V
RANGELAND RESOURCE
USE OF ECOSYSTEM CLASSIFICATION IN RANGE RESOURCE MANAGEMENT*

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INTRODUCTION

I bring you greetings from the grasslands of the Dakotas. I am enjoying your hospitality and the opportunity to learn more about the grasslands of British Columbia. The excellent presentations, field tours and personal visits make this symposium a memorable event for me. Previous speakers have provided an in-depth evaluation of the characteristics of your grasslands and some of the problems of integrating these lands into the ecosystem classification used by the British Columbia Ministry of Forests. One of the major criteria of the success of a classification is its usefulness in management — hence the topic assigned to me.

I will briefly review the nature of range ecosystems, some of the concerns and methods of range management, consider the use of ecosystem classification in range management and close with a few suggestions. Range management may be defined as the management of a unit of land composed mainly of one or more range ecosystems for the optimum sustained production of the optimum combination of products and services.

NATURE OF RANGE ECOSYSTEMS

Ecosystems may be described in terms of their structure, function, temporal patterns of change and stabilization, spatial patterns, human interactions, and resources and uses.

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Ecosystem Structure

The components of ecosystem structure may be categorized as the controlling factors or site determinants, the dependent factors or state variables, and the driving variables. The controlling factors include climate, \( c \); geological materials (comprising parent material or initial state), \( i \); relief or initial configuration, \( r \); ground water, \( g \); and available organisms (the macro- and micro- flora and fauna), \( o \). Time, \( t \), may be considered as a site determinant or as a dimension in which the site determinants interact. The dependent factors are vegetation, \( v \); slowly changing soil properties, \( s \); driven abiotic variables, (including various elements of microclimate, soil water, soil nitrogen and other rapidly changing abiotic variables), \( a \); the communities of the grazing food web, \( g \); and the communities of the detrital food web, \( d \). The driving variables are the various elements of current weather and atmospheric phenomena. The relationship between the dependent factors and the controlling factors may be expressed in the following equation expanded from Jenny (1961) and also from Lewis (1969). 

\[ E \text{ or } v, s, a, g, d = f (c_l, i, r, g, o, t) \]

The slowly changing soil properties may be grouped with the controlling factors and referred to as site constants.

A box and arrow diagram of a range ecosystem is shown in Figure 1 (from Lewis 1973). Boxes or compartments represent the components of ecosystem structure. Compartments with single boundary lines are standing crops, while those within double lines are operating conditions. Arrows represent aspects of ecosystem function. Solid arrows are rate processes that transfer energy or matter, while bow-ties are control valves that regulate the processes and dotted arrows are influences. Management is shown as exerting influence on the control valves, thus affecting feedback mechanisms within the ecosystem and the input or removal of energy and matter from the ecosystem. While no data are shown in Figure 1, data on structural relationships in grasslands studied under the International Biological Program have been reported by Coupland (1979).
Figure 1. Flow chart for a range ecosystem
See text for explanation (from Lewis 1973).

With reference to the ecosystem classification used by the British Columbia Ministry of Forests, it is important to recognize that the classification is made on the basis of the site constants and the vegetation which serve as an index of the status of the other compartments. While soil and vegetation are both dependent factors which have developed together, vegetation changes more rapidly than the slowly changing properties of soil. Furthermore, naturally occurring fires are a controlling factor, a part of the climatic element.
Ecosystem Function

Ecosystem function includes the rate processes of energy flow and the cycling of matter. Energy comes from the sun and flows through the ecosystem to a sink in outer space. In contrast, while matter may be added to or lost from a specific ecosystem, essentially all matter remains within the biosphere. Energy flow may be categorized into net primary production (total vegetation growth above- and below-ground) by autotrophs (primary producers); herbivory, carnivory, and parasitism by biophages (grazing food web); and reduction, comminution, and decomposition by saprophages (detrital food web). Energy flow is paralleled by carbon cycling. In addition cycles of water, nitrogen, and phosphorus are especially important. Orderly cycling of matter is necessary for sustained production, and rapid energy flow and nutrient cycling are necessary for high production. Allocation of a large portion of net primary production to the below-ground compartment appears to enhance stability, but usually reduces the yield of products and services that are economically important. Furthermore, while long food chains appear to enhance stability, shortened food chains result in a greater removable product. While no data are shown in Figure 1, data on functional relationships in grasslands studied under the International Biological Program have been reported by French (1979) and Breymeyer and Van Dyne (1980).

Forests and grasslands are radically different in their pathways of energy flow and cycling of matter. Most obvious are the differences in carbon allocation to above- and below-ground producer compartments, accumulation of organic matter, herbivory, resistance of plant production to decomposition, extent of leaching of mineral nutrients and the extent of differentiation of the microclimate from the regional or local climate (Sukachev and Dylis 1964, Rodin and Bazilevich 1967).
Change and Stabilization

Kinds of ecosystem change are outlined in Table 1 (from Lewis 1969). Changes occur on different time scales, such as geological time and recent or contemporary time. The geological processes of uplift, subsidence, erosion etc. are still continuing. Geological history is reflected in the site constants of the ecosystem, including physiography of the landscape (Ryder this publication) and the available flora (Daubenmire this publication). In some parts of British Columbia stabilization of communities since glaciation, has not been achieved and directional change is still occurring. While this effect may obscure some relationships used in classification, the rate of change is slow enough to be of little significance for management.

Table 1. Outline of ecosystem change in time (modified from Lewis 1969)

Geological Time
 Recent or contemporary time
  Nondirectional
   Replacement
     Noneyclic
     Cyclic (Intracommunity)
   Intercommunity cyclic
   Fluctuation
  Directional
   Progression
     Autogenic (culminates in natural steady-state)
       Primary
       Secondary
     Allogenic
     Induced (culminates in managed steady-state)
   Regression
     Autogenic
     Allogenic
     Induced
Directional change from less complex to more complex communities is progression and the reverse is regression (Churchill and Hanson 1958). Progression, which is due to the effect of communities on the habitat, is autogenic progression (Tansley 1935), which equals the synergetic and endodynamic succession of Sukachev and Dylis (1964). Autogenic progression, which involves soil formation, is primary autogenic progression, often referred to as primary succession (Clements 1935) or ecological succession (Odum 1969). Because of the long time periods involved, stages of primary autogenic progression should be separated into different classification categories for management. These differences are classified as soil series and range sites. Secondary autogenic progression occurs after vegetative denudation or destruction when the disturbing agent is removed and usually proceeds rapidly since a soil mantle is already formed. Progression, both primary and secondary, follows multiple pathways with development of communities that vary in botanical composition and in duration as a result of multiple interacting causes (Langford and Buell 1969, Drury and Nisbet 1973, Bazzaz 1979, Gorham et al. 1979). Autogenic regression occurs rarely, if ever, on dry grasslands, but may occur in water-surplus ecosystems due to continued leaching of soluble ions and clay particles or bog formation (Sukachev and Dylis 1964:565). Allogenic succession (modified from Tansley 1935 and Dansereau 1957; the same as the irreversible exogenous succession of Sukachev and Dylis 1964) occurs whenever controlling factors change and may be either progression or regression. Changes in the controlling factors may be sufficiently severe to warrant the term destruction or they may only modify the ecosystem. Most ecosystems are the result of cataclysmic climatic changes, erosion cycles and organism invasions, as well as slow, continuous change in the controlling factors. Thus, the ecosystem is a product of its history.

Although exceptions have been noted (Drury and Nisbet 1973), there is usually an increase in net primary production and relative stability of communities and an increase in diversity of species and life forms as autogenic progression proceeds, eventually reaching a natural steady-state (climax in the sense of Whittaker 1953), characterized by fluctuation change rather than directional change.
Ecosystem change produced (directly or indirectly) by the activities of man is induced succession and may be either progression or regression. Induced regression in the range ecosystems of the world has been documented by many workers (cf. Lewis 1969). Induced progression or range improvement culminates in the goal of management, the managed steady-state which will provide the optimum combination of products and services. The managed steady-state must be determined by experimentation. Management for induced progression or range improvement is a major part of the subject matter of range science (Heady 1975, Stoddart et al. 1975, McLean 1979, Vallentine 1980).

Fluctuation change due to short term variation in the driving variables and to dynamic adjustments in communities is characteristic of the natural steady-state, but also occurs superimposed on directional change. Consequently, managers must be perceptive to distinguish the temporary improvement that may occur on a deteriorating range during wet years, for example, from true induced progression.

Various kinds of ecosystem change are diagrammatically represented in Figure 2, (modified from Lewis 1969). The controlling factors are shown as three containing walls (climate, geological materials, and available organisms) which limit the development of the ecosystem. The walls have been cut away so that the graph of the dependent factors can be seen. The dependent factors are shown as a pentagonal surface with the five wedges representing vegetation, soil, driven abiotic variables, the grazing food web and the detrital food web. Time is the vertical dimension. The development of each factor is depicted as proportional to the distance from the center to the edge of the wedge representing that factor. The area of the pentagon is indicative of the level of energy utilization. The offset in the containing wall of climate indicates climatic change, and a corresponding change is shown in all of the dependent factors. Likewise, a change in the containing wall of available organisms is shown corresponding to the introduction of domestic animals and plants. The densely stippled blocks denote time periods measured
Figure 2. Three-dimensional graph of a natural pasture ecosystem. See text for explanation (adapted from Lewis 1969).
in centuries, whereas lightly stippled blocks denote time periods in years or decades. Induced regression does not reverse the path of primary autogenic progression but is deflected (Godwin 1929) or twisted (Tansley 1935), which is called the demutation process by Sukachev and Dylis (1964). Likewise, the path of induced progression does not simply reverse the previous regression.

