

# Chapter 2: Concepts

by

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## BIOGEOCLIMATIC ECOSYSTEM CLASSIFICATION

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## ECOREGION CLASSIFICATION

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## LITERATURE CITED

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BIOGEOCLIMATIC ECOSYSTEM CLASSIFICATION

Since 1975, the B.C. Ministry of Forests has been systematically developing an ecosystem classification of the forest and range lands of the province (Schmidt 1977). The classification is based, with some modifications, on the biogeoclimatic system developed in the 1960’s and 1970’s by Dr. V.J. Krajina and his students at the University of British Columbia (see Krajina 1969, 1972). The system incorporates primarily climate, soil, and vegetation data. The resulting biogeoclimatic ecosystem classification (BEC) provides a framework for resource management, as well as for scientific research.

Objectives

The goal of the ecosystem classification program of the Ministry of Forests is the improvement of forest management in British Columbia. To meet that goal, the overall objective of the program has been to develop a “permanent,” land-based, ecological classification which organizes our knowledge of ecosystems and serves as a framework within which to manage resources. In other words, the classification program aims both to organize and apply our knowledge of the structure, function, and relationships of terrestrial ecosystems.

The program has five specific objectives:

1. to characterize, describe, and map the broad biogeoclimatic units (zone, subzone, variant) of British Columbia;
2. to characterize and describe the major forest and range sites (ecosystems) within each biogeoclimatic unit;
3. to provide aids to field identification of these biogeoclimatic and site units;
4. to develop management interpretations for the site units or groups of similar site units (treatment units); and
5. to promote the concept of the ecosystem as the fundamental unit of resource management.

Over the past several years, the entire data base of the program (over 10000 ecological plots) has been re-analyzed and synthesized from a provincial perspective. This is causing some changes to the classification and nomenclature (some of which are presented in this report), which will be evident in forthcoming publications from the program.

Principles and Philosophy

A thorough characterization of BEC is given in Pojar et al. (1987). The concepts and classification summary presented here are an abbreviated account of that material.
Before describing the classification system, it is useful to review some of the basic concepts.

**Ecosystem**

"Ecosystem" is the term used for the sum total of vegetation, animals, and physical environment in whatever size segment of the world is chosen for study (Fosberg 1967). Ecosystems are interacting complexes of living organisms (plants, fungi, bacteria, animals) and the physical environment (soil, air, water, bedrock) immediately affecting them. The ecosystem, as defined by Tansley (1935), has long served as the basic conceptual and functional unit of ecology. However, Tansley's concept of ecosystem is too broad to be easily integrated into a formal classification. Krajina (1960), therefore, proposed that Sukachev's (Sukachev and Dylis 1964) "biogeocoenose" be adopted because, for practical purposes, it best represented a basic ecosystem. A biogeocoenose is a special case of the ecosystem, but the two terms are used here interchangeably.

For our purposes, then, a terrestrial ecosystem (biogeocoenose) is a unit or portion of the landscape and the life on and in it. It is a landscape segment relatively uniform in the composition, structure, and properties of both the biotic and abiotic environments, and in their interactions.

Numerous organisms such as fungi, earthworms, bacteria, insects, birds, and mammals are as much a part of a forest ecosystem as are trees, shrubs, herbs, and mosses. Within the ecosystem exists a complex and dynamic set of relationships among these organisms and between them and their physical environment. For simplicity, however, the classification system deals primarily with two components of the ecosystem: vegetation and soil. The model of ecosystem function is that of Major (1951): vegetation and soils are products of climate, organisms, topography, parent material, and time. Plants and soil, considered simultaneously, integrate all ecosystem components and reflect ecosystem functioning. They are easy to observe and assess, and are considered to be the most convenient and suitable ecosystem features upon which to base the classification.

Thus, for convenience, an ecosystem can be characterized by a plant community (a volume of relatively uniform vegetation) and the soil polypedon (a volume, to the depth of the solum, of relatively uniform soil) on which the plant community occurs. An ecosystem has geographical bounds; its size is determined by the extent of the plant community and the associated soil polypedon. The lateral boundaries may be abrupt, but more commonly they are gradual. As a result, an individual ecosystem usually contains some variation in biotic and abiotic characteristics.

