeds, brush and especially grass weakens existing plants, and being overtopped and shaded by trees soon eliminates them. Sheep, goats and camels will eat the leaves of *Calotropis procera* during droughts but consumption is low. If the leaves are chopped and mixed with other feed, consumption greatly increases with no ill effects. Although it is not possible to eliminate existing stands through management without ceasing grazing

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Activity 6.2

Dear learner; take a short trip to the rangeland which found in nearby your locality, look in detail the main bush encroachers and based on the information gathered on the land use history of a given rangeland discus history of their origin and coverage.

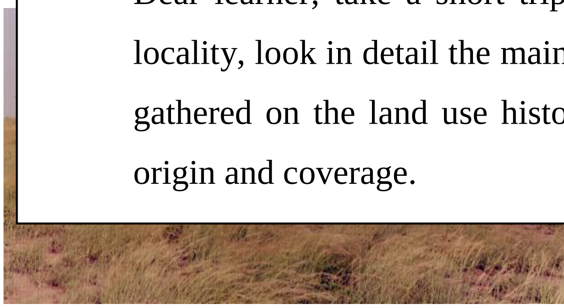

Fig 6.3. Solanum species, aggressive competitors in grass lands (Dr. Abule)

Fig 6.4. Tribulis an undesirable invader of denuded rangeland (Dr. Abule)

The main impact of *C. grandiflora* is the loss of grazing land. The existing control techniques for this plant globally are chemical, mechanical, biological and fire. Integrated management is most effective (chemical, mechanical and biological control, fire and grazing management) and prevention is the cheapest form of controlling the plant. Fire is valuable part of the integrated control of the plant because it kills surface seeds, seedlings and adult plants, yet is relatively inexpensive. It is also important to raise public awareness of the problems. Research finding in Australia showed that when the density of this plant is less than 1000/ha moderately hot fires using grasses as fuel will give good kill rates. If the density is between 1000-2000 plants/ha, hot fires are required. If it is greater than 2000/ha the better option are mechanical and chemical controls.

6.5. Possible causes of bush encroachment

What are the possible causes for bush encroachment?

Factors causing bush encroachments are poorly understood (Ward, 2005). According to Sheuyange *et al*., (2005) the causes of bush encroachments are elaborated upon against the background of two important models:

- ***Walter' s Two-layer Model***, which maintains that, if the grass layer is over utilized, it loses its competitive advantage and can no longer use water and nutrients effectively. This results in a higher water and infiltration rate into the subsoil. Such a scenario will benefit trees and bushes and allow them to dominate.

- ***The State-and-Transition Model***, which recognizes the dynamic nature of savanna ecosystems. Savannas are event-driven where rainfall and its variability plays a more important role in vegetation growth (and composition) than the intensity of grazing. It implies, therefore, that bush encroachment is not a permanent phenomenon and a savanna could be changed to its grass-dominated state by favorable management or environmental conditions. Sheuyange et al., (2005) further explain that, the major factors determining the functioning and dynamics of savannas are the following:

- **Primary determinants** such as **rainfall**, **soils** and **nutrients**, are functions of specific geographical region and are to a certain extent beyond the pastoralist' s control. Rainfall, together with soil moisture balance, has an overwhelming effect on vegetation structure, composition and productivity. Rather than annual increase in bush numbers, the general view is that woody plants establish in large numbers during certain years, and at varying intervals. Prolonged denudation of soils caused by droughts and grazing, followed by above-average rainfall years with frequent rainfall events, favor mass tree recruitment.

- **Secondary determinants**: These act within the constraints imposed by primary determinants. They can often be directly modified by management. The exclusion of occasional hot veld fires, the replacement of most of the indigenous browsers by livestock, injudicious stocking rates, poor rangeland management practices, and artificial water points are regarded as the major causes of bush encroachment. There have been attempts to explain the causes of bush encroachment. One of them is based on the evidence that increasing levels of global CO_2 favor the growth of trees and bushes, which are C3 species rather than grasses that are mainly C4 species (Knapp, 1993; cited in Moustakas, 2006).

Self-Assessment Questions 6.1

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rangeland ecosystems prior to embarking on any bush encroachment intervention

Activity 6.3

Dear learner; take a short trip to the rangeland found in nearby your locality, and try to look in the main bush encroachers and based on informations gathered, state the possible causes of encroachment.

------3. Invasive species pose problems for managers of rangelands because they reduce the land' s usefulness for grazing activities.

Direction II. Choose the correct answer from the given alternatives and write the letter of your choice on the space provided.

-----1. Which statement refers the characteristics of bush encroachment in a rangeland?

a. the spread of plant species into area where previously did not occur
b. introduction of exotic plant species into an area where previously did not occur
c. indigenous species and it is more defined by density than species themselves
d. Increase in woody cover in savanna and grassland ecosystem
e. All

------2. It is may be the consequence of bush encroachment in a rangeland

a. of rangeland degradation
b. the reduction or loss of biological and economic productivity
c. influences species composition, threaten sustainability of livestock production
d. reduce grass productivity through competition, shading and allelopathic effect
e. all

------3. Which of the plants are generally indicators of range rangeland deterioration

a. *Perthineum*, and *Calotropis procera*,
b. *Tribulis terristeris*,
c. *Solanum* species,
d. *Sida ovata*, and *Cryptostegia grandiflora*
e. All

------4. The main and the existing control techniques for weeds and bush plant globally

a. chemical,
b. mechanical,
c. biological and
d. fire
e. all

------5. One of the following is not the cause of bush encroachment in a given rangeland.

a. loses grass layer and its competitive advantage

b. reduction or longer use of water and nutrients

c. higher water and infiltration rate into the subsoil

d. increasing levels of global CO_2

e. all

Summary

Bush encroachment and invasion could be attributed to a number of factors, which by their nature vary with species and locality. These factors cannot easily be ranked according to the strength of causation and/or according to the intensity of their effect on rangeland ecosystems. Factors that are blamed for bush encroachment include improper grazing practices, suppression of fire, drought, rainfall intensity and distribution and climate change. The temporal and spatial distribution of bush encroachment follows a sigmoid distribution curve. Although some invasive species are abundant, they are localized in certain areas whilst, on the other hand, certain species are widely distributed but low in copiousness.

There are the three major methodologies, which fall under the chemical, mechanical/physical and biological and depend on a number of factors within economic and ecological impressions. Bush encroachment occurrences are caused by different factors, at different landscapes, by different plant species and with different effects. Therefore, the invasion control methods should consider this variation for success in treatments. Thus, there are areas and invasion situations where a single method can be used; however, a combination of different methods could be used in simultaneous or alternative or subsequence approaches.

Integrated plant invasion management should have four major stages of execution; these are comprised of diagnostic, preventative, control and management. The diagnostic stage should include identification and characterization of invasion, determination of the degree of invasion, analysis of the ecological and economic impact of invasion, determination of the need for intervention, and setting objectives for intervention. The control stage should include selection of invasion control approach or combinations. Management stage includes post-treatment management, monitoring, evaluation and ecosystems' performance appraisal. Preventative stage is more practical on the areas that are not yet invaded; at this stage management of areas that are not yet encroached is central.

Assessment and characterization of vulnerable areas for invasion will be important in developing an encroachment prevention plan. It is also important to assess plant invasion predisposing factors; however, these may vary with species and localities. In the diagnostic stage, determination of the level of spread is very fundamental, and serve as the background for selection of the bush encroachment control and management methods. The stage of bush encroachment spread can be divided into four broad phases viz, entry phase, adaptation and establishment phase, an exponential growth phase and dominance phase. It is in the exponential growth stage of weeds spread that integrated control programme find a logical relevance.

Prevention, and early detection and eradication, are more appropriate for the first two stages, while options may be severely limited once weed populations reach the final stage of total ecosystem domination. Although there is massive literature on the plant invasion and bush encroachment, there is still a significant need for further research in establishing fundamental characteristics of bush encroachment phenomenon in integrated plant invasion and encroachment management. This will lead in systematic characterization of bush encroachment, subsequently that will lead to development of more practical and radical yet scientific bush encroachment control, and management practices in rangelands.

Further Reading

Ayana Angassa .2005. The Ecological Impact of Bush Encroachment on the Yield of Grasses in Borana Rangeland Ecosystem. *Africa Journal Ecology, 43(1): 14-20.*

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UNIT 7

PARTICIPATORY RANGELAND REHABILITATION AND IMPROVEMENT MECHANISMS

INTRODUCTION

Dear learner, in this unit you will deal with participatory rangeland rehabilitation and improvement techniques. The productivity of Ethiopian rangelands is reducing from time to time; and there are different systems to rehabilitate those degraded rangelands. Those techniques should be applied in a participatory approach. Indigenous and scientific methods of rangeland rehabilitation should be integrated together for better result.

Objectives

At the end of this unit, you should be able to:

- Define terminologies
- Understand and apply rangeland rehabilitation mechanisms
- List different rehabilitation techniques
- Identify cost effective and preferable rangeland rehabilitation techniques
- List the type, advantages and disadvantages of fire

7.1. Definitions of Basic Terminologies

- ***Rehabilitation*:** returns the damaged land to a predefined condition that is desirable and ecologically sound.
- ***Restoration*:** often implies exact duplication of pre-damaged conditions.
- ***Reclamation*:** concept implies the return of ecosystem conditions similar to or better than prior to the disturbance

7.2. General consideration in rangeland rehabilitation techniques

Why rangelands should be rehabilitated?

Once adequate information is gathered on rangeland condition/trend and confirmed that the rangeland needs further improvement, then the next issue becomes how to rehabilitate this. The techniques used to rehabilitate and improve range vegetation vary based on several factors such as environmental, climatic, socio-cultural, economic, and technology. These techniques could broadly be divided as:

- ***Extensive*:** involving low risk, low cost, low inputs and low production. Example the use of fire and grazing management such as light grazing, no grazing and to some extent the specialized systems.
- ***Intensive*:** involving high risks, high cost, high inputs and high production. Example fertilization, reseeding, mechanical removal of unwanted plants, chemical removal.

Proper water development and distribution is considered as intermediate between these two practices. They are used to directly manipulate species composition and/or structure of the vegetation as well as rehabilitation of already denuded rangelands. Rangelands are easy to destroy but difficult to restore and because of low economic returns, relatively low productivity, fertility, low rainfall and site specificity i.e. it is impossible to improve the whole rangeland/ only those with potential are candidates for improvement improving rangelands is generally a costly procedure.

Because of high cost and the low and slow returns involved, before the application of any rehabilitation technique or practice, certain points should be bear in mind. These include resource status assessment and site evaluation, identifying and understanding the root causes of the problem and controlling mechanisms (after correcting the problem what measures can be taken), prediction and evaluation of benefits and risks (impact assessment) on other components of the system (that could result from its application), adaptation to site and use socially and technically.

7.2.1. Resource assessment

In rangeland management, this gives a general overview of the resources within a given site that will be used in planning. This assessment includes description of the physical and biological attributes or characteristics of the site with its historical and current uses. This assessment enables the range manager to determine the nature and condition of resources to be improved, identify areas of priority concern, identify the relative importance of each area in relation to objectives, and develop plan of action. The assessment results are given in map (<1:100,000 scale) and reports.

To correct the problem that initiated rehabilitation, all possible causes must be explored and possible mechanisms of preventing them from happening again should be devised from the outset. Before costly methods are applied to promote range improvement, existing degradation forces should be identified and countered. These causes generally are the result of human activities, overexploitation by man and his animals. Examples are the deforestation of woodlands, further encroachment of agriculture in to the marginal and fragile rangelands, drought, followed by improper grazing on the already constrained range resources. This heavy use pressure could lead to annual, resulting in a sharp reduction of late dry season carrying capacity of rangelands.

7.2.2. Range improvement programs

Programs are classified into four categories depending on the objectives.

- ***Rehabilitation***: of degraded rangelands (bush encroachment, etc.) for forage and wildlife habitat improvement.
- ***Modification*****:** of range practices such as grazing management, multiple uses, forest management to maintain or improve productivity of ecosystem.
- ***Enhancement*****:** of the existing forage (feed) and habitats through maintenance, burning, fertilization, soil conservation, or reseeding/planting to increase the density of existing species.
- ***Manipulation*****:** of animal numbers and distribution using grazing systems, herding, fencing, etc.

Benefits

A properly planned range improvement programs generally increase the potential production of the ecosystem:

- Increase forage quality and quantity
- Increase livestock and wildlife production and diversity
- Control undesirable plants
- Reduce wildfire hazards
- Improve overall economy of the operation

Basic principles/considerations for planning and implementing habitat manipulation practices include:

- ***Justification*** of practices based on biological needs through intensive investigation

- ***Evaluation*** of the proposed practices for their effects on other natural resources and land uses
- ***The practice/project*** should be economically practical
- ***Objectives*** should specify whether the goals are to maintain, improve, or completely alter the existing habitat character.
- Improvement must stimulate natural conditions by perpetuating native flora and fauna
- The project should be evaluated at intervals to determine if the objectives have been achieved. The ultimate goals include:
- Increased livestock and wildlife production
- Economic welfare of the people

Degraded rangeland producing low biomass below the potential, low milk and meat production, high incidence of poverty, high vulnerability of pastoral communities, increase migration trend of Pastoral communities and unemployment, decreased biodiversity of rangeland flora & fauna, un-sustained rangeland ecosystem services and increased events of extreme climate.