Spatial Pattern

The elements of each dependent factor are patterned along gradients of the site determinants. For example, cool season bunchgrasses, such as *Agropyron spicatum* in semiarid regions are usually patterned along the primary gradient of cool-season precipitation. However, the distribution of each species of plant, animal or microorganism is patterned not just along the gradient of a single variable, but along the gradient of a constellation of interacting variables. Patterns may differ among ecotypes and biotypes of the same species (McMillan 1969, Chapin and Chapin 1981). Furthermore, the distribution of a species is likely to be truncated by competition. Thus, a species may exhibit a bell-shaped distribution along an environmental gradient without competition, but with competition may be replaced by its competitor within a fairly narrow increment along the gradient. In addition, the stress of herbivory, disease, or parasitism may influence patterning along an environmental gradient under competition. Different species of plants, animals and microorganisms may be genetically adapted for living with one another, thus facilitating community formation.

Where gradients of one or more controlling factors change rapidly, especially where competition and stress truncate species distributions, community boundaries will be distinct and sharply defined. Frequently, however, ecotones between communities are broad and communities grade slowly from one into another along a continuum, making classification difficult if not impossible. In such cases, multi-dimensional ordination along gradients may be more meaningful for management. If a manager is using a classification which arbitrarily segments continua, he should use judgement freely and extrapolate along continua of variation within the class.
Human Interaction

In most regions of the world, the mosaic of zonal and primary successional ecosystems produced by autogenic and allogenic succession has been extensively modified through logging, burning, grazing, plowing, seeding, fertilizing and other human activities. Thus, the manager is confronted by an array of ecosystems, in varying stages of modification by man, developed from a much smaller array of potential ecosystem types. The manager needs to know the potential ecosystem type to understand how it will respond to management. However, he must also know the nature and extent of human modification and how ecosystems disturbed in different ways will respond. The concept of range site and range condition has been used somewhat successfully to meet this need on natural pastures (Dyksterhuis 1958, Soil Conservation Service 1976, Smith 1978). However, this concept requires extensive modification when the potential ecosystem type is a closed forest and is not usable where monocultures or simple mixtures of either native or introduced species have been seeded. A further complicating factor is the degree of current environmental control, or management level, which can usually be measured in terms of energy input (kcal/ha).

A simplified three-dimensional graph of these relationships is shown in Figure 3. The potential ecosystem type is displayed on the Y-axis, arrayed as a segmented continuum along a moisture gradient from closed forest through open forest, savannah, humid grassland, xeric grassland (or grass-shrubland) and desert. The closed forest is a forest ecosystem. While grazing values are recognized in temporary forest openings due to fire, windfall, insects, etc., these are fleeting values. However, the open forest through the xeric grassland and more productive desert are termed natural pastures, because most of the above-ground net primary production is suitable for grazing by wild and domestic herbivores. The transition from natural pasture to forest occurs where shading of the canopy sharply reduces light penetration, and in consequence, the production of herbage and browse in the understory. Savannahs occur where tree growth is sharply reduced by water stress and where light penetration reaches the base of the tree trunks, resulting in mature trees being limbed to near the ground. Open forests (grazable woodlands) and
Figure 3. Diagram of the major kinds of terrestrial ecosystems as determined by potential ecosystem type, modification by man, and current environmental control.
savannas usually develop a dense growth of short trees (thickets) when disturbed by overgrazing and/or protection from burning (Dyksterhuis 1957). Edaphic grasslands occurring in forest climates are natural pastures also and are extensive and important in parts of British Columbia (McLean 1970). The more productive deserts, with average above-ground net primary production (ANPP) of about 100 kg ha\(^{-1}\) in high range condition, are natural pastures (see ANPP data from Huerou 1979, Rodin 1979, Rodin and Bazilevich 1967). However, the extreme deserts (see Meigs 1953 and revised maps in McGinnies \textit{et al.} 1968) are unable to support a resident population of grazing animals, although grazing may be provided by ephemerals in some years. In this paper, ecosystems with average ANPP less than about 100 kg ha\(^{-1}\) are referred to as non-productive ecosystems. Examples are extreme deserts; barren areas, such as barren badlands; mountains above about 6000 m; glaciers and snow-fields. Basically, these are the areas excluded from the biosphere by Sukachev and Dylis (1964) and which are classified as land capability class VIII rather than a range site by the United States Soil Conservation Service.

The extent of modification by man is displayed on the x-axis. Modification of natural pastures which does not destroy the plant community does not change its classification as natural pasture, although it may lower range condition. However, the native vegetation is destroyed and replaced by native or introduced species for grazing, a derived pasture is formed. Where these lands are managed with a low degree of environmental control, they are a kind of range, but not natural pasture. Where the potential ecosystem type is forest, especially in developing countries, extensive areas are maintained as derived pasture and managed as range. Such areas in native or naturalized cover are called native pasture (Soil Conservation Service 1976). Seedings of monocultures or simple mixtures of native species on rangelands are also derived pastures. In the United States and Canada vast acreages have been seeded to introduced
species, especially crested wheatgrass, and managed with a low degree of environmental control. These are derived pastures, not natural pastures, and are considered to be a kind of range ecosystem when managed like rangeland (Lewis 1969, Range Term Glossary Committee 1974). Areas revegetated with annual or perennial crops and managed for crop production are agronomic ecosystems or agro-ecosystems (Loucks 1977). Land converted to residential and industrial use, including airports, highways, etc. are classified as residential-industrial ecosystems, also referred to as urban-industrial or technological ecosystems (techno-ecosystems: Naveh 1982).

The level of current environmental control or management intensity is displayed on the z-axis. Introduced pastures that receive periodic renovation and/or cultural treatments, such as tillage, fertilization, mowing, weed control, and irrigation, are tame pastures (Range Term Glossary Committee 1974) and are classed here as agronomic ecosystems. When very high environmental control is exercised, even natural pastures should be classified as agronomic ecosystems. For example, if a native range on a clayey range site in the semi-arid portion of the northern Great Plains (vegetated primarily with Agropyron smithii, Bouteloua gracilis, Buchloe dactyloides, a trace of the annual grass, Bromus japonicus and a trace of broad-leaved annual herbs) were put under a waterspreading system, fertilized with nitrogen and treated with atrazine to control the annual brome and 2-4, D to control the broadleaf weeds, a monoculture of the wheatgrass would develop which would be essentially indistinguishable from a seeded stand of this species.

It is imperative for a manager to know the potential ecosystem type and the kind and extent of modification by man of the land which he manages. He should also know the degree of current environmental control which has been exercised in recent years. Combining the y, x and z axes in Figure 3, five major kinds of terrestrial ecosystems are recognized: non-productive, forest, range, agronomic, and residential-industrial. These
categories are similar to the level one categories of Anderson et al. (1978), except that water is not classified; wetlands are not separated from forest or range; tundra is included with range; and both barren and perennial snow or ice are combined as non-productive ecosystems.

Resources and Uses

A resource is anything which is useful for something – either products or amenities (Schwartz et al. 1976). A resource may be present but not recognized; or it may be recognized but not used. A use (or land use) is what an ecosystem is being used for. Important human uses of major kinds of terrestrial ecosystems are shown in Figure 4. It is important to note that range is a major kind of ecosystem, occupying about 43% of the earth's land surface, which produces many products and services. While range is not a land use the term is sometimes used (erroneously) as a synonym for livestock grazing, a land use which may occur on forest, range or agronomic ecosystems.

Management Considerations

The purposes of range management are to obtain the optimum sustained production of the optimum combination of products and services from range ecosystems and to optimize the coupling of other kinds of ecosystems with range to enhance production. In commercial ventures the pitfall of maximizing short term economic gain at the expense of long term environmental deterioration must be avoided by perceptive decision-making (Bernstein 1981). Both private and public ranges are part of the total human ecosystem and are regarded as landscape ecotopes by Naveh (1982). The major objectives of range management are to maintain diversity and stability for the optimum combination of uses, while achieving high production by 1) increasing the allocation of net primary production to the above-ground compartment; 2) altering the pattern of herbivory to favor the objectives of management; 3) increasing the efficiency of resource utilization; and 4) increasing the rate of energy flow and nutrient cycling.
Figure 4. Important human uses of major terrestrial ecosystems (o: none; -: some; √: important; ++: very important)
Of the basic practices available to accomplish these objectives (Table 2), weather modification and management of the detrital food web are least understood. Furthermore, the costs of the direct manipulation of vegetation, soil and water frequently exceed the returns in water-deficient ecosystems. In contrast, regardless of the combination of uses selected, animal management and fire management are two of the most powerful and economical practices available for manipulating range ecosystems.

Table 2. Practices available for manipulating range ecosystems

Animal management (grazing food web)
  Managed grazing animals (domestic and wild)
    Kind and proportion
    Spatial distribution
    Season of use
    Grazing system
    Stocking rate

Unmanaged consumers

Fire management (burning and suppression)
  Vegetation management
    Plant control (herbicides, growth regulators, etc.)
    Range seeding
    Pasture planting

Soil management
  Surface alteration
  Alteration of sub-surface structure
  Soil amendments

Water management

Management of the detrital food web (including the rhizosphere)

Weather modification
CLASSIFICATION FOR MANAGEMENT OF RANGELANDS

Recent legislation concerned with land management in the United States has provided an impetus for the improvement of land classification. Interest has increased in other nations also, especially on an international and global basis. Mueller-Dombois and Ellenberg (1974) reviewed several classification and ordination procedures, including that of Krajina (1965) on which the system used by the British Columbia Ministry of Forests is based. Purposes and methods of classification have been discussed by many workers, including several in the October 1978 issue of the Journal of Forestry (Frayer et al. 1978, Bailey et al. 1978). In addition, West and Shute (1978) compared 12 classification methods used on rangelands and suggested that a combination of ordination and classification may be most useful for management. In the United States, an interagency committee is developing a four-component classification framework including the components of soil, vegetation, water and landform (Merkel 1982, Driscoll et al. in press). Those areas which are uniform with reference to more than one component classification are called "Ecological Response Units".

