FROM INVENTORY TO MONITORING IN SEMI-ARID AND ARID RANGELANDS

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Contents

Summary

The purpose of rangeland inventory and monitoring is to describe and evaluate the environment and the resources. Rangeland inventory is a one-off study with the objective of characterizing the environment, the vegetation and the wildlife. Rangeland monitoring introduces a temporal element with the ultimate goal to evaluate spatial events and changes in relation to management action (grazing, cropping, etc) or catastrophic events (flood, fire, etc).

Measurements and observations developed from rangeland inventory and analysis of specific sites can be repeated through time, over the seasons, the years, to produce the elements supporting ground-based rangeland monitoring. The latter allows establishing the state of rangeland health that may be ‘ stable’, ‘degrading’ or ‘improving’ according to a set of pertinent indicators related to vegetation composition and structure, soil condition or management options.

Ground-based monitoring results are slow to deliver and difficult to scale-up to large areas. Satellite-based monitoring considers different range attributes, delivers swift and accurate range conditions and allows consistent monitoring and comparison throughout

large regions over long period of time. Historical development of principles and methods for range inventory and monitoring in different parts of the world, their past and current use, from the most simple field observations and techniques supported or not with statistical analysis to current sophisticated satellite imagery processing are reviewed with their advantages and limitations. Yet, the most refined up-to-date range inventory or monitoring methods can only supported by accurate and timely field surveys based upon sound ecological basis performed by expert range specialists and managers.

1. Introduction

The arid and semi-arid rangelands of the world are the lands between cropping zones and the deserts. They are too rocky, often have shallow soils, expand under harsh climatic environment, and are too far away from any community centers to be used permanently by settled farmers. These rangelands contribute to the living of the poorest having free access to forage, firewood and wildlife. These populations practice a shifting and transhumant agriculture and mostly livestock industry in a continuous attempt to reduce the risk from climatic and soil hazards especially on the Mediterranean rangelands, between the true desert below the 100-125 mm Mean Annual Rainfall (MAR) isohyets and the agricultural areas where cereal production prevails in the 200-400 MAR. Most Mediterranean rangelands are under extreme population pressure and facing desertification unless proper management measures are developed in a large regional context.

Rangelands encompass a large portion of West Asia and North Africa (WANA), i.e. 270 million ha of the 400-100 mm MAR Mediterranean zones. In the ex-soviet republics of Middle Asia, the cold and dry rangelands cover immense areas of steppe country (some 600 M ha) totally devoted to livestock industries. In China, the Northern cold arid and semi-arid grassland and rangeland cover at least 225 M ha among which 80% are degraded. In the US, the grazing land covers 480 M ha under various types of management from pastoral and forestry industries to eco-tourism, hunting and fishing with much lower level of human pressure than in other parts of the world. In Australia, the pastoral industry dominates most of the 900 M ha rangelands though mining industries are catching up fast with a definite impact on shaping the future Australian rangeland development and communities.

Rangelands are usually not autonomous production zones; they are linked through livestock management to the arable and farming lands as both provide seasonal grazing (See Chapter Range and Animal Sciences and Resources Management). Reports from the mid-1950s indicate that 60-80 % of the small ruminant's diet would emanate from rangelands; half a century later, it is plunging to less than 10 % in most of the countries of WANA (West Asia North Africa) where rangelands are already in poor conditions, rocketing external feed supply and grain imports. Poor agricultural policies, conflicting land tenure issues, food, feed and fuel subsidies, obsolete marketing and banking systems appear to unintentionally generate incentives for destructive practices on rangeland worsening agricultural production of semi-arid and arid zones. Ensuing desertification has a clear bearing not only on nomads' life but also may have global repercussions for the future of mankind at the global scale. Soil surface albedo and regional climate are being altered, reducing convective rainfall and increasing the occurrence of local droughts. Governments and international agencies working on rangelands rarely take into account these vegetation changes on extremely large areas though this is tackled by Australian and North American research agencies.

From time immemorial, users, developers and managers of natural resources had to have a fair understanding of their environment to make the best use of it. Be it primitive hunters, roaming nomads, or settled farmers, all of them had to know their climate, territory limits, soils, water resources, wildlife and vegetation, and also the support, constraints or antagonism they may expect from neighbors when they want to use the resources available on the land. Conquerors', explorers' and travelers' accounts from all races and cultural background added their contribution to new regions visited and what could be found there along with local agricultural practices and traditions.