7.3. Rangeland Rehabilitation/ Improvement Methods

How does rangeland rehabilitated?

Rangeland improvement or rehabilitation programs will be achieved through:

- Propagation of new plants
- Release of existing plants by eliminating undesirable competing species
- Protection of existing habitat from such factors as overgrazing

The most commonly and frequently used improvement options for the rangelands are: seeding/reseeding, development of water points which is done together with grazing systems improvement), control of bush encroachment using fire, mechanical means (using heavy machinery), chemically and biologically and promotion of different physical soil and water conservation measure (all these followed by proper grazing management and fertilization).

7.3.1. Propagation of new plants species (seeding/reseeding)

Propagation is direct planting of desirable seeds or seedlings. Native/exotic seeds or seedlings can be propagated. Re-vegetation is the critical key to the renovation of many rangelands of relatively more humid areas. A cover of vegetation supplies dependable feed for animals keeps the soil and water in place and decreases evaporation and runoff by increasing percolation and soil storage of rainfall. It shelters the soil from scouring and provides a barrier that slows runoff. This re-vegetation is possible both by natural processes (its effect is not extensive) as seed dispersal by wind, birds, and other animals, or carried by seasonal streams and floodwaters; planting by human activity, deliberate or unplanned also promotes new growth. Planned re-vegetation has two components:

- Direct sowing by seeding or planting trees, shrubs, and grasses using a variety of techniques.
- Management interventions that serve to strengthen the role of natural re-vegetation processes. Example: protection improvement in grazing systems (e.g. deferred rest etc).

Deciding to seed

Before the actual seeding or reseeding can begin, several points concerning the need for reseeding, charges in management the seeding site, cost, expected returns and risks must be considered. Before undertaking seeding, the following questions should be answered.

Is seeding absolutely needed?

Rangeland can be rehabilitated more positively and at lower cost by better livestock distribution, better systems of grazing. Only where the desirable native perennial forage plants are almost completely killed is seeding essential. Seeding practice is not substitute for a good management and seeding should be taken as a last resort. As a rule, if (5-10%) of the present vegetation is desirable, stand improvement should come through management that fosters increase of desirable species within a time frame relevant for management (through natural processes).

Is the climate favorable?

Successful seeding generally speaking is infrequent in areas receiving less than 250 mm rainfall. For legumes, the rainfall required is by far higher. With an increase in rainfall, amount perennial species are preferable to annuals.

Is the habitat suitable? (Habitat evaluation for suitability)

This entails soil characteristics, slope, exposure, etc. in case seeding equipment and machinery are used. A rule of thumb in selecting sites for seeding and other range improvement methods is to start with the best habitats and proceed to the less productive once.

Are proven methods available for the site?

Where not available, projects should not be undertaken until satisfactory procedures have been developed.

Can proven methods be used?

On many sites, the procedures are known for the general type but cannot be applied because excessive rocks, steep slope, or other factors prevent use of the type of equipment or procedure needed.

Can the area be given proper grazing management after grazing?

- Seeding should not be started until proper grazing management can be assured.
- Application of appropriate measures after seeding is also a prerequisite
- Predicting costs and returns

Plants for reseeding

Where the rainfall is relatively high, perennial grasses are preferred to annual grasses, which are most suitable for low rainfall areas with short duration of the growing season. Grasses intercept rainfall and conserve soil better due to:

- Numerous tillers
- Abundant and shallow root systems that bind soil particles and prevent soil erosion

Grasses have good grazing value especially during the growing season. When not too old they provide nutritiously well balanced herbage with a CP of 8-12%. The grasses that have given best results in East Africa are all local grass species. Best results might be expected from retaining/reseeding to their former habitats. However, unavailability of seed source may be a problem.

Grasses

The grass species that are commonly used in reseeding program include:

***Cenchrus ciliaris* (Buffel grass)**

- Is a persistent tufted perennial grass, drought tolerant, well liked by livestock, has reasonably good seed production, in moisten areas its seeds are attacked by smut and seeding rate is 2.5-3 kg/ha.

***Chloris gayana* (Rhodes grass)**

- It is a creeping perennial grass, widely grown and several cultivars are known, established relatively easily but is not persistent, moderately drought tolerant, unsuitable for areas with annual rainfall below 700mm, should be sown shallow and seeding rate should be 0.5kg/ha

Chloris roxburghiana

- It is a tufted perennial grass with characteristically flat shoot bases, have been used with success in Kenya and Tanzania and seeding rate is 0.1-0.2 kg/ha

***Cynoden dactylon, Cynoden aethiopicus, Cynoden nlemfuensis (*Star grass)**

- Creeping perennial grass, usually established from roots, particularly useful for planting in watercourses and for alluvial plains and seeding rate is 0.4-0.5 kg/ha

Erogrostis superba

- It is a tufted perennial grass, used widely in the reseeding of moderately dry areas, mostly with success, seeds can be easily harvested and seeding rate is 10 kg/ha

Enteropogon macrostachyus

- it is a tufted perennial grass with large seeds, widely used in the reseeding of rocky slopes or bush land and seeding rate is 5.5 kg/ha
- The choice of seeds however, depends on objectives such as erosion control, forage at critical times, rehabilitation concerns, habitat suitability for the species, etc.

Sowing rates

This depends on the seed size, purity, germination, and stand density needed to be achieved. A rule of thumb for sowing rate is enough seed for ten established plants/m^2 of land. A safety factor of ten necessitates 100 pure live seeds (PLS) of each species/m^2. An approximate guide for determining seeding rate is given by seeding rate kg/ha.

Grasses mixture for reseeding

Although a single grass can be sown, mixtures species can also be performed. To balance the nutrient content of the pasture mixing of different grass species is preferable. Example (1): mixture (in kg/ha) for alluvial plains with 900 mm of rainfall distributed in a single season

- To reseed the pasture it is better to mix *10 Cenchrus ciliaris, 5 Chloris gayana, ½ Cynodon dactylon* and *1 Panicum coloratum*
- Example (2): mixture (in kg/ha) for loose sandy soil with 500 mm of rainfall distributed in two seasons
- *10 Cenchrus ciliaris, 1/4 Chloris roxburghiana, 1/4 perennial Dactyloctenium, 1/4 Sporobolus ioclados* and *2 Chloris virgata.*

Sources of seeds for grasses

- Seeds of grasses for reseeding are often unavailable commercially
- Only *Cenchrus ciliaris* and Rhodes grasses are usually available
- Supply of *C. cilaris* is often inadequate. Therefore, most seeds are collected from wild stands, multiplication centers and research centers.

Forbs/legumes

- Provide livestock with protein, grasses benefit from legume – grass mixture, legumes have poor seed habits and are difficult to establish and maintain and limited seed availability.

Browse species

- Increase quality and quantity of feed and cover types for livestock and wildlife, lack of seeds sources commercially, lacking seeding and management practices.
- Became problem sp.
- Local species are promising

Establishment and management

Procedures for establishing improved grasslands

- Attempt in each planting, only the area that finances and resources will allow to be don thoroughly
- Consider all possible hazards, such as weeds, competition from native grasses, dry spells, fire and pests and prepare for them as soon as possible
- Aim at a fine, firm, weed free seedbed
- Apply adequate fertilizer if necessary
- Inoculate legume seed if necessary
- Sow sufficient, good fresh seed of the recommended species for the area intended
- Sow accurately
- Sow into a moist seedbed when follow up rains are reasonably assured
- Try as far as possible to cover the seed
- Graze carefully after establishment

Methods of reseeding pastures

- Sod seeding directly into heavily grazed sward and applying phosphates
- Establishment in the ashes after burn
- Establishment on a proper seed bed needs mechanization, fertilizer, (very costly)
- Seeding (aerial or ground)- can be broadcasted or drilled
- Use of vegetative material (pieces of stems)

- Use of a nurse crop (*Sorghum bicolor*) as a nurse crop over *Chloris gayana*)

Planting grass seeds

Native grass seeding is more challenging than introduced grasses, but the rewards of establishing a native stand are worth the effort. Your successful planting will be very hardy and, if properly grazed, will last a long time. Properly managing your land can be a real challenge; but it can also be a very rewarding experience.

How to Plant?

Grasses must be planted in a firm, weed-free seedbed, primarily because success depends upon good soil-to-seed contact. Loose soil dries out quickly at the surface compared to firm soil, and native grass seed is planted only 1/4 to 1/2 in deep. Most grasses should be planted with a grass drill, but broadcasting can also be used. Using a grass drill cuts the amount of seed you need for an area by half, since this method of planting is more efficient. In most cases, a grass seedling needs little or no fertilizer during establishment. However, on disturbed sites such as areas around a new house, water lines, trenching, etc., soil amendments may be required to maintain the vigor of the grasses. In these areas, soil testing is recommended if grasses are having a difficult time getting established.

When to Plant?

Recommended seeding dates are during the early rainy season when there is enough moisture in the soil.

Cover Crop Seeding

Seeding native grasses in a suitable cover crop is almost a must. A suitable cover crop decreases evaporation to retain soil moisture and keeps soil temperatures lower because of shading. It protects young grass seedlings from strong winds, collects snow during winter and minimizes the weed problem. The cover crop should be planted in the spring, allowing for hay cutting in the fall and leaving 6" to 8" of stubble. Grass is seeded in to this stubble in the fall. Recommended cover crops are forage sorghum, long-season, forage millet, etc.

What to expect in the first Year?

Most growers of native grasses are convinced they have a failure the first year. Most of the time they actually have a good stand. Native grasses grow down, not up, during the establishment year. The top growth normally amounts to a narrow, straight leaf until late summer. These seedlings can be hard to see, even for the experienced grower. Be patient. Do not graze for at least the first growing season.

Weed control

Weeds are the greatest cause of poor grass stands because they challenge the small seedlings in two ways:

- They take away necessary water and nutrients
- They shade and smother the young plants

Weeds need to be controlled, chemically or with tillage, prior to seeding. We can help you with specific recommendations. Mowing or shredding weeds the first year is important to prevent the seedlings being choked or smothered. All mowing operations should be done to a six-inch height. After the grass plants are established and have adequate size and leaf growth, a light chemical may be applied, if needed. Check with us for recommendations. When applying chemicals, read the directions or contact the chemical representative.

Grazing management

All desired grasses decrease in numbers with continuous grazing, overgrazing or abuse. Undesirable plants will invade immediately. Each grass plant has its growth and grazing characteristics. Proper management practices should be used to maximize the use of each grass. Most range plants provide quality forage and are eaten by some class of livestock during the year. In an overgrazed pasture, 45 to 70 percent of the rainfall is lost to runoff. In a properly grazed pasture, only 10 percent or less is lost to runoff. Proper grazing use allows the land to be grazed at an intensity that maintains enough cover to protect the soil, while maintaining or improving the quantity and quality of the desired vegetation. A rule of thumb for proper grazing use is to "take half and leave half" of the available forage during the growing season. Livestock can graze a plant down to half its weight, which is generally about two-thirds of the mature height, without detrimental effects to the plant.

Fundamental requirements for success of a reseeding program include:

- An appreciation of the ecological potential of the area concerned
- Grasses suitable for reseeding purposes and sufficient seed of adequate quality
- The integration of a reseeding program into an overall land management policy embracing grazing control and bush control where necessary
- Some form of seed bed preparation and a degree of seed protection in keeping with site requirements
- A period of complete rest from grazing after seeding
- Reasonable rains during the establishment seasons

7.3.2. Control of unwanted plants (bush control)

Grasslands overall the world have evolved with fire. However, in East Africa, bush encroachment is a serious problem. Except in areas of very low rainfall or locally where soil water relations exclude trees and shrubs, the natural succession is believed to head towards woody vegetation. The reasons are mainly due to overgrazing and fire ban. For instance, Borena rangelands are troubled by invasion of *Acacia drepanolobium*, and *Acacia brevispica*.

In Borena rangelands where greater than 70000 ha land is reported to be bush infested. Another example is in the Shiket (Aba’ ala) area where *Tarchonanthus Camphoratus*, *Solanum incanum*, Aloe, Prosopis and Euphorbia species and Accacia are alarmingly infesting the rangelands. Bush encroachment is not only limited to communal rangelands; most ranches are also suffering from bush encroachment. Bush encroachment reduces the amount of grass on offer through competition there by reducing the carrying capacity for livestock. The primary purposes of bush control are**:**

- To increase forage production by reducing competition for available water, nutrients and light
- Decrease many woody species that are thorny or thicket forming that makes grasses inaccessible to livestock
- For reasons of controlling pests (e.g. tsetse)
- Reduce the accumulation of litter which prevents growth

Unwanted plants controlling methods include**:**

- Using fire
- Mechanical control
- Chemical control
- Biological control

The use of fire for controlling bush encroachment

Dear learner, how can we use fire as rangeland management tool?

The use of fire as a cheap bush controlling management tool is one of the controversial subjects in rangeland management. This controversy arises because of over generalization (professional biasness) of its effects without describing the intensity and frequency of its occurrences. Besides, there are contrasting views among the range managers, foresters and environmentalists on the use of prescribed fire on rangelands. Despite these controversial issues about the use of fire on rangelands from animal production point of view, the advantage of burning as a method of bush control is the low capital outlay involved. These includes the loss of grazing after burning for recovery, construction and maintenance of firebreaks (fire lines), and the labor (fire crews) needed to ensure that sweeping fire is put under control. Perhaps, the most important advantage of fire as a tool is its replacement of herbicide to control undesirable plants. Cost of mechanical control has increased beyond practical usefulness. The fire is a natural environmental factor now looked up on little disfavor.