A common source of agreement in these reviews is that to be the most useful for range management, an ecosystem classification should provide homogeneous categories for planning and management, facilitate organization and communication of information, and aid in the development of hypotheses for further experimentation. Ideally, the classification categories should be sufficiently homogeneous to: (1) accumulate data to provide estimates of seasonal and annual means, variability, and probability of occurrence of pertinent driving variables, state variables, and parameters of energy flow and nutrient cycling; (2) permit the development of simulation and optimization models which, with obtainable inputs will provide (with suitable precision) seasonal and annual estimates of significant parameters of energy flow and nutrient cycling and estimates of the optimum combination of products and services; (3) permit the reliable prediction of the potential ecosystem structure, function and production with various combinations of uses; and (4) permit the reliable prediction of the responses of the ecosystem to management.
Furthermore, the classification should result in the delineation of units that can be located on maps of suitable scale. In addition, the cost of data collection and processing for both inventorying and monitoring must be within the budgetary restrictions of the agencies involved. Multi-spectral, multi-temporal remote sensing with photography and electronic scanners, using ground, airborne and space platforms offers much promise in meeting these restrictions (Driscoll et al. 1978, Aldrich 1979). A land-use - cover classification has been developed for use with remote sensing (Anderson et al. 1976, Witmer 1978). In some cases, it may not be possible to collect the desired data remotely, but it may be possible to collect data that are highly correlated with the desired data and to predict the desired output with statistical or simulation models.

While remote sensing data alone may not be adequate for inventorying and monitoring range ecosystems, evidence is accumulating that the incorporation of these data with other pertinent information sources in a geographic information system (Steigmer and Giles 1981) may substantially reduce the overall cost of data collection. The theme of the VII Pecora Symposium held at Sioux Falls, South Dakota, in October 1981 was "Remote Sensing: An Input To Geographic Information Systems in the 1980's". Robert H. Haas, EROS Data Center, United States Geological Survey, Sioux Falls, South Dakota in cooperation with the Bureau of Land Management demonstrated the scientific and economic feasibility of using LANDSAT data for mapping present vegetation and then integrating the vegetation map with ancillary data in a geographic information system to delineate uniform Site Write-up Areas. Because of the rapid improvement in remote sensing technology, classifications should be designed to utilize remotely sensed data, especially in monitoring the responses of range ecosystems to management.

SUGGESTIONS

While Dr. Krajina and his students and the British Columbia Ministry of Forests deserve the highest praise for developing an excellent ecosystem classification, from the standpoint of a range ecosystem manager and of a forest ecosystem manager concerned with resources for livestock grazing and big game habitat, several constructive suggestions can be made.
First, while I am an outsider unfamiliar with the use of the ecosystem classification method used by the Ministry of Forests and encumbered by the prejudices of a range scientist, it appears to me that the climatically determined grasslands and savannas of British Columbia should be recognized as zonal ecosystem associations occurring in a bunchgrass biogeoclimatic zone. Krajina (1969) reported that ".. the Ponderosa Pine Bunchgrass on finer soils is characterized by semi-arid steppe or sage brush (Artemisia tridentata) or bitterbrush (Purshia tridentata) plant associations, whereas forest trees may grow only poorly and always on coarser glacial drift soils or coarse alluvial deposits". Brayshaw (1970) noted that ponderosa pine (Pinus ponderosa) parkland gave way to steppe vegetation at the lower elevations due to a combination of low soil water, soil temperatures occasionally hot enough to be lethal for tree seedlings, frequent fires, and competition from the grassland vegetation. Williams (this publication) reported higher water deficits in the grasslands of southern British Columbia than in the driest part of the Mixed Prairie in Alberta. Tisdale (1974 and this publication) and Tisdale and Hironaka (1981) have stated that the grasslands (including grass-shrublands) of southern British Columbia are a part of more extensive grasslands south of the international border.

Second, on the basis of the requirements for the management of range ecosystems discussed earlier in this paper, the classification is inadequate in its present form. With relatively minor modification, most of the variation associated with primary autogenic progression could be classified in this system. However, extensive modification is required to adequately classify the effects of fluctuation change, human modification and current environmental control. In designing a classification for management, the concept of ecological distance from climax could be applied within all ecosystem units. With suitably chosen input data, various multivariate analyses, with both within and between cluster variances, could provide a quantitative measure of the extent of modification by man. Various discriminant analysis and cluster procedures (Ray 1982), canonical analysis (Seal 1964; Gittins 1979) or direct gradient analysis (Whittaker 1973a,b) would be useful
for this purpose. However, Huschle and Hironaka (1980) found the simple index of similarity based on presence or absence of plant species was useful in separating seral stages within a habitat type.

Periodic canonical analysis of above- and below-ground net primary production by species or species group could be very useful for assessing the productivity of pastures derived from forest ecosystems, their potential for various uses, the rate of convergence toward the natural steady-state (forest), and the timing of treatments required to maintain their productivity as derived pastures.

Third, inventorying and monitoring of ecosystems are expensive activities. Consequently, consideration should be given to the use of multi-spectral, multi-temporal, multi-phase remote sensing inputs into a detailed geographical information system to guide management for multiple and coordinated uses. Classification using the ecosystem association phase, coupled with ordination or canonical analysis within phases to separate the effects of human modification, could provide the basic framework of an information system. Because of the very large volume of data involved, such geographical information systems probably will have to be restricted to specific management units. However, geographical information systems incorporating less detail may be required over an entire province to guide policy formulation. British Columbia is fortunate to have an ecosystem classification which, with minor modification, can form the basis of the geographic information system. The Ministry of Forests should be congratulated on the excellent quality of work being done.

REFERENCES CITED


POSTER SESSION:
SYNOPSIS OF THE BIOPHYSICAL FORAGE CAPABILITY
CLASSIFICATION SYSTEM

Dennis A. Demarchi

INTRODUCTION

The British Columbia Ministry of Environment has developed a biophysical classification program that can be used for resource capability inventories and resource planning. The biophysical classification program synthesizes physical and biological data (landforms, surficial materials, soils, climate, vegetation and organisms) to form "ecologically significant" units of the landscape, called a biophysical map unit. This program provides an opportunity for the comparison of all renewable resources occupying the same biological and physical resource land units (Demarchi et al. 1980).

Currently there are several classification systems within the Ministry of Environment that use biophysical land units as the basis for providing capability ratings for agricultural crops, forests, recreation and wildlife (native ungulates) (Demarchi et al. 1980, Walmsley 1976).

The agricultural capability inventory conducted under the Canada Land Inventory Program was recognized to be deficient in the area of rangeland or forage classification (Runka 1973, Kenk and Dawson 1980). Rangelands were considered only as part of the overall agricultural classification, and the emphasis was on domestic livestock forage.

Runka (1973) outlined a tentative land capability classification for grazing; the major
shortcomings of that proposal were that it emphasized grassland areas but did not consider the problem of seral stages in forested sites, and it did not consider the productivity difference amongst different plant growth forms i.e. shrubs, grasses, forbs or lichens. Kenk and Dawson (1980) attempted to clarify the rangeland classification of the Agricultural Land Capability system. However, they ignored all Class 1-4 and 7 agriculture lands, and their emphasis was still on rangelands and domestic livestock grazing.

This paper summarizes the forage capability classification recently developed by the Ministry of Environment (Demarchi and Harcombe 1982)*.

The forage capability classification is intended to classify the biomass potential of various plant life forms and as such should be useful in identifying forage values for all of British Columbia's ungulates (both livestock and wildlife). This classification system, like other capability systems that use a common base of biophysical maps will facilitate management, protection and trade-off decisions made by resource planners and managers concerning wildlife, range, timber and livestock.

FORAGE CAPABILITY CLASSIFICATION

Forage can be defined as "all harvested and unharvested vegetation, except fruits of woody plants and harvested grains, that is available and acceptable to livestock or game animals" (U.S. Forest Service 1963). In the forage capability classification, only native or wild growing introduced plant species are considered.

*Copies are available from the Planning and Resources Management Library, Ministry of Environment, Parliament Buildings, Victoria, B.C.
Forage components include all plant species which may be utilized as food—
herbaceous plants, shrubs, trees and lichens. It is intended that this forage capability
classification system be applicable only to ungulates (both livestock and wildlife).
However, even within this group of animals there is a wide diversity of foraging habits.
Virtually all herbaceous and shrubby vegetation may be consumed in varying amounts at
some point in time. Therefore, all herbaceous plants and browse are considered as forage
when determining production values. Since crustose lichens are too firmly affixed to the
substrate to be utilized, and very little is known of the importance of foliose lichens, in
this classification only fruticose lichens (both arboreal and terrestrial growth forms) are
considered as forage.

Forage production is determined by measuring the annual above ground growth of
vegetation. It is not a measure of total production because it does not account for wood
production, subterranean growth or plant tissue that disappears by weathering and
decomposition. Most above ground biomass of herbaceous plants is annual growth.
Production estimates for herbaceous vegetation are based on oven dried weights of all
living above ground parts (avoiding dead, standing matter) from a given area.

Browse production can be determined by clipping, separating and weighing current
annual leaves and stems. This procedure can be extremely time consuming, and is not
practical for most reconnaissance level inventories. There appears to be a greater
variation of percent canopy cover with shrubs than with herbs, especially on forested
sites. Annual biomass production on shrubs, especially those with a circular growth form,
relates well with percent cover measurements. Therefore, an alternative sampling
procedure for the measurement of browse production would be canopy coverage
estimates. This is obviously much faster than clipping or using a three dimensional
measurement.
Fruticose lichens are the third major forage type considered. Annual growth is usually very slow, and difficult to separate from previous year's growth. Therefore, productivity is best related to biomass without any specific time scale. Terrestrial fruticose lichens are measured by percent cover and are not clipped or weighed. Arboreal fruticose lichens are measured by estimating the abundance of lichens and the abundance of the growing sites (tree trunks and branches) and resulting in a biomass estimate (kilograms/hectare) (see Stevenson 1978 and 1979).