The advent of writing and printing accelerated this trend with knowledge becoming available to larger audience of new colonizers that were going to make use of it, extending their control over territories with untapped resources for ever-expanding population. These stimulated the early land inventories. Later, the heavy demand and degradation occurring on the rangelands of the world and especially in the Mediterranean regions made it necessary to initially develop inventory and later monitoring methods to better manage the scanty and sometimes fragile resources available.

2. Definitions

Rangeland inventory and analysis is to characterize the environment and provide potential users with a one-off study of the vegetation and condition with methodologies that can be repeated at a set of places and at a set date. It may start with simple listing of living material found on a site and evolve to more a complex approach integrating:

- qualitative attributes (i.e. vegetation typology) in relation to climate, soil and human and animal impact,
- quantitative or semi-quantitative attributes (i.e. vegetation density, % cover, biomass, soil and water erosion conditions, vegetation condition, grazing level or human-made impacts or natural events).

The ultimate aim of range inventory is to classify and compare rangelands types and evaluate their actual condition.

Rangeland monitoring consists in repeating, over time, rangeland observations on the same site of a properly identified range vegetation type to capture qualitative and quantitative changes, succession and range trend attributes selected to meet the objectives of the program. The aim of range monitoring is to provide range users with early warning tools to act on unwanted or confirmed range and land alterations.

This article deals mostly with rangeland vegetation from arid and semi-arid environments with most examples extracted from the Mediterranean regions of the world.

3. Rangeland Inventory and Analysis

3.1. Early Botanical Inventory

Arid land records started with long-forgotten travelers and botanists describing landscape and agriculture, or collecting plants mostly for medicinal reasons. Chinese, Arab, Persian, Greek, Roman, European travelers and many unknown others contributed their part to geographic and botanical records. From available written account about arid Mediterranean rangelands, Petrus Forskål's travel report during the 18th century remains a reference. He traveled to and explored Egypt and the western coast of "*Arabia felicis*" – Yemen sailing from Marseilles to Malta – Constantinople – the Dardanelles – the Rhodes Island. He landed in Egypt – walked to the Red Sea and then sailed again to Al Luhhaya (Yemen) to explore the inland from Hodeida down to Mocha from December 1762 to June 1763. He collected 693 identified specimens along with 55 unknown plants from Yemen. He also recorded information on climate, geology, soil, agriculture and use of the local plants with, whenever possible, their local names in Latin, Arabic, Hebrew or Greek. To better characterize the environment described in his "*Idea Geographico-Physica*", he would use "*Aqua forti*" (i.e. chlorydric acid) to identify limestone and locate iron ore, Agate and Onyx sites. He would characterize soil type in a simple way (gyps, marl, schist, flint, etc) and describe the soil color, the apparent fertility and the presence of humus; he would record the daily temperature at 7 am, 1 pm and at 10 pm in degree Réaumur and degree Fahrenheit. He gave a simple description of the main vegetation types, i.e. coastal plants, pasture plants, cereals, forest, garden and developed lengthy notes about Yemeni coffee. Forskål is certainly one of the first botanist-ecologist who produced and published a range survey along guidelines that were logically adhered since.

3.2. Recent Rangeland Inventory and Analysis

Far later, during the 19th and the 20th century, many followed his pace with the study of vegetation, pasture and rangeland. This new science evolved from a strict ecological point of view to understanding and explaining how the vegetation is organized in relation to the environment. For years, arguments flared over the concept of finite "plant associations" or "vegetation continuum". It was soon recognized that "plants associations" where quite distinct and the "vegetation continuum" concept abandoned.

Beside pure science and curiosity, under pressing demands from governments, scientists launched explorations of marginal lands and especially rangelands to locate new agricultural lands for expanding populations; with similar objectives being pursued from the Western to the Soviet world. All started with the tedious task of listing and identifying plant material collected on sites. It evolved into more sophisticated survey procedures that are explicitly listed and detailed here below. These are the standard phases and steps that are necessary when proceeding to range inventories and analysis from a region. It requires a balance and complementary approach of office and field work.