Types of fire occurring in rangelands include:

- ***Wildfires***: uncontrolled fires caused by either lightening or carelessness. It occurs usually in dry season in areas where burning has been excluded for many years. These fires are damaging the ecology.
- ***Intentional fires:*** location and time of burning have been determined. Little or no attempt to confine fire. Common among pastoralists to search for green and pest free pasture during nomadic movements.
- ***Prescribed (Controlled) fires***: systematically planned burning where weather conditions, plant physiology, time and fire confinement are considered to promote greater benefits from the burn. We will discuss this type of fire throughout this lecture.

Prescribed (controlled fire)

Prescribed fire is the skillful application of fire to natural fuels under the conditions of weather, fuel moisture, topography etc, that will allow the confinement of fire to a predetermined 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 of silviculture, wildlife, grazing, hazard reduction, etc. Prescribed burning is applied in rangelands to reduce woody vegetation and litter accumulation and it is recommended under the following conditions:

- When there is good fuel load (usually 1500 kg DM/ha) and if it is dry
- Temperature should be between 28-35^{o}C
- Humidity = 25-35%
- Wind velocity = 10-20 km/ha

Objectives of use of controlled fire

The following are the reasons that rangeland managers use prescribed fire as a tool:

- Modify the composition of rangeland vegetation (example undesirable shrub species removal, reduce competition for desirable species)
- Increase livestock forage and facilitate management (sight ability)
- Increase quality of forage or avoid coarse materials.
- Reduce parasite load
- Prepare land for seeding and
- Reduce wild fire hazard

Planning for a prescribed fire

- ***Site evaluation***: the soil and vegetation must be worthy and capable of being improved; the area to be burnt should be of a size and shape that will permit burning in a day with reasonable expectation of successful burning and complete fire control.
- ***Site preparation- fire lines (firebreaks, fire lanes or control lines):*** must be prepared beforehand. These are strips of land devoid of fuel by scraping the land

using a bulldozer blade, road grader, disc power or manually. As a general guide, if a fire lane 3m in width will not permit fire control, prescribed burning should not be attempted.

Fire characteristics

Knowledge of fire behavior is essential to successful use of it in range management. As fire proceeds across a land escape, it responds to characteristics of weather and, topography and fuel. Fire continues across a land escape only with heat transfer enough to ignite new fuels, which is accomplished by heat conduction (fuels are poor conductors), convection (direct movement of hot air masses), and radiation (the rays of energy sent out from the fire and this play a major role in fire behavior). Fire behaviors, including ignition, combustion, and spread, are closely dependent upon convection and radiation. Burning in general is an oxidation reaction that requires the proper combination of heat, oxygen and fuel. Ignition will not occur until all three factors allow combustion. The balance among these elements controls variation in the rate of burning. In fire management operations, control of heat, O_2, and fuel regulate combustion.

Heat intensity, burn out time, residence time and duration are the principal ecological influences of fire on plants and animals of the rangeland. Fire intensity is the (British thermal unit) Btu per second per meter of fire front (1Btu=252 calories). Fire duration, which is burnout time, also influences fire effects on plants and animals of the rangeland. In general, effects of fire for bush control depend on three important characteristics of fire together with the structure and condition of the plant:

- ***Timing*:** physiological state of the plant and season of the year.
- ***Frequency:*** refers to how often the same patch of ground is burnt
- ***Intensity:*** relates to the temperature, the fire reaches and the duration of the temperature at a particular point. It is a product of frequency and timing of burning and climatic factors. Effectiveness of fire in bush control depends on a variety of

factors, associated with intensity of the fire and the structure and condition of the plant.

The factors that affect fire behavior and effectiveness are summarized below:

- Amount of combustible material/fuel load
- Infrequent fires allow the buildup of fuel (plant biomass).
- The greater the fuel load carried by an area the greater the intensity of fire
- Important fuel characteristics include quantity, dryness, type and distribution
    - Short, small dry grass and fine dry shrubs produce intense fire
    - Large branches and fallen logs give slow, hot fire
    - Mixture of large and small/fine material produces ideal fuel.
- A grass cover in which a large proportion of the fuel is close to the ground usually gives better results than tall grasses with little foliage at ground level. E.g. 600 ^{o}C at a height of 50 cm and 300-400 ^{o}C and >10 cm.
- Fuels have several characteristics such as volume or size, continuity, compactness (loose fuel burns quickly).

Fuels with high surface area to volume ratio dry quickly and burn rapidly. Example a sheet of paper burns more quickly than a book on the same type of fire. The amount of fuel for combustion also affects characteristics of fuel. A minimum of 1500 kg DM/ha is needed for effective burning. With a discontinuous ground cover relatively more material is required if the fire is to carry over poorly covered areas. A grass cover in which a large proportion of the fuel is closer to the ground usually gives better results (in terms of killing woody species seedlings) than does tall grass with little foliage at the ground level, (e.g. Themda burns well while Panicum often burns poorly). This dry biomass for fuel is a function of previous precipitation condition in the wet season. The higher the wet season rainfall, the more accumulation of dry biomass and the more extensive the fires will be in the following dry season. Dry season rainfall has a weak negative influence on fire.

Weather conditions

The most important climatic factors that exert an influence on a fire' s intensity include precipitation, air temperature, relative humidity, and wind velocity.

Precipitation: this is in the form of moisture in fuel and acts in three ways:

- Because of its cooling effect, because heat is used to convert water to steam, thus reducing intensity of burning. For this reason, water used to stop the fire should be directed at the fuel in front of the flame rather than on the flame itself.
- Moisture present in the air as steam or humidity reduces radiation, which retards drying of the fuel near the flame.
- Cooling reduces release of volatile and flammable oils.

Air temperature: this has a direct effect on fire behavior.

- When temperatures are high, less heat is required to rise fuel temperature to the ignition point and for continued combustion as fire spreads.
- Higher air temperature produces intense fire and rapid spread of fire since it dries quickly the combustible material.

Relative humidity: this is a measure of air dryness.

- High humidity will greatly reduce the intensity of fire.
- Other conditions being equal, humidity decreases with an increase in temperature.
- The drier the air, the drier the fuels and the more likely prescribed fires will burn out of control.
- For this reason, prescribed burning should not be attempted when the relative humidity is less than 25% and the temperature is above 24-27 ˚c.
- When the relative humidity is above 50%, even a dense stand of dry grass will not burn satisfactorily, but when it is below 20% a good burn can be obtained from a patchy cover of partially green herbage.

- Burning should not be attempted when the relative humidity is above 40% and for preference, the figure should be 30% or less.
- The use of hydrometer or psychrometer is strongly advised in deciding weather conditions are suitable for burning.

Wind speed: fuel combustibility increases with wind velocity, dries fuel ahead of fire

- Moving air brings O_2 to the flames and removes CO_2 thereby increase combustion rate.
- It also moves hot air masses ahead of the flame where radiated heat dries and preheats new fuels ahead of the fire.
- At high humidity, a steady breeze is necessary while at low relative humidity calm conditions are preferable.
- With low humidity and strong winds, fire sweeps through the area too rapidly to have maximum effect and is more likely to get out of control.
- In many parts of east Africa the best combination of low humidity, low wind speed, and high air temperature occurs during the mid to late morning period.

Topography

- Fuels on the up slop side of the flames are closer to the heat source and receive more radiant heat than do fuels on the down slope side.
- As steepness of the slope increases, rate of fire spread increases, hence chance for the fire to be out of control is high.

Methods of ignition

The usual method is to fire the perimeter of the area to be burned, starting on the downwind side and moving round to finish the up-wind side. Burning the whole area against a light wind gives a slower moving fire, which can be expected to produce more heat around the trunks or stems of woody plants. However, with a discontinuous grass cover it may be necessary to burn with the wind. The simplest is a single line of fire that is set to burn as a head fire (either with the wind or upslope) or as a backfire (against the wind or down slope). It may be set to burn slowly down hills or rapidly up hill.

Another design is ignition of the entire perimeter of the prescribed area. Normally fire is first set on the lee or uphill side to widen the firebreak before the windward or down hillside is set. As the perimeter flames burns towards the center, heat builds up and a very hot fire develops. In such a fire, the time of spread is less than that of a single line type of burn, but heat intensity increases from edge to center. Area ignition (at a number of points) is also another type of ignition where the whole area is burned at once. Firing in successive strips permits greater control with somewhat less intensive burning.

The first fire is set at A and crews move towards B1 and B2 setting fires as they go. After a sufficient firebreak is developed, crews set fire to C1 and C2 and at the same time, two other crews begin setting fires from C3 towards C1 and C2.

- Time and frequency of burning
- Infrequent burning allows the buildup of fuel 9 plant biomass
- Frequent regular fires prevent the buildup of fuel and thus reduce the intensity of fire. It reduces the damage effects of fire.
- The timing of burn affects fire intensity through the moisture content of the vegetation at the time of the burn
- High residual moisture content present in vegetation early in the dry season results into less intense/cool fires
- Lower residual moisture in the late dry season allows a much fiercer, hotter and more intense fire.
- In terms of timing mid to late dry season will produce moderate and effective burning.

Effects of fire on vegetation

Fire may be beneficial or detrimental to a plant depending on it’ s:

- Intensity, frequency, timing, physiology, and growth stage of plants.

Here the interest is the effects on desirable herbaceous vegetation and undesirable woody species.

a) Adaptation of plants to fire determines the effect of fire

(i) position of the major growing points (apical buds) affects its resistance to fire

- Young trees or seedlings whose growing points exposed from the ground level to about 2 meters above ground level are very vulnerable to damage by fire and may be killed.
- Mature trees > 2 meters in height will have their growing points mainly out of reach of the damaging effects of fire. They will survive.
- A growing point at or below ground level, is more likely to escape damage by fire. E.g. Grasses.

(ii) Bark trees with thick, corky bark are better protected from the effects of fire than trees with thin bark

(iii) Dormancy-during the dry season (when fire is more prevalent) dormancy is one of the main adaptations of perennial savanna grasses.

  - At this time nutrients are translocated into their root system under the soil surface at the end of the rains and stored until moisture levels are high to permit new growth
  - Thus, any fire occurring during this time cause little damage;
  - Fire benefits plants that undergo dormancy through the removal of dead leaves on the soil surface, which suppresses new growth.

b) Fire benefits plants through its effect on soils

- Higher temperature mobilizes phosphate and other nutrients in the soil making them available to plants
- Fire adds ash layer to the soil surface

c) Fire benefits adapted and resistant (fire loving) plants

- When fire removes highly competitive plant species, which would otherwise out compete these grasses and prevent their growth. In sum, the effect of fire result into a fire climax vegetation-grassland (savnna) ecosystem that persists solely because of frequent fire, which suppresses other forms of vegetation.

Table 7.1. Summary of effect of fire on sub-humid wooded savanna

Season of burning	Intensity of fire	Effect upon grass	Effect upon woody species
Early dry season	Low	Harmful: because nutrients have not yet been translocated to roots	Slight harm: because intensity is low
Mid to late dry season	High	Rarely harmful: at dormancy stage	Harmful: severe to very severe
Early rainy season	Low or High	Harmful: severe to moderate. Plants mobilize their stored nutrients from roots to above ground plant parts	Harmful: mid to light. No dense dry fuel for intense fire.

Source: Arizona Grazing Lands Conservation Association (AGLCA), 2004

Essentially, the proportion of nutrients stored, by the plant above determines the effect of fire on plants or below ground at the time of fire, which is why woody species are often adversely affected by fire but grasses that are dominant during the fire tend to benefit. As can be seen from the above table, the best time for burning perennial grasses is the mid to late dry season as this results in the greatest increase in productivity and palatability of the fodder grasses.

Problems of bush burning

- Frequent burning may eliminate important woody species from the area
- Poorly managed system damage range vegetation. If burning is followed by untimely or intense grazing
- Poorly managed fire can quickly get out of control and cause devastating damage to property, people, livestock and wildlife
- Lack of protective cover over the soil surface

Management incorporating use of fire

- Burning every 3rd or 4th year in a poorly managed grazing system is common recommendation.
- A rest period is needed prior burning to allow buildup of combustible material.
- A post burn rest is needed to allow grasses to recover and build food reserves before being grazed determined by herbage production and rainfall distribution.
- Precautions must be taken to prevent fire from going out of control: Boundaries or firebreaks need to be prepared (strips of land 2m wide on a flat land and 5-6m in sloppy areas). Burning should be made when people are alert (before noon), and participatory involvement by community members may enable a burn to proceed more smoothly.

Mechanical bush controlling methods

In some cases, it might become necessary to use equipment for the removal of trees and shrubs from a rangeland. This requires heavy machinery and the following account should be given:

- Effectiveness on target species and potential damage to non-target species and desirable ones
- Effect on regeneration by seed and sprouting (for species that grow under the soil)
- Erosion hazard due to cover reduction
- Site suitability and cost

There are two main approaches:

- Removal of the aerial portion of the plant only
- Removal of the entire plant

The following are the commonly practiced mechanical means of control of bush encroachment:

Simple top removal/hand slashing

- *Slashing* of all above ground woody stems by hand. It give good result if combined with burning
- Reducing canopy cover by shredding/chopping
- *Chaining*: Two connected tractors connected by a heavy cable or ship anchor chain to drag down and uproot brush stands. Re sprouting could, however, exist hence this should be accompanied by other treatments like burning or spraying.
- *Bulldozing*: Clear bush and small trees and also push debris into a place for burning
- *Halt breaker*: A heavy roller, which flattens and smashes bushes and small trees. It needs to be followed by burning and reseeding.