Capability Classification

Land-use Capability has been defined by Hills et al. (1973) as "... the potential of an area to produce a specified crop [in this case, herbs, shrubs and lichens] under specified technological controls. The level of production for forage is measured in terms of the amount of forage produced, given the kinds and degrees of limitations which prevent any specific land unit from reaching the maximum production".

The Ministry of Environment's forage capability classification indicates the type and quantity of forage that can potentially grow on a unit of land. Land units are assumed to exist within a single biophysical unit and to be homogeneous with respect to physical characteristics (e.g., soil, surficial material, climate, topography). Each biophysical unit may be divided into a number of successional stages, defined by plant community structure, dominant plant species composition, and competition relationships in the community.

Three general assumptions are implied when a capability class is assigned. These are: 1) the classification is based on the "natural state" of the land without major improvements such as fertilization, drainage, irrigation, or introduction of exotic plant species; 2) in a given capability class, location, access, distance to markets and size of
units are not considered; and 3) access to water, salt, cover and other rangelands, while important to livestock and wildlife management, cannot be realistically appraised at this time and are not considered in this classification.

It is intended that the rangeland biophysical capability program be conducted at a reconnaissance level of inventory. Therefore, the classification is applied to a project area on the basis of one year's data. Forage capability can be mapped at any number of scales and for one or more forage types. The Ministry of Environment has mapped forage capability at a reconnaissance level inventory at a scale of 1:50,000 on biophysical base maps.

Forage Capability Classes

Five capability classes are described for the three types of native forage considered: herbaceous plants, browse, and lichens. The classes are defined on the basis of a range of either dry-weight of biomass per unit area or canopy coverage (see Table 1).

Table 1. Production range for forage types for each capability class

<table>
<thead>
<tr>
<th>FORAGE TYPE</th>
<th>1 (very high)</th>
<th>2 (high)</th>
<th>3 (moderate)</th>
<th>4 (low)</th>
<th>5 (very low-nil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbaceous vegetation (kg/ha/yr)</td>
<td>1000-2000+</td>
<td>500-1000</td>
<td>225-500</td>
<td>110-225</td>
<td>0-110</td>
</tr>
<tr>
<td>Woody vegetation (% canopy coverage)</td>
<td>50-100</td>
<td>25-50</td>
<td>10-25</td>
<td>5-10</td>
<td>0-5</td>
</tr>
<tr>
<td>Terrestrial lichens (% canopy coverage)</td>
<td>50-100</td>
<td>25-50</td>
<td>10-25</td>
<td>5-10</td>
<td>0-5</td>
</tr>
<tr>
<td>Arboreal lichens (kg/ha)</td>
<td>1000-2000+</td>
<td>500-1000</td>
<td>225-500</td>
<td>110-225</td>
<td>0-110</td>
</tr>
</tbody>
</table>
Environmental Conditions

Capability maps often list limiting subclasses in conjunction with the capability class rating (Hills et al., 1973). This implies that a limiting factor prevents that unit from attaining a higher rating based on regional climate and physical site characteristics. However, wildlife (ungulate) capability mapping links the class ratings with environmental conditions rather than with limiting subclasses. These environmental conditions are also used in forage capability mapping. The conditions are defined as factors of the environment that have a significant influence on the production of forage and thus on the capability rating. These environmental conditions may be either positive or negative in their effect on the ability of the land to produce forage.

For convenience, the environmental conditions are described and symbolically represented in three main categories: those relating to climate (such as temperature and snowfall), those relating to the inherent characteristics of the land (such as landforms, soils or vegetation potential) and those relating to permanent anthropogenic (man-made) changes to the land base. This listing is not restricted to those conditions described - it may be expanded or reduced to reflect both the characteristics of the project area and the scale of the project. Map symbols and definitions for some environmental conditions are provided in Figure 1.

APPLICATION OF THE FORAGE CAPABILITY SYSTEM

The capability rating described here can be applied to the ability of any site to produce forage regardless of successional stage. Within this classification forage capability is based on the successional stage that yields the highest forage production for
the given class of forage (herbaceous, woody or lichen vegetation). Herbage production is probably highest at, or near, climax in grassland or alpine environments. In forested environments, maximum herbage production likely occurs shortly after tree removal and prior to tree re-establishment.

Much of the province is under forest, therefore it is useful to understand the forage production potential of forests. On treed sites, potential is considered at two stages:

After tree removal by either logging or fire and prior to tree dominance. The exact timing of the most productive stage for forage is to be at the point in time that the unit can be maintained in the treeless state.

At or near rotation age of the forests or when the trees become mature. The precise period of time for the various areas and types of stands being the standards set by the British Columbia Ministry of Forests (B.C. Forest Service 1976).

For special purposes a further option remains, which is to rate the forage production potential of each successional stage of a forest stand. Such a program will provide more information to the forage managers on the dynamics of forage production. Such a classification will probably be more suited to a map narrative or as an attribute in a table of stand characteristics than as a mappable item.

An abbreviated legend (Fig. 1) provides the appropriate symbols for the above forage types - general or specific. For practical purposes, a capability class rating for terrestrial lichens is only provided for geographical areas where the lichens are considered to be an important ungulate food (e.g. caribou ranges).
Figure 1(a). An abbreviated forage capability map legend.
Figure 1(b). An example of a forage capability map.
REFERENCES CITED


VI
FIELD TRIPS
FIELD TRIPS

Two field trips were conducted during the week of the symposium. Prior to the symposium speakers were invited on a day trip to the Douglas Lake and Thompson Valley areas. The objective was to introduce the southern interior grasslands of British Columbia to those who were unfamiliar with them and to refresh the memories of individuals who had studied them in the past. A second field trip, held the first afternoon of the symposium for all symposium participants, provided an introduction to the grasslands of the Kamloops area. A brief account of the discussions which occurred during the "speakers" field trip and a description of the latter trip to the Lac du Bois range are presented below.

SPEAKERS VISIT TO THE NICOLA VALLEY AND ASHCROFT AREAS

Six stops were made on this helicopter field trip: the first four in the Douglas Lake - Nicola Lake area; a fifth near Spences Bridge; and the last near Ashcroft (Fig. 1). The six sites were chosen as representative of typical climate, parent materials, soils and good condition vegetation at varying elevations.

Much of the upper elevation dry interior grasslands are located on drumlinized till plains; the Douglas Lake area is a good example. The resultant topography is gently rolling. The lodgement or basal till is relatively compact; however, looser meltwater gravels and till also occur in localized areas. A thin layer of loess caps most areas. The lower elevation grasslands of the valleys usually occur on glaciofluvial and lacustrine terraces or colluvial and alluvial fans.

Site one was a grassland-forest transition area at 950 m elevation on a morainal blanket. The soil was an Orthic Dark Gray Chernozem and the grassland vegetation, a
Festuca-Agropyron community, was dominated by *Festuca scabrella* and included such species as *Geranium viscossissimum*, *Stipa occidentalis*, *Delphinium nuttallianum*, and *Carex petasata* which are indicative of fairly moist conditions.

Figure 1. Route of speakers field trip and location of the six sites visited.
Site two, at 1220 m elevation, was similar to the first stop except the grassland was extensive and continuous. *Festuca scabrella*, *F. idahoensis* and *Lupinus sericeus* were the dominant species; the soil was an Orthic Black Chernozem.

Site three, also an upper elevation site (1100 m), had a drier moisture regime as indicated by the Dark Brown Chernozemic soil and the vegetation which included *Chrysothamnus nauseosus* as a dominant with *Agropyron spicatum* and *F. scabrella*.

The fourth site, occurring at a lower elevation (650 m) and close to Nicola Lake, was located within an exclosure on colluvium over lacustrine materials. Prior to fencing in 1968 it was heavily grazed. Recovery has, however, been dramatic; where *Bromus tectorum* once dominated, *A. spicatum* is now vigorous and abundant. Soil was a Brown Chernozem indicating much drier conditions at this elevation.

Site five was on a colluvial fan overlying a fluvial terrace and was representative of dry, low elevation (250 m) grassland. The soil was a silty loam Regosol and the vegetation was dominated by widely spaced *A. spicatum* bunches and a thick lichen crust. A few scattered *C. nauseosus*, *Artemisia frigida* and *A. tridentata* shrubs occurred. Charred remains of shrubs provided evidence of a fire history.

The last site (site six), located on the Ashcroft Ranch, was at 875 m elevation on a morainal blanket. The soil was an Orthic Dark Gray Chernozem and the vegetation was a *Festuca - Agropyron* community with an abundant forb component.

Throughout the field trip the dynamics of grasslands and the various factors contributing to their development and maintenance were discussed. It was agreed that the numerous environmental factors influencing the development of the grassland
landscape are not clear, nor the roles they play easily understood. Many questions require study. Some of the observations made and points discussed were:

1. From a broad climatic perspective, grasslands stratify into lower, middle and upper elevational bands. However, in mountainous regions, such as British Columbia, the concept of macroclimate is difficult to apply because a site will almost always be affected by its peculiar local climate.