3.2.1. Office Preparation

While the following is not specific to rangeland analysis, one has to start with:

- **Geographic overview**: The first task is to properly delineate the region of study and identify homogeneous areas and landscapes from a general geographic-geomorphologic point of view, i.e. the relief, the plains, the drainage lines, etc.
- **Topographic maps**: An appropriate scale used according to the region surveyed and the end use of the project. The current availability of GPS (Global Positioning System) with tracking capabilities may often replace difficult-to-obtain topographic maps from remote areas and countries.
- **Climate**: Long term data from official weather stations are often available from the national or local meteorological services. These have to be checked for discrepancies or dubious weather pattern often due to changes in operator, equipment location and specifications, data recording system, etc.

The most important parameters are:

- Precipitation (rain or snow quantity, seasonal distribution, inter-annual and intra-annual variability)
- Air temperature (mean monthly daily minimum, mean monthly daily maximum, mean monthly daily absolute minimum, mean monthly absolute daily maximum, number of frost days). Soil temperatures data may be useful too but is seldom employed.
- Other parameters such as seasonal wind direction and type, solar radiation, evapotranspiration may be useful, but difficult to integrate into simple range analysis.

All these parameters can then be used to compare aridity between regions using a bioclimatic classification and help us understand the seasonal growth patterns of the native vegetation.

- **Geology**: Knowledge and location of parent rocks are identified from geological maps and field trips. This is paramount when characterizing soil types.
- **Soils**: Information about the soil types and physico-chemical characteristics may be available from the literature or collected during field study.
- **Native vegetation**: Prior to field work, it is necessary to consult the herbaria and derive a listing of native vegetation genera and species, and any vegetation maps that may be available.
- **Land use**: Information about past and current land use i.e. settlements location, active agricultural systems, cropping and grazing history, grazing territories by local communities, water points (seasonal availability, quality, quantity), flocks migration routes, wildlife population, will help understanding vegetation types in the surveyed area.

It is advisable to have all this information available in digital/electronic form and maps and organized them in separate GIS layers that can be displayed on a laptop computer for field work in connection with GPS.

- **Maps, aerial photos, satellite imagery support**: early surveyors would use topographic maps during field explorations. The availability of aerial photos post

WWII at different scales simplified field work allowing an eagle's view of large part of the region to identify and compare of similar landforms – vegetation types. This assumes that accurate photo-interpretation is jointly performed in a collaborative and iterative effort between office work and field explorations by photo-interpreters and range surveyors. Since the mid 1970, satellite imagery (small scale-low resolution to large scale-high resolution), software and computer technology has become increasingly and cheaply available. Present users of satellite imagery should however always remember that computer-generated satellite images are only interpretation, transposition, representation and "coloring" of physical signals collected by air-borne sensors. Complex computer statistical processing is always necessary to correct and obtain truthful presentation of range images due to atmospheric alterations (cloud, dust), shading, geometric distortion, soil albedo, vegetation reflectance, especially in arid and semi-arid environment where vegetation cover is poor (usually below 20-25%). This taken into consideration, Satellite imagery (after astute and careful analysis) is now frequently used for rangeland and vegetation surveys and mostly for monitoring purpose. The frequency and variety of satellite specification and flight paths now allows access to "viewing" any part of the world at nearly any season, and year after year. Carefully chosen and processed satellite imagery permits us to produce pre-processed electronic maps figuring tentative boundaries of native vegetation, land forms, farm land, fruit trees plantation, forestry, irrigated areas, free water, building, roads, etc, in 2 or 3 dimensions (Digital Elevation Model). These preliminary electronic maps can be used to annotate the position of key landmarks, limits in vegetation type changes, main landscape features, etc to be confirmed during field work.

Once this information is gathered and what is missing is determined, one may start the detailed field work.

3.2.2. Field Work - Preliminary Field Reconnaissance / Exploration

Basically, the range analysis typically aims at answering four major questions:

a) What is on the range and in what condition it is (qualifying)?
b) Where is it located (location)?
c) How much is available in terms of acreage and feed (quantifying)?
d) When is it available (seasonality)?

All these information are then synthesized on thematic maps at an appropriate scale.

3.2.2.1. Preliminary Field Reconnaissance and Exploration

Preliminary field reconnaissance and exploration are necessary to identify the physiognomy of the different vegetation types, the soil types and the current land use, and develop contact with the local communities. During these explorations, all useful information is collected with the exact coordinates are fixed using whenever possible a GPS and combined with geographical, topographic, climatic and previously collected data from past literature on the region studied. Other data can be collected and GPS-located to optimize the field work in terms of time and finance.