Chemical control

Many factors should be taken into consideration while applying chemicals to control bush encroachment.

- Method of application
- Risk of contamination to neighboring cropping lands
- Cost of chemicals
- Effect on non-targeted plants and animals
- Residual effect of chemicals

The greatest response for the above four methods of brush control is generally from areas having a high degree of competition for available moisture (i.e. in xeric than mesic areas). Economics will largely determine the eventual place of brush control practice in the overall management of rangelands. The cost and returns are not easily determined because of the diversity of treatment effects such as ease of management of livestock, grazing efficiency, aesthetics (scene), impact on surface and ground water, impact on wild life habitat, etc. all are not easily determined.

Equipment, labor cost, availability of fuel (diesel), etc all influence brush control method choice. Any method should consider benefits to livestock and other uses. Consideration of production potential and subsequent management for areas to be treated should precede actual treatment otherwise, it could be non-effective.

- Herbicides such as 2,4-D and 2,4,5-T formulations are applied as sprays or injected directly on to foliage, slashed stems, or stumps. E.g. Knapsack sprayer, or air craft
- Best result is obtained if it is obtained if it is combined with burning
- Problems-non selective, and also kill valuable plants.

Biological control

- Goats are used as a biological check for woody vegetation. But not so much effective since they select a proportion of woody species
- Plant to plant competition
- We can also introduce insect pests but it is too costly.

7.3.3. Water development

In areas where there is underutilization of range forage, the opening of new water points can lead to uniform utilization of the rangeland. However, the opening of unnecessary number of water points leads to range degradation as is witnessed in areas subject to " water development intervention" by disrupting the traditional mechanism of water use (e.g. Borena).

Water source

Water supplies in range areas may be classified as:

***Ground water*:**

- Springs, which are, flow points of a water table contained in a hill or slope (see-pages at the head of valley or a fissure in a rock).
- Shallow wells, which can be hand, dug, (greater than or equal to 1m in diameter).
- Boreholes (these are expensive but supply dependable water)

***Surface water source and harvesting structures*:**

- permanent streams and rivers that cut across the range
- Earth dams made from erodible material and weirs made from non-erodible material such as mass concrete, reinforced concrete, or masonry (cement, rock, and sand). These are cheap if designed properly. For every m^3 water, the dam needs m^3 of soil removal.
- Tanks (' Hafir' or ' Birka' or ' Horroyo'). These fit to low relief areas and involve an excavation of rectangular design in to which the runoff is guided by means of drains or ditches. As compared to earthen dams, these ones are costly.
- Sub-surface dams control the underflow of water in sandy soils. They are impervious membranes (clay or steel or concrete) set across the river valley, which stop the underflow and bring it to the surface of the body of the sand. They are constructed in sand rivers.
- Rock (roof) catchments
- Rain traps- butyl sheeting bags are used to collect water from catchments areas.

Water requirements

The water requirements of range animals vary depending on animal type and ecological conditions. The watering frequency of stock is also variable – every day, second day, third day etc. camel is exceptional. Under the conditions that cattle are watered every third day, they can drink as much a 45 lt (15 lt/animal/day). However, if the animal is watered every other day, this can reach up to 23 lt or after a long walk 30-35 lt. On average, 25 lt is the minimum requirement for cattle when planning water development schemes.

For goats and sheep, this could be applied by assuming 1 cattle ~5-7 sheep/goat. Provisions must also be made for human requirements. Where the ratio of livestock to people is high (as in the case of low lands in Ethiopia= 1.8 TLU per person, while in the highlands=0.6), the total human requirement is relatively insignificant and can be accommodated by rounding the total livestock requirement upward by 10%. In other cases, calculated provisions for humans may be needed. FAO (1967), for Somalia estimated this at 50 lt/person/day, but this is excessive unless there is a social change in the pastoral areas (e.g. settlement). In addition to human needs, wild animals that inhabit the area must also be considered. In general, the quantity of water for planning should be determined by the season of the highest utilization, the dry season.

Table 7.2. Daily water intake and frequency of drinking of animals

Animal	Daily intake (liters)	Frequency of drinking
Sheep	4-5	Once every two days
Goats	4-5	Once a day
Asses and donkeys	10-15	Once a day
Bovines	30-40	Once a day or once every two days
Camels	60-80	Once in 4 or 5 days

Source: FAO, 1998

Watering point spacing

The distance between water points should be neither too long nor short to affect animal production and rangeland condition. For example, long distance walking in search of water could affect the quality of beef. With normal terrain, a distance of 4 km from the water point is the farthest an animal should graze if a satisfactory increase in weight is to be achieved. This gives an approximate figure of one water point for 5000 ha grazing land. If the carrying capacity is 1 TLU/4ha grazing land, this water point would then need to support 1250 TLUs (5000/4). At a daily ration of 25 lt/head/day, the daily yield at the water point must thus be at least 32,000 lt, allowing for wastage and human consumption (25*1250).

The average requirement for planning purpose from this calculation is therefore 6.4 lt/ha/day (32000/5000), with a spacing not more than 8 km. An improvement in the cc of the range from four to three ha/TLU means that an extra 417 heads of stock can be carried on an area of 5000 ha grazing land. This implies an additional 10425 lt of water. This implies an adequate planning with inclusion of future herd projection and improvement in grazing system.

Issues/Challenges for rangeland rehabilitation

- Low priority at regional and national level, week community participation, communal land issues, conflict, extreme climatic events, status of rangeland ownership, non-availability of bulk seeds, and planting material, lack of trainings for rangeland managers, free grazing systems and rehabilitation cost.

Implementation Strategy

- Current status of rangelands at provincial level and priority areas
- Participatory and community based planning & implantation
- Introduction of site specific grazing systems
- Rangeland rehabilitation techniques (artificial reseeding, natural reseeding, grazing techniques, stock water etc) for various ecological zones tested and developed.
- Suitable grasses, shrubs and fodder tree species for various ecological zones identified.
- Bulk seed (> 5 tons) collected from six ecological zones for
    - Rangeland development programme
    - Capacity building of rangeland managers
    - Exploring funding for rangeland activities

Possible Impacts

- Improved rangeland and livestock productivity
- Maintain the flow of rangeland ecosystem services
- Improved pastoral communities livelihood
- Less soil erosion and more infiltration due to better vegetative cover

Activity 7.1

Dear learner, please go to field and specify area of rangeland and try to study the current status of the area, and identify, which method is applicable and finally apply the preferable rehabilitation technique?

Summary

The process of participatory rangeland rehabilitation is a series of sequential steps in which the elements are put in place to produce a participatory rangeland management agreement. Before undertaking any rehabilitation method, it is better to undertake reconnaissance survey to know the current status of the rangeland and which technique is preferable. There are different techniques for rangeland rehabilitation of which over sowing/ reseeding, controlling of unwanted plant species and developing watering points in rangelands can be mentioned and prioritized.

Self-Assessment Question 7.1

Direction I. Write " True" if the statement correct and " False" if it is incorrect on the space provided.

-----1. Rangelands are non-renewable resources.

-----2. When applying rangeland improvement methods; it is better to make it participatory/ community based.

-----3. Before undertaking any rangeland rehabilitation method, we have to know the cost effectiveness of the method.

-----4. Application of fire may affect rangeland resources.

Further Reading

A. Nefzaoui and M. El Mourid, (2008). Rangeland Improvement and Management in Arid and Semi-Arid Environments of West Asia and North Africa.

UNIT 8

PASTORALISM IN ETHIOPIA

INTRODUCTION

Dear learner, in this unit you will deal with the three " pillars" of pastoralism, conflict resolution in pastoral areas, and challenges and prospects of pastoralism. This section introduces the background of pastoralism and pastoralists; and definition of pastoral production system.

Objectives

At the end of this unit, you should be able to:

- Define terminologies
- Identify and describe the three pillars of pastoralism
- Recognize the role of social institutions on pastoral conflict resolution
- Identify the causes for conflict in pastoral areas
- List the challenges and prospects of pastoralism in Ethiopia

8.1. Defining pastoralism

Dear learner, please define the word pastoralism?

There are several definitions of pastoralism. One of the more recent definitions of pastoralism is given in the policy for the development of Arid and Semi-arid lands (ASALs) adopted by the government of Kenya in January 2012. This definition is particularly interesting because it characterizes pastoralism as a production and social system that takes advantage of the unstable and unpredictable environmental conditions that are characteristics of the dry lands. The term refers to both an economic activity and a cultural identity, but the latter does not necessarily imply the former.

As an economic activity, pastoralism is an animal production system, which takes advantage of the characteristic instability of rangeland environment, where key resources such as nutrients and water for livestock become available in short-lived and largely unpredictable concentrations. Crucial aspects of pastoralist specialization are:

- The interaction of people, animals and the environment, particularly strategic mobility of livestock and selective feeding; and
- The development of flexible resource management systems, particularly communal land management institutions and nonexclusive entitlements to water resources.

Pastoralism is a production system, closely linked with cultural identity that relies on raising livestock on pastures that may be commonly, or privately managed and accessed through agreements based on negotiation, reciprocity and competition. Livestock are social, cultural and spiritual assets, as well as economic assets, providing food and income for the family within and between generations. Livestock management strategies in a pastoralism system include herd mobility and diversification, with a high proportion of female livestock. Typically, pastoralism (as opposed to other livestock production systems) derives economic benefits from lands not suited to crop cultivation, and is dependent upon periodic access to more productive pastures during regular dry seasons or drought.

8.1.1. Who are pastoralists?

Pastoralists are people who depend largely on livestock for their food and income; livestock are used for both subsistence and marketing and pastoralists also look to livestock to define their cultural identity. Pastoralists are men and women, young and old. All members of the family are involved in livestock production and marketing as well as other livelihood activities and maintaining the health and safety of the family.

Pastoralists in East Africa live in very different environments: wet, cold highlands; dry, hot lowlands; swampy wetlands or along riverine forests; and get their water from different sources. By our definition, however, all these environments share a common characteristic: unpredictable and highly variable access to pasture and water within and between years. Pastoralists raise different species and breeds of livestock: cattle, camels, goats, sheep, donkeys, etc. They are responsible for feeding and watering these animals, providing veterinary care, and marketing both livestock and their products. Pastoralists combine livestock production with other activities like agriculture, trade, firewood, non-timber forest products, etc. Many pastoralists live in marginal areas geographically, close to national borders.

Pastoralism is dynamic and pastoralists are constantly changing - responding to change in the social, economic, political and physical environment. Pastoralists in Ethiopia share many common features, including their reliance on livestock and livestock products, a cultural identity associated with livestock, and expertise in livestock rearing in arid rangelands. They also share common problems of land alienation, poverty, environmental degradation and conflict. For these reasons, they are often "lumped together" as a homogenous group. In fact, pastoral systems in Ethiopia are highly diverse, complex and dynamic. Within Ethiopia, it is possible to name more than 20 different ethnic groups that are pastoralists. Some pastoral groups in Ethiopia are Afar, Somali, Borana, Hamer, Dassenech, Nyangatom, Mursi, Guji, Bodi, Gere, Kereyu, Omoro-Bole, Oromo-Harar, Nuer, Gebra, Agnuwak, Tsemay, Bena, Arbore, Surma, Murle, Male, Birale.

8.1.2. The changing faces of pastoralism in Ethiopia

Pastoralism in Ethiopia is not static, or unchanging. Pastoralism is dynamic and constantly responding to change in the social, economic, political and physical environment. Pastoral cultures are also “ modernizing" and adapting to the forces of change around them. Some of these forces include:

- Education
- Global trade and monetization of the economy
- Technology such as mobile phones
- Increasing urbanization
- Increasing involvement by NGOs, the private sector.

Key characteristics common to pastoral systems in Ethiopia

- Families depend on livestock for a significant proportion of their food and income.
- Many pastoralists cultivate crops and carry out other economic activities to meet their subsistence needs.
- Livestock are raised for a mix of subsistence (particularly milk) and market needs (e.g. livestock sales to buy food, to pay taxes, etc.).
- Livestock herds are composed mainly of indigenous breeds.
- Livestock represent more than just economic assets. They are social, cultural and spiritual assets too. They define and provide social identity and security.
- Livestock are largely dependent on rain fed pastures for their diets including crop residues in some systems.
- Pastoralism depends on the work and expertise of all family members, usually divided by gender and age.

- Key livestock management strategies include: herd mobility, raising several species of animals (diversification), active management of age structure and sex ratio, herd splitting, and maintenance of a high proportion of female livestock.
- Pastoral resources are managed through a mix of common property and private regimes where access to pastures and water are negotiated and dependent on reciprocal arrangements.
- Pastoralism is characterized by adaptation and evolution to constraints of climate, economic, political change and opportunities facing them.
- Pastoralism is characterized by its ability to realize economic benefits from environments characterized by high uncertainty and variability.

Pastoral resources in rangelands, particularly the more highly productive areas essential for the dry season survival, continues to be converted to other uses: to agriculture, private ranches, and game ranches, to national parks and other protected areas, to bush encroachment as a result of insecurity or exclusion, to irrigation (often leading to the loss of critical dry season reserves and access to water).

8.2. Pastoralism as a system – the three Pillars

Dear learner, what does a system?