**Climate**

Climate is the most important determinant of the nature of terrestrial ecosystems. As used here, climate refers to the regional climate (Major 1951, 1963) that influences the ecosystems over an extended period of time. It is usually
expressed as statistics derived from normals of precipitation and temperature; and is classified according to general atmospheric phenomena and their interactions (e.g., Koppen 1936; Trewartha 1968; Major 1977). In our case, however, climate is classified using the concept of zonal ecosystems. Because climatic data are scant or lacking in many areas and climatic analysis alone will not produce a practical ecosystem classification, a reliable functional link between climate and ecosystems is needed. The concept of the zonal (or climatic climax) ecosystem provides this link.

The zonal ecosystem is that which best reflects the mesoclimate or regional climate of an area. The integrated influence of climate on the vegetation, soil, and other ecosystem components is most strongly expressed in those ecosystems least influenced by local relief or by physical and chemical properties of soil parent materials. Such ecosystems have the following characteristics:

1. middle slope position on the meso-slope in mountainous terrain (meso-slope is the slope segment that directly affects site water movement); upper slope position in subdued terrain;
2. slope position, gradient, aspect, and location that does not result in a strong modification of climate (e.g., frost pocket, snow drift area, steep south or north aspect);
3. gentle to moderate (5-30%) slope; in dry or cold climates, on slopes to less than 5%; in wet climates, on slopes up to 50%; and
4. soils that have: (a) a moderately deep to deep (50-100+ cm) rooting zone, (b) no restricting horizon within the rooting zone, (c) loamy texture with coarse fragment content less than 50% by volume, and (d) free drainage.

Hence, the biogeochemical cycles and energy exchange pathways of zonal ecosystems are more or less independent of local relief and soil parent material, and are in equilibrium with the regional climate.

Other ecosystems in a given area are influenced more strongly by local physiography and the physical and chemical properties of soil parent materials. They can be drier, wetter, richer, or poorer than zonal ecosystems; and overall they do not provide as clear a reflection of the regional climate.

Because zonal ecosystems are characteristic of the regional climate that dominates their development, they are used to characterize biogeoclimatic units, which represent broad geographical areas of similar macroclimate. The distribution of zonal ecosystems also determines the geographical extent of the biogeoclimatic units.

**Climax and succession**

The term “climax” in ecology refers to a condition of dynamic equilibrium, a steady state rather than a static endpoint. A climax ecosystem is in theory a stable, permanent occupant of the landscape, self-perpetuating unless disturbed by outside forces or modifying factors. The living components of a climax ecosystem are in
equilibrium with the prevailing factors of the physical environment, and the member species are in dynamic balance with one another.

In climax vegetation, the species of plants are self-perpetuating. Tree species of a climax forest are present as seedlings, saplings, and subcanopy and canopy trees. Similarly, climax shrubs, herbs, mosses, liverworts, and lichens are present in all stages from seedling or sporeling to maturity.

Climatic climax ecosystems reflect the development potential of the prevailing regional climate. Other types of climax ecosystems occur where certain environmental factors have a greater influence on ecosystem development than does the regional climate. An edaphic climax differs from the climatic climax due to extreme soil or substrate conditions such as very coarse texture, high base saturation, or poor drainage. A topographic climax reflects compensating effects of topography on local climate (e.g., a steep south slope). A topoedaphic climax results from the combined influence of soil and topography (e.g., shallow, stony soil on a steep south slope). A fire climax can result from recurrent wildfire.

Ecosystems arrive at climax through a process of change called ecological succession, the progressive development of ecosystems through time. The BEC system implicitly accepts the so-called traditional view of succession (Drury and Nisbet 1973). Sequences of successional stages are called seres. Several seral or successional stages are recognizable in ecosystem development from, for example, an original bare surface to a mature forest. In theory, succession ends in a mature, climax ecosystem.