2. The vegetation and soil boundary between grassland and forest tends to be sharp. It was suggested that this could be the result of the concerted or independent influence of a number of factors. Several suggestions follow:

   a) Tree seedling encroachment depends on microclimate conditions and competition factors. Thus soil moisture often serves as a limiting factor at the point where moisture deficit becomes too great for seedling establishment and survival. The vane shaped foliage of bunchgrasses intercepts precipitation, while the fibrous root system takes up any moisture in interplant spaces. Tree encroachment often occurs during a series of favourable growing seasons but one season of drought may affect the survival rate of trees significantly.

   b) Compact basal till may restrict root development.

   c) Total stone content may determine the depth to which moisture can penetrate, thus limiting trees.

   d) Determining the age of the soil and distinguishing between degrading and regrading soils (structure is entirely different and organic litter does not accumulate on the surface of a regrading soil) would be important aids for understanding the dynamics of the forest-grassland transition.
e) Fire may be an important determinant of treeline. Nevertheless, it was noted that in the soils of the Douglas Lake area there appeared to be little evidence of an extensive fire history. From observations of grassland fire patterns in British Columbia it appears that fire tends to concentrate in the gullies and draws, rarely sweeping across large open areas.

3. The dry interior grasslands of British Columbia extend quite a distance north and south. In the south, i.e. in the Okanagan, the vegetation is strongly influenced by the unglaciated grasslands beyond the border. In the north, the communities appear to be similar to those in the south with analogous species filling certain niches. Festuca idahoensis is an important dominant south of the border. It becomes more or less codominant with F. scabrella in the southern portion of British Columbia's grasslands; neither Festuca species extends north into the Cariboo – Chilcotin grasslands. Bromus japonicus and B. mollis, common invader species south of the border, occur much less frequently in British Columbia, where B. tectorum is usually abundant on disturbed sites.

4. Heavy livestock grazing, cultivation, pocket gophers, grasshoppers and fire were considered to have contributed to masking the natural climax vegetation of many parts of the grassland. For example, in the lower elevation Artemisia tridentata – Agropyron spicatum community, the sagebrush increases dramatically with grazing pressure but is eliminated when burnt. After a burn on a favourable site it may take years for the sage to overcome the vigorous grass competition and regain its original cover.
GUIDE TO THE LAC DU BOIS GRASSLANDS

Alastair McLean

We must have knowledge of historical utilization to interpret vegetation patterns and understand the complexities of range trend and condition. In addition, to make proper resource management decisions, we must have an understanding of surficial geology, climate, soil, native vegetation, wildlife and water resources of the area under consideration. The purpose of this paper is to provide that information for the area north and west of Kamloops covered in the symposium field trip.

GENERAL DESCRIPTION

History

The known history of the Lac du Bois rangelands dates from about 1842, when horses from the Hudson's Bay Company trading post in North Kamloops were pastured there. Records show that more than 700 company horses were grazed. This season-long grazing pressure resulted in rapid deterioration of the range. Once the Cariboo wagon road was completed in 1863, use of the range by the Hudson's Bay Company declined and, about 20 years later, the area was virtually abandoned by the company, after which range condition improved. Subsequently, Kamloops cattlemen probably took over the Lac du Bois range. No records have been found prior to 1900, when forestry maps show two major grazing leases.

In the early 1900's, settlers moved into the area to take up 160-acre homesteads. The homesteaders immediately fenced their property and again range condition declined. The homesteading era peaked in 1913 with a population of about 35 families. However,
the soil proved too rocky and the climate too harsh. By the late 1920's the sawmill had closed down and all of the families left the area. By 1928 the area was returned to ranchers through land sales and grazing leases. Two major leases developed: Joe Bulman, who ran cattle and horses on the west and south portion; and the Heron brothers, who ran sheep in the north and east portion. Rannie Hayward, took over the Bulman lease with a sheep operation in 1939, and Reg Hook took over the Heron lease in 1947 and ran cattle. The range recovered markedly under the Hayward management. The sheep were moved off the grasslands in early May, trailed to alpine range west of the Fraser River and did not return until mid-October; the range rested during the summer. By contrast the Hook lease did not improve since the cattle were left on the range longer in early summer.

During recent years the range has been managed by the British Columbia Ministry of Forests through grazing permits. Dates of grazing and number of animals are set annually. Numbers of stock are controlled so as to leave about 50% carry-over of herbage. Animals are removed early enough to permit adequate regrowth before spring growth ceases.

Climate

The Kamloops climate is one of relatively mild winters, hot summers and light precipitation. It is strongly influenced by the rain shadow from the Coast mountains. Differences of topography and elevation, however, modify the climate locally. March and April are the driest months, while December and January are the wettest. Precipitation in the form of rain is heaviest in June and August, while snowfall peaks in December and January. The annual precipitation averages 260 mm in the valley floor, while at the forest edge (975 m) it is about 20% more (310 mm). The increase in available moisture and the decrease in temperatures with increasing elevation is an important determinant of the type of vegetation which grows at different elevations. Air inversions, a common phenomena of interior valleys, also modify the climate significantly at the lower elevations (up to about 700 m).
Surficial Geology

On the east side of the Lac du Bois plateau there is a group of sedimentary and igneous rocks, while just west of the area is a band of volcanic rocks. Glaciation has played an important role in shaping the present topography. The interior ice sheet, which was about 2000 m deep, retreated about 10,000 years ago and resulted in numerous depositional and erosional features, many of which can be seen on the Lac du Bois range. A mantle of glacial drift including glacial till covers most of the area. Wind distributed fine surface materials before vegetation became established; therefore most of the area is covered by loess from a few to 30 cm deep. The Glacial Lake Thompson, which covered the valley during the ice melt to a depth of about 550 m, left extensive silt deposits on the valley terraces.

Soils

The major kinds of soils on the grasslands of the Lac du Bois area are Chernozems. These soils developed under the intense weathering processes characteristic of the grassland environment. Organic matter from decaying plant parts accumulates in the topsoil, and the degree of accumulation depends in large measure on the moisture efficiency of the site. The organic matter content increases with increasing elevation and accounts for the darkening of the surface horizons with increasing elevation as the soils move from Brown to Dark Brown and Black. At the forest-grassland boundary there is a sharp increase in available moisture. As a result, Luvisols and Brunisols develop with their characteristic thin layer of organic matter on the surface.

Vegetation

In the Lac du Bois area, between the valley floor and the Pseudotsuga menziesii forest edge there are four major plant communities or zones: three grassland zones and, visible to the west, one savannah-forest zone, the Pinus ponderosa zone.
All three grassland zones are dominated by perennial bunchgrasses, with *Agropyron spicatum* being common to each. The number of species and biomass production increase considerably with increasing elevation. The phenology of the plants is delayed with increasing elevation by approximately 10 days between the valley floor and upper forest edge.

Tour Stop Descriptions

Tour stop locations are shown on the climate parameter maps (Williams this publication: 57-60).

Stop 1: Aberdeen (720 m). *Pinus ponderosa* savannah zone. The *Pinus* zone is found between 600 and 900 m elevation and is characteristically an open mixed stand of *P. ponderosa* and *Pseudotsuga menziesii* and a continuous phase of bunchgrass vegetation. For logistical reasons this stop was made at a site south of Kamloops rather than in the Lac du Bois range area.

The degree of tree influence is important in determining the nature of the soil. This is clearly shown in savannah areas. The soils at Stop 1 were a Dark Brown Chernozem and what appeared to be an Eluviated Eutric Brunisol. These soils were found in aeolian material over colluvium over basal till. The Chernozem occurred under the open grassland vegetation on upper slope positions, while amongst the trees on lower slopes and in depressions the A horizon did not meet the criteria for a chernozemic Ah but had an Ae > 2 cm. Chemical analysis is necessary to confirm classification as an Eluviated Eutric Brunisol.

Near the trees the soil profile has a thicker and lighter textured colluvial layer than the profile under the open grassland. The deeper material may allow greater penetration of soil water enabling pine, a tap-rooted species, to take
advantage of the deeper stored water. Once a tree canopy forms, it appears that the trees intercept enough precipitation to result in a drier solum than under the open grassland, resulting in sparser ground cover.

Bunchgrass vegetation is dominated by *Agropyron spicatum* (36% cover) and *Festuca scabrella* (15%). *Koeleria macrantha*, *Poa sandbergii* and *Antennaria parvifolia* also contributed a considerable proportion of the cover. *Artemisia frigida*, *Tragopogon dubius*, *Taraxacum officinale*, *Gaillardia aristata*, *Erigeron corymbosus*, *E. compositus*, *Arabis holboellii*, and *Stipa comata* were common but less abundant.

This zone provides spring-fall range for domestic stock, winter range for mule deer (*Odocoileus hemionus hemionus*) and yields low-productivity forest of *Pinus* and *Pseudotsuga*. Historically, fire has been important in maintaining the characteristics of this zone.

**Stop 2. Water Tower (400 m) Artemisia tridentata zone.**

The sagebrush-bunchgrass vegetation of the *Artemisia* zone is found from the lower valley slopes (330 m) to about 700 m elevation. The soil at the stop was a Brown Chernozem on glacial till with a capping of loess. Lime was found at about 30 cm. The upper profile was low in organic matter (1%).

The plant cover was dominated by *Artemisia tridentata* and *Agropyron spicatum*. Also important were *Poa sandbergii* and *Castilleja luteaens*. *Arabis holboellii* and *Comandra pallida* occurred frequently but occupied only a small part of the cover. The species list on sagebrush sites in good range condition is normally short (12 to 18 species). *Stipa comata*, *Koeleria macrantha*, *Poa sandbergii*, *Artemisia tridentata* and *Antennaria dimorpha* all may increase as range condition declines. However, *Stipa* and *Koeleria* may, in turn, decrease,
with extended heavy grazing pressure and be replaced with weedy species such as *Bromus tectorum*, *Salsola kali* and *Descurainia sophia*. Under some conditions *Artemisia frigida* may increase, and this species may provide winter feed for deer during periods of light snowfall.