A system is a unified whole of regularly interacting and interdependent components or units. Pastoralism is a system by which families, living in areas characterized by high levels of variability and unpredictability in rainfall, raise livestock as a primary source of livelihood and cultural identity. Pastoralism is a production system with three distinct components that interact with each other:

- The family and other wider social institutions;

- The natural resources; and
- The herd

Within the system, rules and strategies help to manage the risks that are a defining characteristic of pastoralism: environmental risks associated with the variable and unpredictable environment where pastoralism takes place; and risks associated with markets, disease, policy change and insecurity.

Livestock provide the key cultural, social, and economic identity of pastoralism, but increasingly pastoralists are engaged in other forms of livelihood activities. Pastoralists are also farmers, lawyers and soldiers, security watchmen, artists and artisans. Livestock management recognizes that pastoralism is a broader livelihood system in which pastoral families derive livelihoods from a range of economic activities. The pastoral system is composed of three components or pillars that are interdependent and work together, according to a set of rules: natural resources, the herd, and the family and wider social and economic institutions. These pillars are common to all pastoral systems in Ethiopia and represent the essential resources needed to practice pastoralism.

Other resources such as veterinary drugs or supplementary animal feeds such as molasses or cotton seed cake, may support or impact one or more of the pillars. In the above model, these other resources exist within the broader context of market forces, service provision and policies that impact on the three pillars. Many pastoralists do not have easy access to veterinary drugs, education, and markets, but even without these, they can still raise livestock and support their livelihoods. Similarly, the importance of " Land" lies in the resources that it provides water, forage and grazing, timber, etc. for people, for animal production as well as other livelihood systems. Good policies are essential to provide an " enabling" environment to let pastoralism flourish. In other words, policy issues and markets are the contexts in which the systems operate.

- ***Natural resources:*** Livestock need to eat and then they need to drink before needing to eat again. Water, trees, pastures, water, salt pans, etc., together constitute the resources found within the rangelands on which livestock and the pastoral family depend. Pastoralism exists in parts of the world where rainfall is highly variable and unpredictable in time and space. In pastoral systems, livestock depend almost exclusively on these pastures and use mobility to access food between seasons and years. The quantity and quality of natural resources on which pastoralism depends are strongly influenced by rainfall patterns.

- ***Livestock herd:*** Livestock in pastoral systems includes cattle, camels, sheep, goats and donkeys. Livestock in pastoral systems represent more than just economic assets. They are social, cultural and spiritual assets too. They define and provide social identity and security.

- ***Family/social institutions****:* Pastoralism depends on the work and expertise of all family members, usually divided by gender and age. It is impossible to consider the pastoral family without considering the wider social and economic institutions within which they live. The family provides the labor, technical knowledge, marketing expertise, and social networks that allow the system to function. In addition, different members of the family contribute in different ways.

Women are experts in marketing cattle milk and small stock, as well as being experts in animal health, monitoring the growth and health of calves and their mothers, deciding how much cattle milk to take for the family and informing decisions when the family needs to move based on the quality and quantity of milk being produced. Negotiations among clan leaders (older men) are implemented and influenced by social and economic networks established by younger men who are herding and taking livestock to markets. The three pillars of pastoralism do not exist in isolation of each other and interact so that the sum is more than the whole. Livestock bring cultural and social identity and security to the family as well as economic security and health.

Natural resources are impacted in both positive and negative ways by the livestock that depend on them, and this is influenced by the decisions made by members of the family about, for example, how many livestock to keep, when to move, and which livestock to keep where. Interactions between the three pillars and the broader policy context:

- The herd has an impact on natural resources e.g. by eating pastures, animals have a direct impact on plants.
- Natural resources have an impact on the herd e.g. plants provide food for animals.
- The family has an impact on the herd e.g. they take the animals to pasture, provide them with water, occasionally slaughter them, etc.
- The herd has an impact on the family e.g. it provides milk, meat and blood.
- Natural resources have an impact on the family *e.g.* providing fuel wood, water, food and medicines.
- The family has an impact on natural resources e.g. they cut wood for shelter, dig wells for water, burn pastures, etc.
- Wider social and economic institutions have an impact on natural resources and the family e.g. traditional institutions can manage access to some natural resources; they also manage conflict.

8.2.1. The environment and natural resources in pastoral areas

Natural pastures are the major source of feed for the majority of pastoral livestock in Ethiopia. Other resources such as cottonseed, hay, crop residues or irrigated pastures will improve livestock diet if pastoralists can access them, but for many pastoralists this is difficult or impossible. The natural resources that are essential for pastoral production in Ethiopia are:

- Grasses.
- Certain herbs and trees products (pods, leaves, bark). These are also important as food and medicine for people.
- Water for people and livestock.
- Natural saltpans and crop residues (in certain areas) for livestock diets.
- Wood for fuel, fencing, building, etc.

Pastoralists access different pastoral environments in different seasons. In order to understand why, we must first understand the basic dynamics of pastures. Availability of pasture and water to pastoralists and their livestock is based on the quantity and distribution of those resources in the rangelands, as well as the conditions of access to those resources. In other words, there may be water in the well, but availability depends on your right and ability to draw the water from the well.

Types of natural pasture

Natural pastures are found in many different environments in Ethiopia - from the dry, hot lowlands to the wetter, cooler highlands. The natural environment (rainfall, temperature, soil type and aspect, humidity, etc.) determines the species of the plants and the quality and quantity of pastures, and their distribution in time and place.

- Highland areas are cooler and receive more rain. Pastures will be more abundant and stay greener for a longer period than the lowlands. However, there will be more disease (e.g. ticks).
- Lowlands have higher temperatures and less rain for a shorter time. Pastures will be mainly composed of grasslands, shrubs and acacia-type trees. There will be minerals such as saltpans, and the risk of disease may be less.

- Wetlands or swampy areas in dry lands will have high temperatures. Some areas will have permanent dry season water and some vegetation will remain green through the dry season. There may be more disease.
- Riverine forests in the lowlands will have high temperatures. Permanent water will support forests, shrubs and possibly some grassland, and there may be more disease.

Highlands and lowlands, wetlands, and riverine forests are all important sources of natural pasture for pastoralists, representing wet and dry season pastures, or places of refuge during drought years. In some pastoral systems, wetlands, swamps, or riverine forests are very important providing green grass or tree products and water during the dry season. In other pastoral systems, highland areas can be important sources of water and pasture during the dry season. Rangelands that have areas of permanent water in the dry season attract production systems other than pastoralism such as irrigated sugar cane production or bio-fuels produced along the banks of a permanent river. The cultivation of these crops often undermines the ability of pastoralists to access water and finds fodder for their livestock during the dry season. This destabilizes the functionality of the pastoral system.

Figure 8.1: Natural pastures are found in many different environments: lowland and highland areas; open grassland, shrub land and dry land forest; riverine valleys and areas with little or no permanent water.

Factors determining the quantity and quality of natural pasture

The quantity and quality of grasses, shrubs and trees available to livestock have important implications on the health and productivity of livestock and pastoral livelihoods. Identifying and understanding the factors that influence the availability and quality of natural pasture allows us to understand the rationale-underpinning pastoralists' management decisions and strategies. Different fodder plants grow and reproduce at different rates and in different conditions. Seasons, rainfall, altitude, fire, wildlife, livestock, and soils, all affect the quality and quantity of different grasses and trees.

Variation in rainfall between the wet and the dry season

The variations in moisture for plant growth between the wet season and the dry season have an important influence on the quantity and quality of pastures between these seasons. This is normal in arid and semi-arid areas of Ethiopia. Grasses in wet season pastures are " alive" and going through their life cycle. They contain more water and are richer in protein, digestibility and minerals. In contrast, during dry season many grasses either have completed their life cycle (annuals) or dormant (Perennials).

Low nutritional content of grass species during the dry season means that trees and shrubs are important for livestock diets during dry seasons and droughts. During the dry season, trees and shrubs generally have higher levels of water, protein, digestibility and minerals than the surrounding grasses. Access to trees during the dry season can thus provide livestock with a higher nutritional diet thereby reducing livestock weight loss and maintaining a level of productivity that would not be possible if they only grazed on grasses.

Variation in rainfall amount and distribution in time and space

In Ethiopia, rainfall is unevenly distributed within the rainy season. The amount of rainfall that falls in any given rainy season is highly variable in time and space. Furthermore, the distribution of rainfall from one rainy season to the next is also highly variable in time and space – no one rainy season has the same rainfall patterns as another rainy season. This means that not only is rainfall highly variable, but it is also highly unpredictable.

Figure 8.2. Rainfall is highly localized in space; this means that pastures do not grow evenly over the rangelands during the rainy season.

Rainfall variability and unpredictability is common to all areas of Ethiopia, not just the dry lowland pastoral areas. However, the degree of variability and unpredictability is higher in those areas that receive less rainfall – i.e. the dry lowlands. All pastoral areas the world over share this common characteristic - rainfall is highly localized in space, highly variable in time and thus very unpredictable. To understand the impact of variation of rainfall in time and space on the quantity and quality of pasture, we must start to understand the way in which grasses and other pasture species grow.

Total rainfall amount has an important influence on natural pastures. In general, there is a correlation between the amount of rainfall and the amount of pasture that grows - i.e. the more it rains the more pasture will be produced. This is a positive correlation between the amount of rain and the amount of biomass (pasture) produced. However, there is not necessarily a positive correlation between the amount of rain and the nutritional quality of pastures.

Research in the Sahel show that pastures in the northern Sahel, where rainfall is low, are more nutritious during the rainy season than in the southern Sahel where rainfall is higher. Plants can be categorized into ephemerals, annuals and perennials, based on their life cycle.

- Ephemerals, as the name implies, at plant species with a short life cycle, whose seeds germinate, grow to produce new seeds and then die all in a very short time within a year (2 weeks to 3 months depending on the total quantity of rainfall in one season).
- Annuals are plant species with a life cycle that takes approximately twelve months or less to complete (from seed to seed).
- Perennials are a plant species that usually lives for three or more years. During the rainy season, perennials develop new growth while during the dry season they tend to lie “ dormant” .

Annual grass species predominate in the drier lowland regions (often these will be the rainy season pastures), while perennial species are more predominant in mid-altitude and highland regions, and are more typically found in dry season pastures. The rangelands in pastoral areas are made up of a mosaic or patchwork of pasture areas each at different stages of growth, producing different amounts of grass and, more importantly, each offering different levels of nutritional quality. This variable distribution of nutrients in pastures is not necessarily a constraint for livestock production and productivity. Pastoralists have several strategies to exploit this variability to increase the productivity of their animals.

- ***Livestock mobility***: is probably the most important strategy. Through livestock, mobility pastoralists are able to lead their animals to those areas where the pastures are at the peak of their nutritional content. In this way, they are able to feed their animals on a more constant diet of high nutritional pastures than would be the case if they did not move. Mobility is therefore of critical importance.

- ***Selective breeding of livestock***: Pastoralists are constantly reviewing the qualities of their livestock to meet their production objectives in the context of the wider ecological and economic environment. In those environments where there is high variability in pastures, pastoralists very carefully breed livestock that are able to exploit the unpredictable environment in which they live. Through controlled breeding and selection they keep animals that are not only able to reach distant pastures (through mobility), but once they are there to carefully choose those plants in the rangelands that are the most nutritious. Pastoralists have found by observing their animals that some of them are more " selective feeders" than others are and are able to identify those plants that are more nutritious that others – this is called selective feeding.

- ***Species diversity***: Most pastoralists keep several different species of livestock – camels, cattle, sheep and goats to enable them to make optimal use of the variable rangelands and pastures.

Dry land plants species have biological mechanisms to respond to high rainfall variability and unpredictability and thus maximize the chance of their survival as a species. These mechanisms include the following: ephemeral and annual grass species produce very high quantities of seed. Because rainfall, particularly at the start of the rainy season comes in a " start-stop" manner, seeds may germinate but then die for lack of rain. Thus, for the species to survive, plants produce a lot of seeds thereby enabling several phases of germination to take place to coincide with sufficient and well-distributed rainfall to enable the seedlings to grow to maturity and produce the next generation of seeds.

Furthermore, plant seeds react to differences in rainfall amounts and timing to ensure that the species as a whole reproduces itself (e.g. not all germinating at the same time with some seeds lying dormant in the ground for years before they germinate. Some seeds may require very high temperatures associated with fires to successfully germinate. The sheer quantity of seeds produced per plant can ensure long-term successful germination year on year, provided the conditions are right. In some pastoral areas, there is evidence that shows that seeds can remain dormant in the ground for 20 or 30 or even more years waiting for the right conditions to come to germinate. Perennial grass species do not need seeds to survive from year to year, but survive by maintaining a rootstock in the ground during the dry season, which sprouts in the rainy season or when triggered by events such as fire. Production of seeds by perennial plants allows the plant to spread further, and also creates genetic variation that makes the species more robust and resistant to disease.