Many forest ecosystems in British Columbia have escaped large-scale catastrophic destruction by fire, wind, and other agents (Parminter 1983 a,b,c, 1984). Succession can continue over centuries; large tracts of climax forest occur throughout the wetter parts of the province. Many other areas of British Columbia are dominated by ecosystems that have not attained climax and perhaps never will. In such areas, the classification must be developed primarily with maturing seral stands (usually 70 years and older). Because seral stands usually exhibit definite successional trends, potential climax trees can be predicted from stand structure and relative shade tolerances of tree species. The understory in these stands is generally well developed and can be used as an indicator of site quality, successional development, and the potential natural vegetation of a site.

Ecological equivalence

The same climax vegetation can occur over a range of sites because of the compensating effects of environmental factors on plants. In consequence, even a climax plant association may represent ecosystems from different regional climates and with different soils. The plant community that develops on a particular site also varies according to the site, disturbance, chance, and time. Hence, several different plant communities can occur on the same site. To address the problems of environmental compensation and temporary variations in vegetation, ecosystems can be organized according to the principle of biological (Cajander 1926).
or ecological (Bacusis 1969) equivalence. This principle implies that sites with the same or equivalent physical properties have the same vegetation potential, and underlies site classification according to BEC.

**Soil moisture regime**

Soil moisture regime (SMR) is the average amount of soil water annually available for evapotranspiration by vascular plants over several years. Krajina (1969) adopted nine SMR classes (see Figure 1). Thus, in a relative sense, the driest soil in any regional climate is always “very xeric” (0) and the wettest is “hydric” (8). We use the subjective synthesis of soil properties to infer the relative soil moisture regime (Table 1).

![Soil nutrient regime grid](image)

**FIGURE 1.** Edatopic grid of soil moisture and nutrient regimes.
# TABLE 1. Relative soil moisture regime classes and characteristics

<table>
<thead>
<tr>
<th>MOISTURE REGIME</th>
<th>DEFINING CHARACTERISTICS</th>
<th>SOIL PROPERTIES</th>
<th>FIELD RECOGNITION CHARACTERISTICS</th>
<th>SLOPE GRADIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VERY XERIC 0</strong></td>
<td>Water removed extremely rapidly in relation to supply; soil is moist for a negligible time after ppt</td>
<td>precipitation</td>
<td>very coarse (gravely-S), abundant coarse fragments</td>
<td>very shallow (&lt;1.5m)</td>
</tr>
<tr>
<td><strong>XERIC 1</strong></td>
<td>Water removed very rapidly in relation to supply; soil is moist for brief periods following ppt</td>
<td>precipitation</td>
<td>rapid</td>
<td></td>
</tr>
<tr>
<td><strong>SUBXERIC 2</strong></td>
<td>Water removed rapidly in relation to supply; soil is moist for short periods following ppt</td>
<td>precipitation</td>
<td>coarse to mod. coarse (LS-SL), mod coarse frag</td>
<td>rapid to well</td>
</tr>
<tr>
<td><strong>SUBMESIC 3</strong></td>
<td>Water removed rapidly in relation to supply; soil is moist for moderately short periods following ppt</td>
<td>precipitation</td>
<td>mid slope, normal, rolling to level</td>
<td>moderate to fine (L-SL), few coarse fragments</td>
</tr>
<tr>
<td><strong>MESIC 4</strong></td>
<td>Water removed slowly enough to keep the soil wet for a significant part of the growing season; some temporary seepage and possibly melting below 20 cm</td>
<td>precipitation and seepage</td>
<td>moderately to well</td>
<td>moderately well to impeded</td>
</tr>
<tr>
<td><strong>SUBHYGRIC 5</strong></td>
<td>Water removed slowly enough to keep the soil wet for most of the growing season; permanent seepage and possibly weak gleying</td>
<td>seepage</td>
<td>moderately well to impeded</td>
<td>variable depending on seepage</td>
</tr>
<tr>
<td><strong>HYGRIC 6</strong></td>
<td>Water removed slowly enough to keep the soil wet for most of the growing season; permanent seepage and organic soils present; possible weak gleying</td>
<td>seepage or permanent water table</td>
<td>imperfect to poor</td>
<td>variable depending on seepage</td>
</tr>
<tr>
<td><strong>SUBHYORIC 7</strong></td>
<td>Water removed slowly enough to keep the water table at or near the surface for most of the year; gleyed mineral or organic soils; permanent seepage less than 30 cm below the surface</td>
<td>seepage or permanent water table</td>
<td>poor to very poor</td>
<td>variable, depending on seepage</td>
</tr>
<tr>
<td><strong>HYDRIC 8</strong></td>
<td>Water removed so slowly that the water table is at or above the soil surface all year; gleyed mineral or organic soils</td>
<td>depression, peaking</td>
<td>very poor</td>
<td></td>
</tr>
</tbody>
</table>