This zone provides early spring and late fall range for domestic stock, habitat for sharptail grouse (*Pedioecetes phasianellus*) and chukar partridge (*Alectoris chukar*) and winter range for deer where *Pinus ponderosa* or *Pseudotsuga menziesii* are in close proximity.

Stop 3. Pruden Road. (700 m). *Agropyron-Poa* zone (middle grassland)

The *Agropyron-Poa* zone was found on mid-valley slopes from 700 to 850 m. The soil at the site was a Dark Brown Chernozem on compact glacial till. The soil colour was a little darker than at Stop 2 because of an increase in organic matter in the surface horizon (4%).

An exclosure, which was fenced in 1958, is in place at this stop. The vegetation protected inside the exclosure was dominated by *Agropyron spicatum* (23% plant cover) and *Stipa comata* (40%). *Koeleria macrantha*, *Poa sandbergii*, *Antennaria dimorpha*, *Centaurea diffusa*, *Taraxacum officinale*, *Tragopogon pratensis*, and *Artemisia frigida* are common but occupy only a small part of the cover. On the grazed area the crown cover of *Agropyron* decreased to only 1%, *Stipa* to 28% and *Koeleria* to 1%. The frequency of *Antennaria dimorpha*, *Erigeron filifolius*, *E. pumilus*, *Grindelia squarrosa*, and *Tragopogon pratensis* was greater outside the exclosure than inside.

This zone provides spring-fall range for cattle but is of relatively little importance for wild ungulates. A variety of waterfowl occupy the many small potholes in the zone and the uplands provide nesting sites for ground-nesting birds such as the meadowlark (*Sturnella neglecta*), killdeer (*Charadrius vociferus*), horned lark (*Eremophila alpestris*), vesper sparrow (*Poecetes gramineus*) and curlew (*Numenius americanus*). Many of these birds are present throughout the grassland zones.
Stop 4. Lac du Bois (900 m). **Festuca-Agropyron** zone.

The **Festuca-Agropyron** zone reaches from 850 to 975 m in the Lac du Bois area. The climate is considerably cooler and more moist than in the lower zones.

The soils vary from Dark Brown to Black Chernozems depending on location and exposure. The surface organic matter is about 10%. The lime layer is now found at about 60 cm. The parent material is mostly till with glacial features such as morainal gravels, meltwater channels and eskers in evidence.

The plant cover on this site was completely dominated by **Festuca scabrella** (47% cover) with less than 1% **Agropyron spicatum**. No other species contributed significantly to the cover. However, species with low cover ratings, but which frequently occurred, were **Poa pratensis**, **Stipa richardsonii**, **Juncus arcticus**, **Achillea millefolium**, **Cerastium arvense** and **Geranium viscosissimum**.

This range is used as late spring and early fall grazing for cattle. The numerous species of poisonous plants which grow in this area present a hazard to livestock. Mule deer spend much of the winter on adjacent forested south-facing slopes but make some use of these grasslands as they move in and out of the trees. The rolling topography and great diversity of flora and fauna make this an attractive recreation area. It is popular for cross-country skiing, snowmobiling, All Terrain Vehicle (ATV) traffic and many other uses.

The Interior Douglas-fir zone (dry) borders upon the upper edge of the **Festuca** zone at elevations from approximately 970 to 1200 m. There is a rapid change in climate adjacent to this interface between forest and grasslands. Soils are generally Luvisols and Brunisols, depending to a great extent on soil texture.
Pseudotsuga menziesii is the dominant tree accompanied by Populus tremuloides, Pinus ponderosa and P. contorta. The ground cover is dominated by Calamagrostis rubescens with a wide variety of shrubs and forbs.

The Pseudotsuga zone offers early summer - early fall range for cattle. Tree harvesting is an important activity. The area provides late fall and winter range for mule deer and moose (Alces alces andersoni).
VII
DISCUSSION SUMMARIES
GROUP DISCUSSION RESULTS

The main objectives of the group discussions were: to introduce the participants to problems, ideas or approaches that they may not normally consider; to promote communication among symposium participants; and to assist the British Columbia Ministry of Forests Research Branch in identifying critical needs in grassland research and classification as determined by a cross-section of individuals interested in grassland ecology. To complete these objectives groups of eight or nine persons were assigned to one of three topics. The topics were:

1) Should fire be considered a natural component of "true" grassland ecosystems in British Columbia?
2) What are the major research needs of grassland classification in British Columbia?
3) What are the major research needs in grassland ecology in British Columbia?

The findings of these discussion groups are summarized below.

1. Should Fire be Considered a Natural Component of "True" Grassland Ecosystems in British Columbia?

Although fire was not dealt with in any of the papers delivered it was thought important enough to warrant discussion. In British Columbia fire has been used by range managers to eradicate unwanted species and enhance forage species. Fire has also been suggested as the causative agent for the perpetuation of grassland vegetation on "forest" sites.

The motives in presenting this question were:

1) To determine whether those who attended the conference thought there was evidence for fire and to climate to be closely united and fire to be considered a natural component, thus dispelling the theory that many grassland ecosystems were merely pyroclimaxes on "forest" sites.
2) To gain information regarding the value of fire as a range management technique.

3) To determine the "state of the art" regarding the use of fire as a range management tool.

4) To determine whether historical information is known regarding the role fire has played in the evolution of British Columbia grasslands.

5) To determine the general background information that is known to be available regarding general fire ecology and grasslands, particularly with respect to British Columbia.

Unfortunately this topic did not generate the heated discussion that was expected. One group went so far as to suggest that "wire" might be better considered a natural component of grassland ecosystems. All working groups felt, however, that prior to organized suppression activities fire was a natural component of many grassland ecosystems in southern British Columbia. Logically, the origin and maintenance of natural grasslands would be related to a variety of environmental factors, of which fire may be one. It would be a misconception to think all southern British Columbia grasslands are fire induced, however.

Because the grasslands of southern British Columbia are the northern extent of the bunchgrass grasslands to the south there is a great deal of forest-grassland ecotone, particularly in the Cariboo - Chilcotin. One of the major changes resulting from fire suppression activities has been suggested to be the re-establishment of trees in grassland areas adjacent to the forest. In view of this, the working groups felt that planned and prescribed burning is a necessary management tool for some grassland ecosystems.

In order to effectively use fire as a management tool, the working groups felt it was necessary to have an understanding of naturally occurring fires. It was concluded that
general information on fire and fire history of grasslands is sparse. The working groups therefore directed attention to discussing several of the effects and characteristics of fire which were deemed as important considerations over both the long and short term. In summary they were:

1) The effect of fire on vegetation distribution and community composition. It was noted that many grassland species are adapted to a fire environment while others are very susceptible to burning. Fire generally reverts vegetation to an earlier successional stage. Thus succession after fire would somewhat depend on the original assemblage of species.

2) The effect of fire on soils with respect to structure, nutrients, organic matter, leaching and moisture was related, over the long-term, to its effect on changing the vegetation to an earlier sere. Over the short term, it was suggested a moderate fire may only affect the top 1 or 2 cm of the soil horizon depending on the combustible fuel available on the surface and the moisture content of the upper soil horizon. Studies were mentioned that have shown, for some soils, a short term increase in N, K, P and Ca and that soil temperature and non-wettable resins may increase.

3) It was generally felt that the effect of fire on wildlife is primarily related to the effect on vegetation with respect to forage type and productivity, cover and movement.

4) The effect of fire on man as it relates to proximity to settlements, aesthetic appeal, economics and scientific needs was mentioned.

5) The physical characteristics of fire including: available fuel; location (i.e. crown or ground); climatic condition before, during and after; slope direction and angle; and frequency were thought to be critical considerations.
In addition, several research items were mentioned. To identify research needs with respect to fire and management of grasslands, all groups felt that it is critical to determine management objectives; a fire that benefits one resource may be detrimental to another. The research areas which were discussed are divided into various topics below:

A. Methodology
   - determining impacts of burning at various seasons on forage availability, growth cycle of plants, nesting period etc.
   - how to have a "safe" contained fire
   - how to assess fuels to determine heat and speed of burn.

B. Classification of Fires
   - fire results predicted for various geographic areas, fire intensity, season of burn and soil moisture.

C. "Pyro-ecology" of Individual Plant Species
   - survival strategies; effect on role in community as a whole.

D. Economics
   - who will benefit at who's expense; the rancher-farmer, forester, wildlife, researcher, recreationist?
   - can you put a monetary value on the improvement?

F. Fire History
   - date fire frequencies and compare grasslands with forests.

In conclusion, the working groups felt that unless there is a basic and accurate understanding of the nature and organization of the ecosystems within grassland areas it would be difficult to utilize fire as a management option.
2. What are the Major Research Needs of Grassland Classification in British Columbia?

The British Columbia Ministry of Forests ecosystem classification program is predicated upon the concept that ecosystem classification provides the resource manager with a constant framework upon which he can base various interpretive needs. At present an attempt is being made to classify grassland ecosystems within the ecosystem classification system. Due to the specialized nature of grasslands, particularly the general absence of grasslands in a climax condition and their commonly over-grazed state, this is not an easy task. As a result many research needs regarding grassland classification in British Columbia come to mind.

Research needs discussed by the working groups generally fell into three categories:

1) Specific Research Needs
2) Ecological Reserves and Exclosures
3) Communication.

These are discussed, by category, below. It was generally considered that enough fundamental information was available to construct the framework of a classification system. Therefore, further effort should address more specific problems identified by managers; thus investigations would not only assist in refining the classification scheme but would also be popular and viewed as practical.


a) Climate

It was recommended that climate stations be located in order to characterize individual classification units. Determining effective precipitation and evapotranspiration were two fundamental objectives.
b) Soils

It was recommended that soil moisture dynamics of various soil types be documented and related to various readily recognizable soil features and vegetation types. Soil features most commonly mentioned were: Ah horizon thickness and colour; and depth to carbonates.

c) Vegetation

It was generally agreed that grassland classification research should focus on developing successional relationships. It was agreed that knowing the potential vegetation of an area is critical to management.