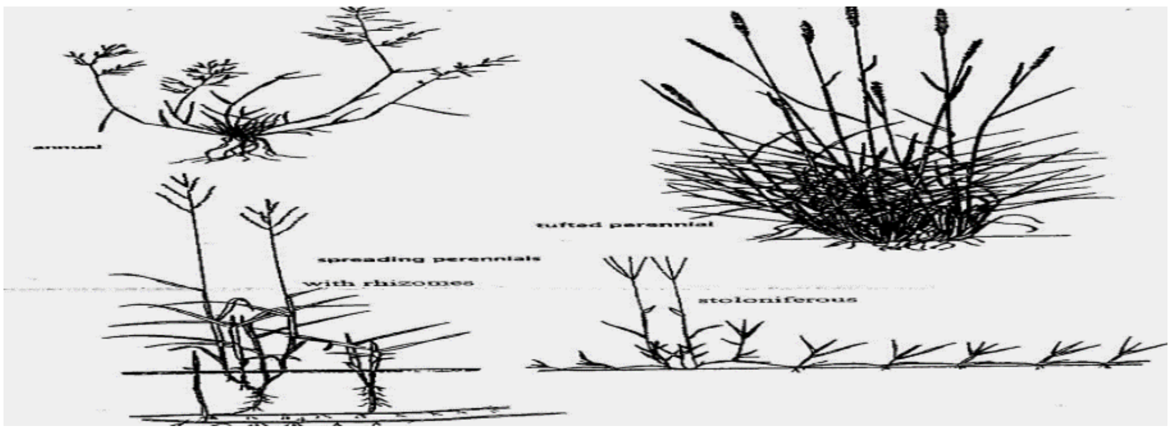

Figure 8.3. Different types of grass species, annual and perennial, showing their reproductive strategies.

Plants have complex mechanisms to ensure the species is not made extinct either by erratic rainfall or by animals. For example:

- Grasses react to differences in rainfall amounts and timing to ensure that the species as a whole reproduces itself (for example, not all seeds germinate at the same time).
- Grasses produce thousands and thousands of seeds to perpetuate the species.
- Grasses in drier areas generally produce more seeds per plant than grasses growing in wetter areas.
- Most grasses have various defense mechanisms to protect themselves from being over-grazed to ensure they complete their cycle and produce seeds for the next generation.

Dry land pastures are diverse, complex, adaptable and resilient-contrary to popular perception they are not fragile. Like other ecosystems (wetlands, highlands), they have the capacity and the potential “ to fix” themselves and to “ bounce back” . This is largely because of the seed bank in the soil. However, like all other ecosystems, the pastoral rangelands have to be carefully managed; care has to be taken not to damage or destroy their capacity to “ fix themselves” .

Inter-annual variability of rainfall and drought

So far, we have mainly considered the impact of variation in rainfall on pasture production within the year. Between years, irregular rainfall and periodic drought are also normal characteristics of dry land areas in Ethiopia, and that pastoral systems have strategies to manage this uncertainty. One of the defining characteristics of pastoral areas is a high level of variation in rainfall.

Pasture management - the interaction between livestock and pasture

In this section, we look at the interaction between animals and plants, and again must start with understanding a bit more about the nature of plants and their reproductive cycle. Once the rainy season is over there is little or no new pasture growth. Annual grass species will die, while perennial grass species lie dormant. Grass growth during the rainy season therefore represents the feed supply over both the rainy and the dry season. The amount of grass that remains at the start of the dry season is called the standing biomass.

The standing biomass at the end of the rains represents the total amount of pasture available for livestock until the next rainy season and as such represents an important source of food, which has to be carefully managed. The standing biomass will reduce throughout the dry season for a number of reasons. Livestock and wildlife as well as termites, birds and rodents may eat it. It may be damaged by wind and also by unseasonal heavy rain. It can be trampled by livestock or wildlife. In addition, it can be destroyed by fire. Since the grass does not grow, any losses are irreversible until the next rainy season begins.

Figure 8.4: The standing biomass at the end of the rains represents the total amount of pasture available for livestock until the next rainy season.

Ideally, the standing biomass should be consumed gradually over the dry season to ensure it lasts until the arrival of the rains and the growth of fresh new pasture. If it is consumed too quickly, animals may have nothing to eat until the arrival of the next rainy season. Furthermore, depleting all the standing biomass may lead to a greater risk of wind and water erosion of the soil. However, if the standing biomass is not sufficiently consumed by the end of the dry season, there is a risk it rots when the rains come forming a sodden layer that prevents the sprouting of new pasture.

Contrary to popular belief, livestock can benefit pasture and the environment and do not necessarily degrade or destroy the environment. Grazing livestock (or wildlife) play an important role in promoting healthy pasture growth. In addition to enhancing the natural regeneration of plants and reducing excessive litter cover, livestock have other beneficial impacts on pastures and the environment. These include trampling of the soil and the burying of seeds, Transporting of seeds on their coats, the natural regeneration of trees (through digestion), and cycling of nutrients in the ecosystem and fertilizing the soil (dung).

However, just as with any production system, under certain conditions, livestock may also degrade the environment and damage its potential " to fix" itself. Overgrazing may be defined as when pasture is exposed to intensive grazing for extensive periods of time without sufficient time to recover. There must be a minimum residual level of plant cover (both annuals and perennials): to avoid soil erosion and thus the loss of the seed bank, to avoid soil compaction affecting germination; and to enable the regrowth of perennial grasses.

Fire in Rangelands

Pastoralists actively use fire to manage pastures. Fires are set deliberately for a number of different reasons: to control pests (especially ticks that spread disease such as East Coast Fever), bush clearance to encourage more palatable grasses to grow, and litter removal to stimulate early growth at the start of the rains. When properly used and managed, fire can be an effective pasture management tool. The timing and intensity of fire in rangelands can also determine the types of vegetation and soil properties and so affect the nutritional value of pasture to livestock.

Fire affects vegetation directly and also indirectly through impacts on soil property:

- Reducing the amount of organic matter/litter in the soil.
- Depending on the season of burning, fire potentially reducing the loss of soil moisture (reduced transpiration) due to reduction in vegetation cover.
- Increasing soil alkalinity (pH) due to the increased release of minerals into the soil e.g. phosphorus and nitrogen. This improves fertility of the soil.
- Creating cracks in some soils, where seeds of certain grasses are protected and lie dormant, easily germinating when moisture becomes available. The seeds are also protected from being destroyed or eaten.
- Leaving unprotected soil exposed to sunlight and rain.

At the end of the dry season, just before the short rains it is important to clear plant litter; and some grasses (e.g. *Themeda triandra*) require "heat shock" for their seeds to germinate.

Figure 8.5: The Borana burn pasture to improve the quality and quantity of grass, minimize or eliminate pests, control growth of bush and shrubs, and encourage fresh grass growth.

In contrast, fire at the start of the dry season in a pasture of predominantly annual grass species is a catastrophe for pastoralists. This is because they risk losing all the standing biomass required to nourish their livestock, which will not be replenished until the following rainy season.

Soil, vegetation and other rangeland resources

The last environmental factor to consider is soil. Topography and different soil types also have an impact on the nutritional quality of pastures. Soils are important for pasture plants: they anchor the plants and are the reservoir of nutrients needed by plants. Pastoral areas of East Africa and Ethiopia have a diversity of soils with different characteristics or properties. The type of soil influences the species composition, quantity, and quality of pastures. Some plant species are able to grow on many types of soils (they have a wide ecological amplitude), while other species tend to be restricted to a few soil types or even a single soil type. Fire can influence soil structure and alkalinity. Soil nutrients, ground rock and moisture influence soil properties from below, while rainfall, grazing and fire can influence rangeland soils from above.

Water, natural pasture and pastoralism

Water provision in the dry lands has frequently been considered from two perspectives: The need to provide water for livestock, with limited attention on how it will impact on pasture management; or, the need to provide domestic water where the focus has been on issues of water quality and accessibility, particularly for women. Rarely are the dual requirements of water for both livestock and people considered in policy and development projects in the pastoral areas of Ethiopia. Water sources, and rights over their use, are critical in determining access not only to water, but also to pastures and other resources in pastoral areas.

The location, legal status, and technical characteristics of a water source are critical components that determine the conditions under which pastoralists can access and manage pastures. The types of water sources available and used by pastoralists and the links between water and natural pasture will be discussed:

- The different types of water sources used by pastoralists and the implications for labour and family health.
- The relationship between pasture and water, during the dry season in particular.
- The importance of the technical characteristics and legal status of water points for sustainable range management.

Types of water sources (and their implications on labor demands and family health)

Pastoralists use many different water sources in Ethiopia, all of which have different characteristics and conditions of access, particularly in the dry season. In pastoral areas, most water points serve both livestock and domestic needs. Water has important implications for women's workload and the health of the family. It is important to identify these different water sources in order to get an overall picture of how the pastoral system works. Water sources in pastoral areas can be categorized in three different ways: Underground water vs. surface water, natural water points – man-made water points and dry season (permanent and temporary) – wet season

In many cases, the same water point will serve for livestock and people. Depending on the type of water source, watering livestock and collecting water for domestic needs is hard work for all the family, both men and women. However, while watering livestock is generally not a major activity for men in the wet season, fetching water for the family needs is a daily year round activity for women, which is generally harder in the dry season. In the wet season, water is more available and accessible due to surface ponds, but there are issues of its quality and hygiene and the impact of poor family health has on women's labour (e.g. looking after sick family members).

The physical and technical characteristics of the water point will influence the amount of time and effort women spend drawing water, and the quality of the water (hygiene). The distance of water point from the homestead will influence the time spent fetching water. The management system of the water point, for example: If there are no provisions for separate watering points for people and livestock, women often have to wait until the livestock of their family/clan is watered before gaining access to watering point, This will affect the amount of time women have for other activities. The availability of donkeys may determine:

- The amount of water that can be transported back to the homestead,
- The frequency of visits to the water point,
- The amount of water available for domestic use.

Pastoral systems in Ethiopia have a variety of water sources for both livestock use and human use. The labor and time requirements for utilizing the water sources particularly in the dry season will vary depending on the technical and physical characteristics of the water point. The quality and hygiene of water in Ethiopia’ s pastoral systems has an impact on family health. This has implications for women’ s

The relationship between water and pasture

For the majority of pastoralists in Ethiopia, watering livestock is most critical in the dry season. This is because animals need more water more often, and because surface water and pasture become scarcer as the dry season progresses. The number of water points and their distance from natural pastures will determine the frequency and distance livestock have to trek to reach water and pasture. Understanding the dynamics of these movements and particularly the distance animals have to trek before returning to find water is critical. Different livestock have different water requirements in terms of both frequency and amounts.

On average during the dry season, camels require 60-80 liters per day, but can last 5 days or longer without water, while sheep require just 4-5 liters but must drink every 1-3 days. Cattle must drink 30-40 liters on average per day and should drink every 1-3 days. It is during the dry season that careful management of water and pasture is most important. Animals need water more often as it is hot, pastures are dry and often they have to trek long distances to find pasture. There is a maximum distance different species of livestock can walk before they need to return to the water point to drink often called the "grazing circumference" or " zone of influence of the water point" .

The "grazing circumference" represents the pasture area "attached to" or associated with that water point. In the dry season, it represents the total amount of pasture (standing biomass) that is available to livestock using that water point until the next rainy season. It is therefore important to manage it very carefully to ensure the animals have enough pasture until the start of the next rains. If the pasture is eaten too quickly, before the arrival of the rains, livestock will suffer. There are two factors determining the speed at which dry season biomass is consumed: The number of animals using water point and the time they spend there. The more animals around a water point and the more time they spend there, the quicker the standing stock will be eaten, and finished up. The more water that a water point provides the more animals can be watered there in one day. This will have an impact on the speed at which pastures are eaten in the grazing circumference of that water point.

The technical characteristics and legal status of water points

The number of animals that can be watered per a day depends on the technical characteristics of the water point as well as the legal status and control of public access. The type of water supply and control over its access can thus have a crucial impact on the speed at which pastures are eaten in the grazing circumference of that water point. Underground water sources like wells, springs and boreholes will have a limited capacity, while modern water points tend to provide more water than traditional water points.

In addition, the more open the accessibility to that water (e.g. a pond versus a borehole), the harder it is to control the number of livestock accessing the source. The legal status of a water source, and whether or not groups or individuals have the rights or capacity to control the number of animals that use them. Thus, determines the degree to which pastoralists are able to manage the stocking rates on pastures. Access to a water point is the key to access to pasture: no access to water and the livestock must move to a different area.

Figure 8.7: Traditional Ellas (deep wells) form 96% of the Borana pastoralists permanent water source.

Most modern water points developed by government and donor projects are considered public resources open to use by all citizens and for all purposes including domestic use and consumption. Committees or associations set up to manage such water points normally have no authority to manage the number of animals that use it. Access is usually determined by the capacity of pastoralists to pay for water rather than the availability of pasture within its "grazing circumference". This has led to the concentration of many animals around water causing degradation and conflict. This degradation may take the form of a scarcity of palatable species and/or soil erosion and gully formation depending on topography and soil type.

It is better to have more, smaller water points in a network each producing relatively little water, which will ensure livestock, are well distributed over a wider area thereby rationalizing pasture utilization in the dry season. It is also critical to give water user committees of public water points the right to control the number of animals that can use it so as to manage pastures in a sustainable way. There are thus a number of key factors that need to be in place to manage the number of animals using a water source: local people have the authority to regulate access; there is negotiated access, both within the group, and with outsiders; and the principle of reciprocity. Finally, let us not forget that water development in pastoral areas has to serve domestic and livestock needs, while at the same time being sensitive to the surrounding environment and resources.

In the dry season, access to water is the key to sustainable pasture management. Two factors are critical to accessing water: Technical characteristics determine water discharge rates and thus the number of animals that can be watered and legal status of the water point determines who has authority to control access.

is measured in terms of the weight of beef produced per year, sold for meat or for fattening by others. However, meat production represents only a part of the use made of livestock in a pastoral system in Ethiopia or elsewhere.