* From Walmsley et al. (1980), and Luttmerding et al. (1990)
To assess the moisture regime of a site quantitatively, Klinka et al. (1984) suggested the use of a water balance approach. They proposed a classification of actual soil moisture regimes (ASMR), using the occurrence and duration of phases of water use, the ratio between actual and potential evapotranspiration (AET:PET), and the occurrence and depth of the water table (see Table 2).

The ASMR classes can be related to the relative soil moisture classes for each regional climate (Green et al. 1984; Lloyd et al. 1990). In this report, ASMR’s are used in the ecosystem descriptions.

**TABLE 2. Classification of actual soil moisture regimes**

<table>
<thead>
<tr>
<th>Differentia</th>
<th>Class</th>
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<tbody>
<tr>
<td>Rooting-zone groundwater absent during the growing season</td>
<td></td>
</tr>
<tr>
<td>Water deficit occurs (soil-stored reserve water is used up and drought</td>
<td></td>
</tr>
<tr>
<td>begins if current precipitation is insufficient for plant needs)</td>
<td></td>
</tr>
<tr>
<td>Deficit &gt; 5 months (AET/PET ≤ 55%)</td>
<td>excessively dry</td>
</tr>
<tr>
<td>Deficit &gt; 3 months but ≤ 5 months (AET/PET ≤ 75 but &gt; 55%)</td>
<td>very dry</td>
</tr>
<tr>
<td>Deficit &gt; 1.5 months but ≤ 3 months (AET/PET ≤ 90 but &gt; 75%)</td>
<td>moderately dry</td>
</tr>
<tr>
<td>Deficit &gt; 0 but ≤ 1.5 months (AET/PET &gt; 90%)</td>
<td>slightly dry</td>
</tr>
<tr>
<td>No water deficit occurs</td>
<td></td>
</tr>
<tr>
<td>Utilization (and recharge) occurs (current need for water</td>
<td>fresh</td>
</tr>
<tr>
<td>exceeds supply and soil-stored water is used)</td>
<td></td>
</tr>
<tr>
<td>No utilization (current need for water does not exceed supply; temporary</td>
<td>moist</td>
</tr>
<tr>
<td>groundwater table may be present)</td>
<td></td>
</tr>
<tr>
<td>Rooting-zone groundwater present during the growing season</td>
<td></td>
</tr>
<tr>
<td>(water supply exceeds demand)</td>
<td></td>
</tr>
<tr>
<td>Groundwater table &gt; 30 cm deep</td>
<td>very moist</td>
</tr>
<tr>
<td>Groundwater table &gt; 0 but ≤ 30 cm deep</td>
<td>wet</td>
</tr>
<tr>
<td>Groundwater table at or above the ground surface</td>
<td>very wet</td>
</tr>
</tbody>
</table>

**Soil nutrient regime**

Soil nutrient regime (SNR) is the amount of essential soil nutrients that are available to vascular plants over a period of several years. Complex relationships among climate, topography, soil, and organisms complicate evaluation of SNR's, especially if one is trying to determine quantitative criteria. Krajina adopted six SNR classes, five of which are presented in Figure 1. The sixth, which is only presented where appropriate, is an ultrarich category (F). The classes are assessed according to a subjective synthesis of soil properties (Figure 2).