Two or three groups suggested that autecological studies of dominant species are essential to determine ecological tolerances and to clarify relationships of classification units.

d) History

It was generally felt that information pertaining to fire history and relatively recent impacts by man and domestic livestock is essential to understanding disturbed sites.

Paleoecological studies were consistently mentioned as an available method to further understand grassland classification.

e) Integrated Studies

Considerable emphasis was placed upon coordinated plant-animal/plant-soil investigations. These were unanimously considered to be vital for the understanding and classification of ecosystems.
2. Ecological Reserves and Exclosures

All groups agreed that exclosures and other protected areas are basic to any research program. More exclosures and reserves were felt to be necessary, especially in areas where pressures on land use exist. It was suggested that exclosures would assist in determining range condition indicators and potential vegetation of various sites. Long-term monitoring and detailed documentation of sites was mentioned as vital, because, although range recovery often occurs after five to 10 years of protection from grazing, some grassland areas are particularly unyielding, and 20 to 50 years would not be an unreasonable time frame. It was suggested that one agency be designated responsible for maintaining an up-to-date directory of exclosure information and that all information available on older exclosures be deposited into this directory.

The selection of sites for exclosures and reserves was deemed important. It was thought that at least some reserves should be representative of large areas so that research results could be meaningfully extrapolated to other sites in addition to being large enough to provide research and control sites within the same area. The working groups noted the conflict between preservation and research functions of ecological reserves and that it is a problem requiring immediate attention. It was agreed that exclosures should be large enough to represent a functioning ecosystem identified by the plant community, probably a minimum of one hectare, and that careful selection to represent particular terrain, soil and climate conditions is of the utmost importance.

3. Communication

The need to convey research information to managers and other researchers was the centre of much discussion. It was felt that interdisciplinary research should be encouraged
to refine grassland classification and understanding of grassland ecology. A plea was made for professional co-operation to overcome ignorance of other disciplines, interagency competition or suspicion. It was suggested that research projects should be advertised and findings made more quickly available; progress reports should be encouraged and final results published.

To aid communication of recent work and to exchange ideas, conferences were deemed invaluable. It was recommended that a central data bank be established to house grassland information which would be available to anyone working on British Columbia grasslands, researchers and managers alike. In this regard a bibliography of range research in British Columbia which has been compiled by the British Columbia Ministry of Forests Research Branch (in press) would provide much of the necessary baseline information.

3. What are the Major Research Needs in Grassland Ecology in British Columbia?

Research appears to be required in nearly all phases of both applied and pure grassland ecology. As discussed by the groups dealing with Topic 2, more exclosures and ecological reserves were thought to be essential, although to retain their preservation role research use should be non-destructive. It was noted that ecotonal areas deserve equal consideration for preservation as these grassland/forest transitions would be a very important source of information on grassland ecosystem dynamics. Other research needs discussed generally fell under one of seven headings:

1) Ecosystem Structure and Function
2) Range
3) Wildlife
4) Recreation
5) Land Alienation
6) Reclamation
7) Industrial Impact
These are discussed by category below:

1. Ecosystem Structure and Function

As information on the structure and function of grassland ecosystems is based on integrated soil, vegetation and climate studies, it was thought that general studies to monitor and describe ecosystems were needed for "LOWER", "MIDDLE", and "UPPER" grasslands and forest/grassland ecotones. It was also suggested that subalpine and alpine grassland ecosystems be studied. One working group recommended that systems models be developed as data becomes available in order to help indicate additional information requirements. The recovery potential of variously disturbed grassland ecosystems was considered to be an important research topic. It was thought that paleoecological research would provide useful historical information about grassland development and species distribution. In conjunction with general description all groups felt more specific research topics must be studied to gain a good understanding of ecological processes. For example:

a) Soils
   - examination of the tertiary origin of parent material
   - soil moisture and soil temperature studies (tied in with energy budgeting) and their application to, or effect on, soil-vegetation relationships, e.g.:
     - moisture availability;
     - moisture stress;
     - organic content versus moisture holding capacity
   - soil forming processes; rates of development and degradation
   - physical and chemical characteristics of soils
   - nutrient studies; mineral cycling (grassland compared to forest)
   - effects of disturbance by grazing and fire and the susceptibility at various times in the year.
b) Vegetation
- examination of floristics or species composition variations geographically in British Columbia; the question of species analogues; ecotypic variation or ecological amplitude of different species; species phenology.
- autecology of preferred and invader species (including trees encroaching on grasslands), e.g.:
  - permanent wilt;
  - nitrogen fixation of different plants;
  - mycorrhizae - role in nutrient uptake; fungi involved; culture, improvements, developments;
  - rhizosheaths;
  - genetic studies
- range readiness - appropriate season of use for important species; time when species are most susceptible to grazing
- lichen-bryophyte crust studies, such as:
  - nutrient cycling;
  - moisture retention;
  - soil protection
- cultivars - do naturally occurring species yield optimal production or would introduced species give better production?; what cultivars are best for what site conditions?; what would long term ecological effects be on soil, productivity, insect/disease, wildlife?

2. Range
- forage preference studies of domestic animals and wildlife
- domestic/native ungulate interactions
- domestic animal behaviour relations to distribution, water sources, etc.
- relationship between climax, seral and introduced systems
productivity studies, seasonal and annual, for various range sites
- range condition and trend studies for different sites and geographic areas
- soil fertility assessments necessary to help determine whether poor range
  condition is due to overgrazing or poor nutrient status, and, therefore, whether
  improvement could be gained by regulation of cattle use or through fertilization
- management treatment effects, both long and short term on species
  composition, cover, palatability and productivity, such as:
  - fire;
  - fertilization;
  - grazing systems e.g. stocking rates, rest, deferral, high intensity, short
    duration, animal species diversity
- management of "tame" grassland, e.g. community pastures, re-seeded range
- seeding clear-cuts
- mechanisms of weed control; impact of herbicides
- tree and shrub invasion control.

3. Wildlife

- inventory, census and role of native birds, mammals, reptiles and invertebrates
  in grassland ecosystems
- habitat use, distribution, densities and behaviour patterns
- effect of other grassland uses on wildlife populations
- impact of pesticides on ecology of plants and animals.

4. Recreation

- impacts of various recreational uses
- carrying capacity for recreational use
- research methods to effectively promote public awareness of the grassland
  resource.
5. Land Alienation

- economic and social values with respect to agriculture, urban and industrial development.

6. Reclamation

- effective methods to reclaim and rehabilitate grassland environments previously disturbed.

7. Industrial Impacts

- long term widespread effects of air quality, acid rain, trace elements.
FINAL GRASSLAND CLASSIFICATION DISCUSSION

During the symposium several concerns pertaining to the classification of British Columbia grasslands in the Ministry of Forests Ecosystem Classification System arose. These included the correlation with grasslands beyond the province's border, the unique nature of grassland ecosystems and management. During a summary meeting attended by several of the invited speakers and British Columbia Ministry of Forests personnel involved directly in grassland classification, many of these concerns were reviewed and further ideas and recommendations put forth. These are summarized below.

Ministry of Forests personnel, responsible for conducting the Ecosystem Classification Program in the Kamloops Forest Region, opened the meeting by presenting their preliminary classification of the grasslands. This presentation served as an excellent catalyst for discussion of the classification of British Columbia's grasslands and is briefly summarized.

Ecologists and pedologists in the Kamloops Region have been working on the classification of grasslands since 1978 and to date have recognized an elevational sequence of biogeoclimatic zones and subzones beginning with the Ponderosa Pine-Bunchgrass (PPBG) Zone at the lowest elevations. The only (climatic climax) grassland subzone recognized occurs in the warmest and driest valley bottoms of the PPBG. Above that subzone are (climatic climax) *Pinus ponderosa* forested subzones. The Interior Douglas-fir (IDF) Zone, comprised of lower and upper elevation (climatic climax) *Pseudotsuga menziesii* forested subzones, occurs above the PPBG zone. Within this interpretation grasslands extending beyond the PPBG grassland subzone into the PPBG and IDF forested subzones are considered to be the result of topographic, edaphic, topoedaphic or historical factors which override an otherwise forest type climate.
Three lines of evidence were presented to substantiate the claim that the macroclimate is the same for both forested and grassland sites within any one subzone in the Kamloops Region. First, a series of climatic parameters measured at specific sites were plotted as a function of elevation. The sites above approximately 600 m elevation were similar in terms of those parameters and shown to be a mixture of forested and grassland sites whereas below 600 m only grassland sites occurred. In the second approach Köppen's (1936) classification was used to group similar climate stations. Like the previous approach, only the climate of the grassland sites at the lowest elevations appeared to be distinctly different from the forested sites. A third approach related vegetation to the climatic moisture deficit information (growing season precipitation - potential evapotranspiration) presented in parameter maps prepared by the Ministry of Environment. It was pointed out that in the Douglas Lake area the same isohyet lines occur in grassland areas as in the adjacent forest. Discussion ensued.

Before proceeding to the discussion, however, to help the reader maintain a more objective perspective, it should be noted that many of the discussion participants have a strong background in the "Habitat Type" concept of classification. The fundamental difference between the Habitat Type approach used extensively in the western United States, and the Biogeoclimatic approach adopted in British Columbia is noted earlier in the INTRODUCTION (page 2).