Pastoralists extract value from their livestock throughout their lives and postpone slaughtering them so long as they have potential use for the herd of the family – to grow the herd, provide milk, or to provide a bride price or other social value associated with the exchange of live animals. Meat is “ a residual benefit to be realized only at the end of an animal’ s productive career” . In contrast, ranching is a predatory system in that it exploits animals by killing them, but does everything possible to insure their well-being up to the time of slaughter, and kills them in their prime. The herd, in a pastoral context, is thus managed to support the ongoing needs of a pastoral family, providing meat, milk, one-off and regular cash demands, and the social and economic demands of a family today and tomorrow and into the future.

Herd composition

Herd composition refers to the number of different species (e.g. camels, goats, sheep, and cattle) and breeds (e.g. Zebu, Boran and Jersey cows) within a herd. Herd composition is determined largely by local environmental conditions: some species and breeds are more resistant to drought or disease and different species have different dietary needs. However, herd composition also depends on the socioeconomic status of the family and other factors. For example, some breeds are able to cover greater distances, some produce more milk, some reproduce more quickly and different species and breeds have different values at market.

Figure 8.6. Herd composition in pastoral areas.

Pastoralists in East Africa and Ethiopia usually keep several species and breeds of livestock within the family herd. There are major advantages in diversifying the livestock within the herd, whether to meet different needs and objectives or to better manage the variable environment. For example; different species are better able to exploit the very varied pastoral environment– cattle and sheep graze off grasslands while goats and camels prefer browse. This makes good use of the available resources, as well as managing risk where rainfall is highly unpredictable over time and space. Different species are able to exploit the different seasons in different ways – goats and camels, because they prefer to feed off tree products, keep producing milk in the dry season when milk productivity of sheep and cows decline.

Different species have different roles – donkeys and camels are used for transport; goats are sold to meet immediate household needs or slaughtered to feed a guest. Cows provide milk and blood. Small stocks are of lower value and can more easily be sold to meet occasional cash needs. If disease strikes, not all species may be affected, spreading the risk. Diversifying the herd also comes at a cost. For example, different species may have to be taken to different pastures depending on their dietary and water needs, which requires extra labour.

> Pastoralists carefully manage the age and sex ratios of their herds to balance the number and category of animal to meet family needs today while planning for the future. Generally, pastoralists keep more female than male animals so as to get enough milk for the family today while ensuring the birth of animals for tomorrow. Herd structures are changing as pastoralists move into a monetized economy, which may have different impacts on men, women and children within society.

offset losses due to drought, disease and old age.

A herd is composed of animals of different ages and sexes, based on the objectives of the production system or the socio-economic status of the family. There is no single herd structure – the structure of the herd will depend on the context and the objectives of the herd owner. A herd that has suffered major losses will need to be skewed towards reproductive females to rebuild the herd, whereas a herd being kept more as a capital investment might be skewed towards steers that can be easily sold.

Social and cultural institutions in pastoral societies

In this section, you will look at what makes up a pastoral family, how it relates to the herd, and the labor demands of pastoralism (for men and women). Individual families combined constitute the social and cultural fabric of pastoral communities. Moreover, conflict in pastoral areas and the role of customary and modern institutions in conflict creation and mitigation will be discussed.

The pastoral family and institutions

Dear learner, can you define a family by your own words?

“ A family” means different things from one pastoral society to another in Ethiopia and elsewhere. In some societies, there are extended families with married sons living together with their father, and where all the livestock are kept together as one management unit. In other societies, sons leave their father's home as soon as they marry, and take their livestock to set up their own family. All those people (men and women, old and young) who may or may not be related by blood or who are directly involved in the day-to-day management of the herd, on which they are dependent for the greater part of their livelihood.

Labor management and gender roles in pastoral societies

Pastoral work is hard and difficult. Within the system, there exists a strong division of labor, consistently challenges the family to find the right balance between the size of the herd, and the number of people it has to support. In addition, beyond the management and maintenance of the livestock herd, different members of the family will be involved in alternative income generating activities– small scale marketing of tea and sugar, herding, agriculture– not to mention the day-to-day management of the family and homestead – collecting water and firewood. When considering different customary roles within pastoral families, men and women, girls and boys, it is useful to categorize pastoral activities into three types:

- Productive activities: looking after livestock and other economic activities.
- Reproductive activities: cooking, fetching, childcare, health care, etc.
- Community activities: participating in cultural meetings, ceremonies, decision making at community/local government levels, etc.

Productive activities

Productive activities are those, which relate to economic well-being of the household. Both women and men are involved in productive activities. In many cases, they do the same type of activity, but are responsible for different aspects: e.g. different species of animals or ages of animals. Productive activities can be daily activities such as milking the animals, seasonal activities such as digging wells, or occasional activities such as repairing equipment or the family home. Seasonal " bottlenecks" occur when labor demands on all members of the family are high.

The availability of labor during such bottlenecks can act as a limiting factor in the growth of the herd. Many productive activities require knowledge and skills, which have built up over time and passed on from generation to another – e.g. the selection of which animals from which to breed, veterinary care, harvesting and processing wild foods and medicines. Productive activities are organized and implemented at different levels (individual, family and sub-clan or clan) depending on the nature of the task, the value of capturing economies of scale and dealing with such external issues as insecurity.

While marketing of cattle and camels tend to be the responsibility of adult men, women are also very active in the markets. They are often responsible for selling small stock, livestock products (such as milk and butter), and other goods often collected from the forests – herbs, fruits. Women play a major role in deciding how much milk can be sold versus consumed within the household or left to the calf, and in monitoring livestock health, calf mortality and the herd's potential for growth.

Reproductive activities

Reproductive activities are those that relate to the health, growth, and well-being of the family: cooking, fetching, childcare, health care, etc. Women alone tend to be responsible for reproductive activities. Many reproductive activities tend to be daily activities. Many involve hard physical work that continues at a high level all year, but particularly in the dry season. Some activities require knowledge and skills such as collecting and processing bush products for food, knowing where to find such food in ecosystem, understanding the dynamics of such products (when they are edible, when they might be poisonous, etc.). Activities, workloads, obligations and rights also vary according to the age of women. For example, girls will work for their mother, young wives will help their mother in-laws, mothers and their daughters and daughter-in-laws will help mother in laws, and grandmothers will supervise and organize.

Community activities

Both men and women are involved in and have responsibility for community activities. In some cases, they do the same type of activity (e.g. organizing ceremonies) but have different responsibilities (e.g. men are responsible for men's issues, women are responsible for women's activities). Just as there are different roles in specific activities such as herding and milking, there different roles in decision-making. For example, decisions such as when to move may be the responsibility of men, but once the decision is made, the women are closely involved in how to move.

It is often assumed that men are decision-makers in pastoral families. There is evidence that the role of men as representatives of pastoral (as well as agricultural) communities was elevated during the colonial period. Colonial officers, exclusively men, would meet exclusively with male members of local communities. In this way, the information gathered, and any consultations, excluded women and their experiences. In European societies at the time, it would have been unheard of for women to own livestock or be involved in livestock management decisions, and this assumption carried over to the colonies, in the process cementing men' s roles as community representatives and deepening their economic and political power. Social capital and mutual assistance are key elements of customary institutions binding pastoral communities.

Pastoral institutions today are a combination of customary and modern. Customary institutions may be kinship based or geographically based, and vary in strength. " Kinship institutions continue to provide the only even partly most reliable safety nets for destitute pastoralists through clan-based livestock redistribution, despite several
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> Pastoral labor is hard, difficult, and often demands a great deal of knowledge and skill. Some activities are daily, while others are seasonal or occasional. Women tend to play a greater role than men in reproductive activities: water collection, firewood collection, food preparation, etc. Activities are carefully organized and divided by age and gender and organized at different levels (individual, family and clan). Pastoral men and women work closely together to ensure the health and well-being of both the herd and the family. A key role of institutions, customary/modern, is to regulate natural resource use through negotiated access and authority. This control is between open access resources and common property resources.

8.3. Conflict in Pastoral Areas

Pastoral areas in Ethiopia, and in the region, are characterized by high levels of insecurity and conflict. In this section, we consider the nature of pastoral conflict where it is found, why it is so prevalent and some of the responses to conflict at the local and regional level. Within pastoral societies, where pastoral resources (pastures, water, and minerals) are highly variable and unpredictable in time and space, both in terms of quantity and quality, access must always be negotiated and reciprocal. In this manner, pastoral families are able to manage the risk of variability by ensuring access over a very wide area.

Conflict describes a state of disharmony between two parties arising from opposing or incompatible needs, ideas or interests often accompanied with perception of threats to either party's interests, needs or concerns. Conflict is not inherent to pastoral society, as is often believed. Conflict exists in all societies as a result of the failure of institutions and frameworks for managing and mediating access to and control over strategic resources (e.g. pastures, oil fields, dry season water, etc.).

In pastoral areas, traditional institutions responsible for managing conflict are losing their authority while formal government institutions such as the police, the army or the judiciary are either absent or ineffective. This is creating a "governance vacuum" at the local level, which is further exacerbated by the proliferation of small arms as a result of wider regional conflicts (e.g. civil wars). Institutions and mechanisms to resolve conflict are becoming ever more vital, and there are a number of initiatives at the local government, and the inter-governmental levels ongoing.

8.3.1. Causes and impacts of conflict in pastoral areas

Conflict in pastoral areas may be caused by internal factors the communities themselves, by external factors that are a function of interactions between pastoralists and other external institutions and agencies, and by both internal and external factors. The weakening of traditional institutions and the rapid changes occurring within pastoral societies are responsible in part for the escalation of conflicts in pastoral areas. All members of society feel the impacts of pastoral conflicts, directly and indirectly. Direct impacts on people include physical injury, mental trauma and death and women and children are often particularly badly affected, for example, rape and mutilation of women and girls is a tactic of war and counter-insurgency, child soldiers in South Sudan and Northern Uganda. Direct impacts on infrastructure, such as schools or medical centers can have long-term indirect impacts on the provision of services like education, vaccination programs, and veterinary services.

The effects of conflict can be felt immediately, such as the direct and violent depletion of livestock or closure of markets. Some effects can also be felt much more broadly and over the longer term– a reduction in investment and trade interest in a region, the ongoing diversion of government resources from service provision to security; the breakdown of traditional safety nets and social support systems. And of course, many of these impacts are also accumulative: Internal and international displacement of communities leads to the breakdown of traditional leadership and institutions, restrictions on mobility reduces productivity and increases poverty. Ultimately, conflict can itself lead to more conflict and the emergence of new and violent " social norms"

Generally, the causes of conflict in pastoral areas are:

- Absence or ineffective institutional arrangements for managing access to and/or control over variable and unpredictable pastoral resources– water, pasture, salt licks.
- Absence or inappropriate policies and laws managing competing land uses– especially with conservation, agriculture, settlement and infrastructure.
- Inappropriate development and natural resource management policies– non recognition of pastoralism, constraining mobility, absence of support to the pastoralism after drought (livestock raids to restock).
- Weakening, marginalization or collapse of traditional institutions of resource management and conflict resolution
- Intra-state crises of governance and insecurity in the Horn of Africa, including civil wars - Somalia, Sudan, Ethiopia, Eritrea
- Proliferation of small arms
- Inadequate government machinery and infrastructure for law enforcement, etc in pastoral areas.
- Opportunism of political leaders in pastoral areas.
- Banditry and terrorism

8.3.2. Responses to conflict

Given the complexity of the underlying causes of conflict in pastoral areas, it is not surprising that the responses should also be many and diverse, at different scales geographically and politically. Support at the local level ranges from facilitating dialogue and negotiations between groups for the establishment of community based conflict early warning systems – e.g. village or district peace committees, supporting the involvement of women, facilitating local dialogue and negotiation, and supporting traditional peace meetings. More violent and chronic conflicts have seen police or military action/violence, the deployment of peacekeepers, support to militia and disarmament programs.

Policy and advocacy can also play important roles in mitigating conflict in pastoral areas, through addressing the underlying causes of pastoral vulnerability.

- Recognition of pastoralism will lead to investment in support of pastoral institutions and livelihoods, thereby addressing some of the underlying causes of conflict.
- Political and policy recognition and legal support for traditional institutions to play their part in conflict management.
- Empowerment of women in decision-making and in conflict management.
- Research on emerging causes of conflicts and how they can be addressed.
- Mobilization of communities in the spirit of solidarity to promote co-existence and good neighborliness.

8.4. The Role of Pastoralism

Pastoralism has different roles in country, regional and family levels.

8.4.1. Pastoralism as a sustainable livelihood

A livelihood can be defined as "the means of securing the necessities of life". Sustainable livelihoods share three common features: They are based on resources or "assets" that can be social or economic that provide a living (food security, reduced vulnerability, health and wellbeing, etc.); sustainable livelihoods are able to cope and recover from shocks (e.g. economic or environmental); sustainable livelihoods do not undermine the resource base on which they depend. It is possible to categorize the resources, or "assets" on which livelihoods depend into six types:

- ***Human capital***: skills and knowledge of family/people, the ability to work, good health, strength, etc. quantity and quality of labour.
- ***Social capital:*** the networks and relationships that people develop and use to build trust and enable them to work together effectively and efficiently; relationships of

reciprocity and exchange; working in cooperation; providing safety nets and support. Ensuring the reproduction of society.