**Edatopic grid**

The edatopic grid is a moisture/nutrient grid of relative SMR and SNR (Figure 1). For most regional climates, a grid of eight (0-7) RSMR's and five SNR's is used to display relationships among the site units occurring in the climate. Wetlands with a RSMR of 8 have seldom been sampled in our work to date.
Classification System

The BEC system is a hierarchical classification scheme with three levels of integration: regional, local, and chronological (Figure 3). Coupled with this, BEC combines three classifications: climatic (or zonal), vegetation, and site. At the regional level, the vegetation/soil relationships are used to infer the regional climate; this climatic or zonal classification defines biogeoclimatic units. At the local level, ecosystems are classified using vegetation and soils information, into vegetation and site units. At the chronological level, ecosystems are organized according to site-specific chronosequences. To do this, the vegetation units recognized for a particular site unit are arranged according to site history and successional status.

![Table showing relationships between site properties and soil nutrient regime.](image)

**FIGURE 2.** Relationships between site properties and soil nutrient regime.
FIGURE 3. Levels of integration in the classification system.

For practical purposes, users need only be concerned with the zonal and site classifications (Figure 4); the vegetation classification, however, is integral to developing both of these (Figure 5).

**Vegetation classification**

Vegetation is emphasized because it is considered to be the best integrator of the combined influence of a variety of environmental factors affecting the site, and because floristic criteria can be determined to differentiate units.
FIGURE 4. Schematic relations between zonal and site classifications.

FIGURE 5. Categories and relationships of vegetation, zonal, and site classifications.
In keeping with the Braun-Blanquet approach (Westhoff and van der Maarel 1980), vegetation units are floristically uniform classes of plant communities. They are arranged in a hierarchy where the **plant association** is the basic unit; **alliances, orders, and classes** are groups of associations, and **subassociations** are divisions of an association (Figure 5). Vegetation units are differentiated using “diagnostic combinations of species” (Table 3). These are species that distinguish one vegetation unit from another, when the unit is considered within the context

<table>
<thead>
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<th>TABLE 3. Differentia and examples for classifications and categories of Biogeoclimatic Ecosystem Classification</th>
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<tr>
<td><strong>Category</strong></td>
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<tr>
<td>Vegetation classification</td>
</tr>
<tr>
<td>Class</td>
</tr>
<tr>
<td>Order</td>
</tr>
<tr>
<td>Alliance</td>
</tr>
<tr>
<td>Association</td>
</tr>
<tr>
<td>Subassociation</td>
</tr>
<tr>
<td>Zonal classification</td>
</tr>
<tr>
<td>Formation Region</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Zone</td>
</tr>
<tr>
<td>Subzone</td>
</tr>
<tr>
<td>Variant</td>
</tr>
<tr>
<td>Site classification</td>
</tr>
<tr>
<td>Association</td>
</tr>
<tr>
<td>Series</td>
</tr>
<tr>
<td>Type</td>
</tr>
</tbody>
</table>

\(^a\) DCS = diagnostic combination of species; must include at least one differential - or dominant differential - species.

Differential (d): species that is clearly associated with more than one unit in a hierarchy; presence class III and at least two presence classes greater than in other units of the same category and circumscription.

Dominant differential (dd): species that does not meet the presence criteria above but shows clear dominance in more than one unit in a hierarchy; presence class III, mean species significance 5 and two or more significance classes greater than in other units of the same category and circumscription.

Present classes as percent of frequency: I = 0-20, II = 21-40, III = 41-60, IV = 61-80, V = 81-100. Species significance classes and percent cover: + = 0.1-0.3, 1 = 0.4-1.0, 2 = 1.1-2.2, 3 = 2.3-5.0, 4 = 5.1-10.0, 5 = 10.1-20.0, 6 = 20.1-33.0, 7 = 33.1-50.0, 8 = 50.1-75.0, 9 = 75.1-100.