A list of useful data is presented here below. It is not exhaustive and must be adapted to the end-use of the rangeland survey:

1. Physiognomic vegetation types (based on reconnaissance). This is further complemented by proper site description and floristic surveys on each homogeneous ecological zone or land units or each and every physiognomic vegetation type identified.
2. Location of local communities and administrations controlling the region with limit of their jurisdiction.
3. Cropping, fruit trees, forestry zones (this can be checked on recent aerial photos or satellite imagery),
4. Livestock (type of animals, seasonal numbers on the rangeland (from census or from community surveys), usual location on the range, indicative stocking rates (from livestock owners),
5. Location or boundaries of available facilities in the area

   - Isolated dwellings, villages, public service, tourist sites,
   - Main roads and tracks
   - Water resources (springs, wells, cisterns, lakes, permanent or temporary ponds, road water catchments, water delivery systems, wind mill, water trough, water trucking delivery site) with information on the water quality and quantity seasonally accessible to livestock and population.
   - Grazing territories limits with indication of the current or occasional users, grazing rights and seasons of use,
   - Migration corridors, migration routes and period of utilization
   - Fences, exclosures, prohibited areas (civil or military conflicts, mine fields, etc)
   - Protected zones, National parks,
   - Wildlife spotted (name, number, population structure e.g. age distribution)
   - Special landscape features (outstanding tree, monument, ruins)

6. Current problems identified (Rangeland access, conflict for land or water between farmers and livestock owners, firewood collection sites, potential or current war zones, diseases prone areas, invasive epidemic, water or wind erosion, impact of livestock on wildlife, or vice-versa, etc)

The intricate combination of all this information would have a definite impact on the shaping and evolution of the native vegetation and will be useful when analyzing and monitoring the rangeland vegetation. It helps to stratify the future detailed vegetation and soil surveys that must be located within homogenous units in the region. The ecologist's accumulated field experience, judgment and talent is often sufficient to identify the most common and particular vegetation types/landscape.

Nowadays with the availability of sophisticated computer software using GIS with different layers containing the appropriate parameters, it is possible to identify and locate the ecologically homogeneous area to be field surveyed in detail to better characterize them.

3.2.2.2. Field Vegetation Survey – Ecological Survey

This aims at qualifying precisely the main vegetation types with their relationship with the environments (climate, soils, human or animal impact).
The surveyed sites (or "station") are carefully chosen in homogeneous ecological zones defines with preliminary office studies and preliminary scouting. It is now more often complemented and prepared with GIS support. Stations are often coupled when different types of vegetation occur on homogeneous area (same climate, same soil type) but sustaining different land uses or agricultural systems (example of rangeland adjacent to a cropped site). Changes of vegetation types on a site that appears ecologically homogeneous may indicate a change in land use (past cropping, overgrazing due to high stocking, etc). Logistical reasons (mountains, conflict areas, etc) and time available for surveys may impose a priority in choosing sites, starting with the most representatives (largest areas) to smaller sites that appears not having a impact on future management or rehabilitation actions. It may be useful to locate reference sites (seldom found in the old Mediterranean world) that are still in pristine conditions and displaying undisturbed vegetation (cemetery, protected zones, national or regional parks, etc). It often shows signs of plants that may have disappeared from near-by degraded stations and could be used later for rehabilitation operations.

The vegetation analysis combines two parts:

- *The vegetation composition and organization*; it refers to a floristic listing of the plants present on site and their organization in vegetation association or community; it allows comparison between vegetation associations from different sites and their classification to reach a synthetic view of their relationship.
- *The vegetation structure* relates to plant architecture and spatial arrangement. It results from intra- and inter-specific competition (positive or negative) within the vegetation association to maximize available resources (light, water, and nutrient). It is often used to straightforwardly and visually characterize a vegetation type by its physiognomy.

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Range ecologist / Range management (Mediterranean regions and Central Asia),

- MSc (Botany, Plant physiology, Biochemistry, Microbiology, Geomorphology), Strasbourg, France, 1970,
- Range ecologist (Algerian Steppe and High-Plateau country), Algerian National Agronomic Research Institute, Algeria (1970-71),
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- Senior Scientist, Etudes Comparées des Systèmes Agraires, Institut National de la Recherche Agronomique INRA, Montpellier France (1985-1992),
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- International consultant, Range ecology and management
- Chevalier de l'Ordre National du Mérite Agricole (France, 1991), Scientific Secretary IVth IRC Montpellier, April 1991, Member of Continuing Committee International Rangelands Congress (1991-2003).

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