- ***Natural capital***: natural resources on which a livelihood depends; pastures, water, soil, trees and tree products, genetic resources, etc.
- ***Physical capital***: infrastructure and producer goods that support a livelihood and allow people to be more productive – shelter, transport, tools, etc.
- ***Financial capital:*** these are both inflows of cash from income, gifts, etc as well as stocks and savings held by a family
- ***Political capital***: political representation and ability to engage with political and policy issues external to pastoral system at regional, national and local levels.

8.4.2. Economic contribution of pastoralism to the family

Livestock lie at the heart of the pastoral livelihood system – they are the central pillar. However, additional income generation and livelihood strategies have long supplemented pastoralism. These include relatively small-scale rain-fed or flood retreat agriculture, the use of non-timber forest products, sale of artisanal crafts (e.g. beads, jewelry, leather goods) and wage labour (e.g. herding, security).

Families or individuals from within pastoral families may also move in and out of pastoralism over time and to differing degrees, finding alternative employment when the herd becomes too small to support the family, and then moving back into pastoralism when it has been possible to invest in and grow the livestock herd. The majority of pastoralists, particularly those with smaller herds, gain far more value from the non-monetary services of their herds – as a source of food (meat and milk), manure, draught power and hauling services, savings, insurance, social capital and women empowerment.

8.4.3. Evaluating the national economic contribution of pastoralism

It has been estimated that the pastoral livestock and meat trade in the Greater Horn of Africa was valued at US $1 billion in 2010. However, within countries such as Ethiopia and Kenya, the value of this trade continues to be underestimated, misrepresenting the value of pastoralism to the national economy, and justifying underinvestment at best, or poor policy outcomes at worst for pastoral production systems. In 2006, there were an estimated 12-15 million-pastoralist people in Ethiopia out of a national population of 83 million. Pastoralists are a minority, and have long been considered more interested in accumulating livestock than engaging in livestock trade.

A recent study (by ILRI) found market access made a significant difference in the average number of sales per livestock keeper as a percentage of their herd, suggesting that more herders would sell livestock if access to markets were improved. Government valuations of livestock contributions to the national economy have long been considered inadequate and inaccurate. In Ethiopia, livestock contributions to the national GDP are based on estimates of livestock populations and a series of estimates of market prices and offtake rates (for sale, milk production and dung for fuel). In addition, inputs to the system include the costs of prepared animal feeds, vaccines, salt for cattle, oil cake and artificial insemination.

A recent working paper from IGAD’ s Livestock Policy Initiative (LPI) found many of the coefficients used to calculate the livestock contribution to GDP were too low and livestock population figures did not include significant pastoral areas in Somali and Afar Regions. Available government data were not disaggregated according to the different systems in which livestock are reared – for example milk production figures were averaged and did not take account of the difference in milk productivity or scale of dairy herds (a very low number in Ethiopia), agro-pastoral cattle and pastoralist cattle).

The IGAD review suggested that the current government estimate that livestock contribute about 25% of total agricultural GDP in 2008/9 should be revised to 45% of agricultural GDP. Much of this increase can be attributed to the value given to livestock traction in agricultural production. Excluding the value of animal traction, the value of ruminant production was valued at 48 billion Ethiopia Birr in 2008-2009 – an increase of 47% of the government' s official figure. In addition to the direct benefits that pastoralist families derive from their livestock and rangelands, pastoralism as a system brings indirect benefits to the national economy, making productive use of arid lands, conserving rangeland biodiversity, and supporting wildlife conservation.

Pastoralism also contributes in an indirect manner to the local and national economies. For example:

- Dry lands constitute nearly half the land area in sub-Saharan Africa, and pastoralism makes productive and efficient use of the scarce resources that exist across these areas that would otherwise be un-used or poorly used.
- Biodiversity conservation and tourism. Many protected areas in East Africa' s dry lands were originally pastoral dry season grazing areas populated by relatively abundant wildlife co-existing alongside domestic stock. The preservation of wildlife and dramatic scenery in these areas is largely due to the practice of pastoralism over other forms of land use such as agriculture or mining. Following their often-forceful expropriation, few benefits have been returned to the displaced pastoral communities.
- In addition to tangible benefit generation through handicraft sales, traditional village installations and cultural performances that directly bring some revenue to pastoral communities, the material culture of pastoralists benefits artisans and merchants and indirectly intensifies tourist interest in the culture and lives of pastoral and other rural communities.
- For many tourists, pastoral societies evoke feelings that attract initial and repeat visits to East Africa. Northern tour operators and their East African affiliates regularly use pastoral imagery to sell their products. A range of other industries including airlines and mobile phone companies also use similar marketing practices.
- Improved agricultural returns (traction and manure)

- Employment. A minimum of 9 million (and as high as 20 million) pastoralists live in East Africa, of which an estimated 60% are adults of working age gainfully employed in raising livestock and other subsidiary activities (e.g. livestock trade). In arid and semi-arid rural areas, pastoralism and agro-pastoralism are often only form of employment. Displacement of pastoralism will result in unemployment, urban drift, migration and a host of issues that have very direct and tangible costs for the national economy (e.g. conflict).

8.5. Land Tenure in Pastoral Areas

In Ethiopia, rural and urban lands, including the pastoral areas, belong to the state but in
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Pastoralism has other benefits. Livestock raised under pastoral systems are very cost effective, supports an estimated 20 million people who otherwise would require alternative livelihoods, makes optimal use of scarce resources with minimal environmental costs, and represents an important knowledge reservoir and experience of good environmental management under conditions of increasing climate change. Through common property resource tenure regimes, it greatly contributes to social capital and nourishing collaborative and peaceful relations between different groups.

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systems that administered land use and tenure. Pastoralist land has been given over for

national parks, commercial farms, mines, military camps, airports, oil exploration and cropping. Land administration and use policies and laws that superficially address pastoral issues have not been sensitive to pastoralist traditions and hence pastoralists do not benefit from investments made in their lands.

The government has started to address pastoralist land tenure. The current land administration and land use policies of the Afar Region and the draft land use policy documents of Benishangul-Gumuz regional government provide good examples of how to deal with pastoralists' land rights. Policies such as the 2005 Federal Land Use Policy, the 2002 Oromia National Regional State, and SNNPR policies and laws exist and address the specific needs of pastoralists both nationally and regionally. The policies are superficial and often not practiced. Even though the government has listened to the needs of pastoralists, still challenges remain in addressing their complex needs. Issues such as compensation, certification as well as conflict and gender empowerment in land use present challenges. The overriding need is to consult and involve pastoralists, including women, in all decision-making processes in order to move forward.

Many international rules on human rights and environmental protection provide group rights for the indigenous communities to their communally possessed lands. The African Commission on Human and Peoples' Rights has recognized and categorized the pastoralists in Africa as 'indigenous communities'. The Declaration on the Rights of Indigenous Peoples, which was adopted by the UNHRC, 2006, guarantees the rights of the indigenous communities.

resettlement schemes, encampment of refugees and/or returnees and ranches. This is leading to an increase in poverty among these communities.

8.6. Challenges and Prospects of Pastoralism

National and international policies governing trade, land access, access to health and veterinary services and education, wildlife conservation, and land tenure, all play a crucial role in determining whether the pastoral production system can provide viable livelihoods for dry land communities in Ethiopia and elsewhere. The overall policy environment in Ethiopia is broadly positive to pastoralism: the Constitution of Ethiopia says land belongs to the people and there are specific provisions to protect pastoralists from eviction from their land. Pastoralism remains a resource-a system of producing meat and milk cheaply on land that is otherwise hard to exploit. This resource can be protected and managed effectively or ignored, and allowed to decline.

The pastoralist production system can be improved in many ways. These include building on the growing interest and concern about pastoralist affairs within government. Pastoralists and their allies should try to ensure that unlike the failed top-down strategies of the last century, 21st century policies are designed with full pastoralist involvement.

Pastoralism as a livelihood system and has many positive provisions to improve livestock development and veterinary and social services.

Governments have also given a lot of prominence to pastoralism within their formal institutions. There is a parliamentary pastoral standing committee and pastoral commissions at regional level in Ethiopia. In Ethiopia, pastoral parliamentary groups exist in parliament. The Ministry of Federal Affairs in Ethiopia has pastoral development department as does. The African Union has a pastoral policy framework that is supportive of pastoralism including livestock mobility within and between countries. There is a strong and/or emerging pastoral civil society movement in the region raising pastoralist issues at the national level (e.g. National Pastoralist Day). Many NGOs and donors are increasingly supporting development activities in pastoral areas of Ethiopia.

In spite of pastoral areas huge resource potential and significant contribution to the national economy, the majority of pastoral communities do not get enough food or basic services. The livestock production system is under serious pressure and is unable to adequately support the livelihood of the majority, particularly the poor and very poor segments of pastoralist society. Across the country, grazing areas are shrinking and becoming less productive. Traditional water distribution and utilization systems are being challenged by industrialization and modernization. Indigenous coping strategies have suffered a decline. Moreover poor physical infrastructure, uncoordinated development efforts, low levels of pastoralist involvement and lack of appropriate research and extension services contribute to the downward trend.

Despite its central role and contribution to society, pastoralism has been attacked as outdated and unproductive. Pastoralists in Ethiopia face not just unfavorable physical and environmental factors but also long years of neglect and the failure of development policies and strategies to satisfactorily reflect their views and interests. Reconciling government objectives for economic growth and poverty reduction through the commercialization of the agricultural sector, particularly through irrigation in the lowlands, with the recognition of pastoralist livelihood strategies based on adaptive management (mobility) in variable environments. Building capacity at all levels for policy implementation (establishment of institutions, availability of resources, deepened understanding of pastoralism).

Any support to pastoral systems must be underpinned by a sound understanding of pastoralism as a livelihood system, regulated by ecology with complex modes of social, economic and political organization, which can adapt to present day environmental and economic opportunities and constraints. Moreover, an understanding those pastoralists have the right to make choices about the future they want.

> Pastoral mobility has four key objectives: to maximize productivity, to access markets, to avoid danger, threats and shocks, to participate in social and cultural events. Mobility is difficult but carefully planned; it is not haphazard. Mobility impacts on men, women and children in different ways. Mobile livestock are more productive than sedentary livestock under dry land conditions of variable resources.

Summary

Natural pastures are the main source of feed for livestock in pastoral systems in Ethiopia, but these resources are: Variable in quantity and quality from one season to the next. Pastures in the wet season are more abundant and more nutritious - they contain more water and are richer in protein, digestibility and minerals. Trees are also important in the pastoral system for other reasons (food, shelter, medicine, etc. often central to women' s livelihoods). Different species of animals of local or mixed breeds each with different characteristics adapted to the environment, in which they live, manages risk and ensures the maximal use of variable and scattered resources. Indigenous breeds are better able to make optimal use of variable resources, and are more resistant to drought and disease.

Self-Assessment Question 8.1

Direction I. Write " True" if the statement correct and " False" if it is incorrect on the space provided.

----1. Pastoralists are people who depend largely on crop production for their food and income.

----2. Pastoralism is most excellent system in dry land areas of the country.

----3. Pastoralists practice mobility to track fresh nutritious pastures, avoid over grazing and evade disease, conflict or drought conditions.

---- 4. Pastoralists use known strategies to maintain an optimal balance between pastures, livestock and people.

-----5. Mobile livestock are more productive than sedentary livestock under dry land conditions.

-----6. Soil type and fire have an important influence on pasture composition, quantity and quality.

-----7. Social capital and mutual assistance are key elements of customary institutions binding pastoral communities.

Further Reading

To have more explanation on unit 8 you can refer the following:

PFE, IIRR and DF. (2010). Pastoralism and Land: Land tenure, administration and use in pastoral areas of Ethiopia.

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Answer Keys to the Self-Assessment Questions

Self-Assessment Question 1.1

Direction I. True or False part

1) False 2) True 3) True 4) False

Direction II. Multiple-choice part

1) E

Self-Assessment Question 2.1

Direction I. True or False part

1. False, 2. False, 3. True, 4. True,

Direction II. Multiple-choice part

1. B, 2. E

Self-Assessment Question 2.2

Direction I. True or False part

1. False, 2. False, 3. True

Self-Assessment Question 2.3

Direction I. True or False part

1. False, 2. True, 3. False, 4. True, 5. False

Direction II. Multiple-choice part

1. E, 2. C, 3. F, 4. A, 5. E

1. E, 2. H, 3. B, 4. I, 5. D, 6. F

Self-Assessment Question 3.1

Direction II. Multiple-choice part

1. B, 2. E, 3. E, 4. B

Self-Assessment Question 4.1

Direction I. True or False part

1. True, 2. True, 3. True, 4. False, 5. False

Direction II. Multiple-choice part

1. D, 2. F, 3. C, 4. C, 5. A, 6. C

Self-Assessment Question 4.2

Direction I. Multiple-choice part

1. A, 2. E

1. D, 2. F, 3. E, 4. A, 5. B

Self-Assessment Question 5.1

Direction I. True or False part

1. False 2) True 3) True

Self-Assessment Question 6.1

Direction I. True or False part

1. True 2) True 3) True

Direction II. Multiple-choice part

1. E 2) E 3) E------4) E------5) E

Self-Assessment Question 7.1

Direction I. True or False part

1) False 2) True 3) True 4) True

Self-Assessment Question 8.1

Direction I. True or False part

1) False 2) True 3) True 4) True 5) True 6) True 7) True