\(^b\) Sxw = *Picea engelmannii* x *glauca.*
of the circumscribing vegetation unit from the next highest level. Determining diagnostic species requires that tables of vegetation data be compared and a hierarchy formed. Tree species, or forest types, are emphasized at the upper levels of the hierarchy (classes/orders), and understory vegetation at the lower levels.

Although the vegetation classification could be developed for any vegetation data, regardless of age of the stand or sward, we have concentrated on classifying the late successional ecosystems because they are most useful to our classification and its present application. Vegetation units are named after one to four plant species that dominate or characterize the unit (see, for example, Table 3).

Vegetation classification determines the plant associations and subassociations. These units are important for determining biogeoclimatic subzones and variants, and site associations.

**Zonal (climatic) classification**

Biogeoclimatic units are the result of zonal (climatic) classification and represent classes of ecosystems under the influence of the same regional climate. As in vegetation classification, there is a hierarchy of units, with the biogeoclimatic subzone being the basic unit (Figure 5). Subzones are grouped into zones, regions, and formations, and divided into variants. In addition, phases are recognized and used, although the phase is not a formal category in the classification.

A biogeoclimatic subzone has a distinct climax (or near-climax) plant association on zonal sites (Table 3). A subzone thus consists of unique sequences of geographically related ecosystems in which climatic climax ecosystems are members of the same zonal plant association. Such sequences are influenced by one type of regional climate. Since subzones are the basic units of zonal classification, they are the first to be recognized in the classification process.

Subzones contain considerable variation, for which we have provided the category of biogeoclimatic variant. Variants reflect further differences in regional climate and are generally recognized for areas that are slightly drier, wetter, snowier, warmer, or colder than other areas in the subzone. These climatic differences result in corresponding differences in vegetation, soil, and ecosystem productivity. The differences in vegetation are evident as a distinct climax plant subassociation (Table 3). They can also be manifested as changes in the proportion and vigour of certain plant species, or as variations in successional development or the overall pattern of vegetation over the landscape. Differences in soils can be confined to the variation in intensity of certain soil-forming processes; they need not be markedly expressed in morphological features.

The biogeoclimatic phase accommodates the variation, resulting from local relief, in the regional climate of subzones and variants. Phases are useful in designating significant, extensive areas of ecosystems that are, for topographic or topoedaphic reasons, atypical for the regional climate. Examples could be extensive
areas of grassland occurring only on steep, south slopes in an otherwise forested subzone; enclaves of apparently coastal forest on moist, northeastern slopes in an interior, continental subzone; or valley-bottom, frost-pocket areas in mountainous terrain. The biogeoclimatic phase relates to local climate and hence is not a formal category in the classification, but phases can be identified and mapped for management or descriptive purposes.

We group subzones with affinities in climatic characteristics and zonal ecosystems into biogeoclimatic zones. A zone is a large geographic area with a broadly homogeneous macroclimate. A zone has characteristic webs of energy flow and nutrient cycling and typical patterns of vegetation and soil. We characterize zones as having a distinct zonal plant order; that is, the vegetation classification groups zonal plant associations in the category of plant order. Zones also have characteristic, prevailing soil-forming processes, and one or more typical, major, climax species of tree, shrub, herb, and/or moss.

Zones are usually named after one or more of the dominant climax species in zonal ecosystems (the Alpine Tundra Zone is a self-explanatory exception), and a geographic or climatic modifier.

Subzone names are derived from classes of relative precipitation and temperature or continentality. Variants receive short geographic labels.

Zones are given a two- to four-letter code, corresponding to the name. For example, the Coastal Douglas-fir zone code is CDF (see zone chapters for others). Subzone codes correspond to the climatic modifiers (Figure 6); variants are numbered from south to north; phases are noted by an alphabetic code. For example,

\[
\text{ICHmc1a}
\]

refers to the coastal (a) phase, of the Nass (1) variant, of the Moist Cold (mc) subzone, of the Interior Cedar — Hemlock (ICH) zone.