The geographic breakdown of the units (subzones and their grassland "phases" within the subzones) as established by the Kamloops Forest Region was agreed upon; however, there was much contention concerning the actual classification of the units. It was generally agreed that as grassland ecosystems are very different from forests, they should be clearly recognized as distinct from forests in the classification. Pertinent points of this discussion are outlined below.
1. Several specific points were made with respect to the climate information:

(a) Although the Ministry of Environment's climatic parameter map indicates that there are similar moisture deficits for both forests and grasslands in the Douglas Lake area, it should not be assumed that the overall climates are similar. In all cases the resultant climate at each particular site is a unique set of interrelated factors.

(b) The reconnaissance level climatic moisture deficit maps (1:100,000) do not accurately reflect moisture available to plants since all water does not come directly from precipitation but may result from a groundwater source which may not be readily evident. For example groundwater may move down slope between the till and bedrock for great distances, and, where the till is shallow (i.e. on the slope), tree roots may reach below the till to the groundwater.

(c) Climate is not static. In fact, climate may change more rapidly than the vegetation. Predicting the response of vegetation to climate will always be difficult because it involves a highly variable genome which has evolved over thousands of years. As a result, interpretive problems can be expected, particularly when classifying and managing grassland/forest transition zones. Within this mosaic differences in microclimate between grassland and forest ecosystems further perpetuate differences in the species which invade and survive.

2. Although available climatic data are limited in British Columbia the interpretation approaches presented by the Kamloops Region are valid; however, a truly ecological approach, which is implied in the term "Ecosystem Classification System", must be a holistic approach. All elements of the landscape mosaic, i.e. all contributing factors
to the climatic climax including plants, animals, climate, soils, parent material, genetic pool, must be considered. If a measurable climatic difference is required to delineate logical units one may be unsuccessful because the climatic differences are often very subtle or the significant climatic factor not measured.

3. Grasslands are conceptually and functionally very different ecosystems from forests. For example they have different mineral nutrition and cycling, different types of organic matter and different pedogenic processes.

4. It was suggested that as good condition "zonal" sites are often difficult to locate and as grasslands and forests function under two different sets of environmental conditions the "normal" situation might be a useful guide for the classification. For example if forest communities occur on all aspects, slopes, surficial materials and soils, then the area would be classified as a forest unit. Conversely if grassland communities are continuous across a broad spectrum of sites, then they should be grouped as a grassland unit.

5. Classification should be approached from specific to general categories. In attempting to follow Dr. Krajina's Biogeoclimatic System this is not always possible. Judging from the Kamloops Forest Region's proposed classification of the grasslands within the present array of zones and subzones, the system does not easily accommodate non-forested vegetation. Although the grasslands were inserted into the system as best as it appeared possible, it is inadequate.

6. Likely some of the contention which has resulted from the Kamloops Forest Region proposed classification is a result of terminology. For example, including a
climatic climax grassland subzone in an essentially forested zone may be misleading. There was some concern that the term "phase", as applied to grasslands classified within the IDF zone, suggests only minor differences and, therefore, would not adequately differentiate between grassland and forest ecosystems. To be useful for management purposes it was agreed that a classification should be straightforward, nomenclature simple and units obvious.

7. The problem the Ministry of Forests must address with the Biogeoclimatic Ecosystem Classification is one of philosophy. Classification of ecosystems, like classification of any other natural body, reflects the state of our knowledge on the subject and those systematic principals which serve as its basis. The Biogeoclimatic System was clearly designed for forests; if non-forested ecosystems are to be classified within this system then modification to the system will be necessary.

In summary, the discussion participants generally felt that as distinctive grassland vegetation and grassland soils clearly exist in British Columbia, grasslands should be clearly recognized in the biogeoclimatic classification. The most difficult classification problem with respect to grasslands - succession - has yet to be addressed.
VIII
CLOSING ADDRESS
GRASSLAND SYMPOSIUM SUMMARY

Alastair McLean

This symposium was organized to promote an exchange of information pertaining to grassland ecology and classification research in the southern interior of British Columbia and to place the grasslands of British Columbia in the context of the neighbouring grasslands to the south and to the east.

In order to accomplish this we first require a vocabulary to facilitate accurate communication. Some of the most valuable terms used in discussion of grasslands are listed below:

**Grasslands** - The general physiognomic term "grasslands" is used for plant communities where the Gramineae are dominants and trees absent, or where there is a continuous cover of herbaceous plants. It is a broad term and has relatively little definitive meaning. The Society for Range Management in their Glossary of Terms in Range Management (Range Term Glossary Committee 1974) suggests that an area is grassland if at least 80% of the canopy cover is herbaceous.

Natural grasslands occur in subhumid to semiarid regions and constitute the grassland biome. We have been concerned in this symposium with the temperate grasslands or steppes; the latter is the term I prefer and will use. A combination of cold and drought produce steppe vegetation; soils are too dry for trees, and herbaceous perennial grasses are well represented. Three common categories are:
1. Meadow-steppe: meadowlike vegetation characteristic of the less arid margin of steppe regions; dwarf shrubs may be common but not dominant.

2. Grass steppe: floristically poor and relatively xerophytic steppe, with the grasses having narrow blades; forbs and shrubs poorly represented.

3. Shrub-steppe: steppe in which scattered shrubs form a layer rising above the grasses. Sometimes this type is not considered to be grassland.

Savannah - A savannah community is closely related to grasslands and is characterized by the presence of trees scattered over a matrix of lower vegetation. It is found in places where there is enough moisture for trees to maintain populations on zonal soils but not enough for them to grow in sufficient density to exclude a substantial layer of xerophytic grasses. Fire is an integral part of the savannah.

Parkland - Parkland, as defined by Daubenmire (1968), refers to patches of low vegetation occurring in a continuous phase of forest (cf. groveland) or vice versa. This is a mosaic of two communities rather than a single homogeneous one (cf. savannah). The Range Term Glossary Committee (1974) groups this category under savannah. I prefer to keep it separate, since it is a mosaic of two environments.
STEPPE CHARACTERISTICS

Climate

The steppe environment always has a season when low rainfall plus high evapotranspiration desiccates soil enough to kill tree seedlings. The steppes of southern interior British Columbia are largely determined by the strong rainshadow from the mountain ranges to the west. Low precipitation is further accentuated by two other characteristics of the general area: (1) the wide annual temperature range (25°C) and (2) the seasonal pattern of precipitation combined with drying winds in the spring.

The southern Interior has the driest climate in Canada. Compared to the prairies it is more susceptible to drought exceeding ten days, receives less annual precipitation (a smaller percentage of which is effective), has higher mean daily temperatures and higher estimated potential evapotranspiration.

Soils

Soils of the steppe are characterized by the presence of a chernozemic A horizon. This horizon is nutrient-rich with more than 80% of the exchange surface occupied by calcium ions. The transition between forest and grassland appears to be sensitive to plant-available moisture. Levels and distribution of soil moisture as modified by soil texture is crucial in determining the presence or absence of trees. For example, it appears that coarse soil materials under Pinus ponderosa have a lower water-holding capacity than do the heavier-textured soils under grasslands; this allows the precipitation to penetrate deeper into the profile where it is less subject to evaporation.

Vegetation

The grassland plant associations in British Columbia show a stronger affinity to those
south of the border than to the prairies to the east. In this province, we are at the northern geographic limits of a number of plant species and communities from Washington, Idaho and Oregon.

*Festuca idahoensis*, *F. scabrella* and *Agropyron spicatum*, all species of wide ecological amplitude, along with *Poa sandbergii*, occur in abundance in all the above states and British Columbia. Although there are many regional differences among associated species, these affinities are important in the recognition of our grasslands.

**GRASSLAND CLASSIFICATION**

Any classification system should be based on ecologically sound fundamentals and be versatile enough for use by a relatively broad spectrum of resource managers. In the classification of our plant communities, one of the greatest problems involves the *Festuca–Agropyron* community: whether it should be placed in the associated *Pinus–Festuca* or *Pseudotsuga–Festuca* or within the treeless steppe dominated by *Festuca*. Daubenmire (this publication) suggests that each layer in a community is controlled by a different set of environmental factors and, therefore, has a distinctive distribution, usually occurring in combination with taxonomically different layers in different regions. Therefore, a comprehensive vegetation classification cannot be made simply on the basis of floristics in the local vegetation mosaic.

We must gain an understanding of the environmental factors which together and separately determine the presence or absence of plant communities. As Dr. Daubenmire said, the common climatic parameters are not necessarily important ecologically – to that we could add soil parameters. We need to explore other environmental factors, or combinations of factors more closely. Sometimes we extrapolate too far with limited data. Dr. Daubenmire had sound advice when he said that in writing a classification we should start with the basic unit (in this case the habitat type or ecosystem association) and work up in the environmental hierarchies.
RESEARCH NEEDS

Some of the areas of research that need attention, and were expressed during the discussions are listed below:

1) Environmental factors which determine the presence of shrub-steppe, grass-steppe, savannah or forest. For example, more field measurements of seasonal soil-water regimes within the root zone may provide the information required to assess the distribution of steppe versus forest vegetation.

2) The need for accurate predictions of actual evapotranspiration for a thorough understanding of plant responses to the change in the water budget and thence response to drought.

3) The importance of exclosures as benchmarks. These are useful if approached with good planning, i.e. well-defined objectives, adequate documentation and follow-up. Also, their artificiality has to be recognized. Exclosures can be very useful in relation to altitudinal or other transects.

4) The need for more autecological studies. Such studies are fundamental to good resource management.

The deliberations of the past few days have been successful in establishing what comprises grasslands and the factors that determine their makeup. We have reviewed the composition of British Columbia grasslands and how they fit into the complex of those in the northwestern United States and adjacent Canada. From the discussion I hope that we have gained some ideas of how we might best study and understand them.
My congratulations to the British Columbia Ministry of Forests for sponsoring the symposium and to the organizers who so well planned and executed the exercise.

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