**Site classification**

Site units represent groups of sites or ecosystems that, regardless of present vegetation, have the same, or equivalent, environmental properties and potential vegetation. Vegetation units do not provide the most efficient, convenient, or stable framework for ecosystem classification because vegetation changes over time, thereby continually dating the results of its classification. For this reason we use the potential vegetation of a group of sites, along with selected environmental properties, to delineate site units.

The potential vegetation of a group of sites, as determined by our climax or near-climax plant associations and subassociations, provides the initial delimitation of site associations, the basic unit of site classification. The site association can be considered as all ecosystems capable of producing vegetation belonging to the

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3 Codes also presented in Table 4, p. 56-57.
same plant association (or subassociation, in some cases) at climax. Thus, a site association is a group of related ecosystems physically and biologically similar enough that they have or would have similar vegetation at climax. One site association can include a variety of disturbance-induced, or seral, ecosystems, but succession should ultimately result in similar plant communities at climax throughout the association. The use of plants from the climax plant association to name site associations does not imply that climax vegetation dominates the present landscape. Many ecosystems in the province reflect some form of disturbance and are in various stages of succession towards climax.

![Diagram of ZONE naming system](image)

**Figure 6.** System of naming and coding subzones. Precipitation and temperature regimes, and degree of continentality, are all relative within the biogeoclimatic zone.

Site associations can be differentiated from one another by the range of environmental properties outlined in Table 3. It is these site properties that are used to identify a site association in an early successional stage. The site association is equivalent to the habitat type of Daubenmire (1968) and Pfister et al. (1977) and conceptually similar to the forest type of several European classifications (see Jahn 1982).

The name of site associations follows the name of the parent plant association or subassociation as closely as possible. Common names of one to four species are used and tree species codes are usually substituted to shorten the name. For example, the parent plant association of the Sxw — Huckleberry site association is the Picea — Vaccinium plant association (Table 3).
A site association can contain ecosystems from several different climates and so be variable in actual site conditions. Dividing the association into site series using subzones and variants (Table 3) produces site units that are climatically, and therefore usually edaphically, more uniform. As a result, site series are more predictable in their response to management.

Site series have the same name as the site association, prefixed by the biogeoclimatic subzone or variant and a “slash” (see Table 3). Each site series is also given a two-digit numeric code. So, for example, the SBSmc2/Sxw — Huckleberry site series (Table 3) is coded SBSmc2/01 in all field guides and data forms.

Ideally, the name for a site series would incorporate features of physiography and soils, but in reality that is impractical. However, a reference to the SBSmc2/Sxw — Horsetail site series signifies that group of ecosystems which occurs at the base of slopes or in depressions, over poorly to moderately drained fluvial, morainal, or lacustrine parent materials; which has developed Gleysols, Dystric Brunisols or Cumulic Regosols and Hydromoder or Mormoder humus forms; which generally has an excess of soil water and an abundance of nutrients but often poor soil aeration; and which at climax develops vegetation that may be characterized by the Picea — Equisetum plant association. Provided the classification is adequately described, explained, and understood, a relatively simple name can convey a great deal of useful information about individual ecosystems in the field.

To form edaphically more consistent units, site series are partitioned into site types according to one or more edaphic properties thought to affect ecosystem response to management. Site types reflect the compensating effects of various site conditions within a uniform climate which, together in different combinations, produce similar vegetation. Of all the ecosystem units, they are uniform in the largest number of environmental characteristics.

Site types are named with a single edaphic modifier and are given a two-digit numeric code. For example, the Sandy site type in Table 3 might be coded as follows: SBSmc2/01/02. Often the site series is also the operational unit on which we base silvicultural and other management decisions. For example, to make prescriptions the forester usually only need know that a sub-boreal site belongs to the Pine — Huckleberry — Cladonia or the Spruce — Horsetail site series. In some cases, however, the site series must be subdivided into more operationally significant units. This is especially true of widespread site series that encompass a range of habitat conditions.

The site phase can be used for better site differentiation and identification. It is not a formal unit in the classification, but it can be used to subdivide site series or site types. For example, recognition of two general particle size classes (coarse and fine) as two phases of widespread sub-boreal site series gives much more meaning to silvicultural interpretations of these units. In other cases, site phases could be based on slope classes, aspect, parent materials, soil climate, or bedrock geology. Recognizing

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4 Humus form (forest floor) terminology after Klinka et al. (1981).
any change in such characteristics can be important because they influence an ecosystem's response to external disturbances. Use of the phase also allows more consistent prediction of ecosystem response to management treatments.

A phase is named according to the differentiating criteria and is given an alphabetical code. For example, a coarse-textured phase of a SBSmc2/01 site series would be coded SBSmc2/01(a).

The representation of edaphic variation within the site series as site phases or site types is related to the number of sample plots and the perceived need for more consistent classes. Because site types are more edaphically uniform, a greater number of sample plots is required to characterize types adequately. A classifier may choose only to recognize phases where the data base is limited. As well, where the “direct” interpretations to be made for the edaphically consistent units are few and straightforward and the edaphic variation is complex, the classifier could recognize a few phases instead of several to many types.

In some cases, another informal unit termed the site variation is used to describe vegetative trends or floristic features that diverge from the central concept of the association. Usually such variation is related to short-term successional factors and it involves recent stand history. Variations could be recognized on the basis of stocking, species composition of the tree stratum, understory structure and composition, etc.

**Successional classification**

Successional (often termed “seral”) classification in BEC involves an integration of the site and vegetation classifications and the determination of structural stage of development. Klinka et al. (1985) and Hamilton (1988) have presented their concepts of how this could take place. Since very little classification of successional ecosystems has occurred using BEC (see Klinka et al. 1985; DeLong 1988; Lloyd et al. 1990), some differences in the recognized structural stages exist.

Over most of our managed and natural forests there is a complex pattern of seral ecosystems. As previously explained, the BEC system makes sense of the array of ecosystems through site classification. After that, the series of successional ecosystems that occur on a site unit can be classified into seral plant associations and seral structural stages. The result is the application of a seral plant association name to one or more seral stages. Depending on the use for the classification and the relationship between the seral stages and plant associations, the presentation will emphasize either the seral stage or the association. A code for the stage (or several stages) is used to identify the seral stage/association segment of a site series in field guides and data banks. For example, a pole-sapling stage of the SBSmc2/01 would be coded SBSmc2/01-PS.
Methods

Field procedures of the Ministry of Forests' classification program follow those detailed in the manual Describing Ecosystems in the Field (Walmsley et al. 1980; Luttmerding et al. 1990). Analytic and synthetic methods adopted by the Ministry have been described by Klinka et al. (1979, 1977\(^5\)), and are similar to those of Krajina and his students (e.g., Brooke et al. 1970; Wali and Krajina 1973; Kojima and Krajina 1975). Nevertheless, it seems that the Ministry's methods are still not well understood and need further explanation.

Plot sampling

Field sampling is stratified on the basis of biogeoclimatic units and soil moisture and nutrient regimes. Based on reconnaissance and other available information, tentative biogeoclimatic units are often delineated before plot selection. An edatopic grid (Figure 2) is used as an aid to stratification within each biogeoclimatic unit. We try to sample five or more plots representing each of the possible combinations of moisture and nutrients. Intensity of sampling varies according to the areal extent of the ecosystem, its apparent diversity, and its importance for forestry or range management. Sampling intensity also depends on available access and the nature and scale of the project.

We sample selectively. Sample plots are located in habitats that are as uniform as possible; heterogeneous, transitional, or disturbed sites are avoided. To date, most sampling has been confined to climax or near-climax ecosystems. Plots are located so as to represent particular combinations of moisture and nutrients (see Table 1, Figure 2). Slope position, indicator plant species, relative tree growth, soil texture, seepage, and base status of parent materials are used as clues to moisture and nutrient regimes. The professional judgement of experienced fieldworkers in selecting representative ecosystems is an important part of the approach.

The smallest unit of sampling in ecosystem studies is the “sample plot” (also termed “sample plot” by Mueller-Dombois and Ellenberg [1974] for vegetation sampling, and termed “pedon” by Soil Survey Staff [1975] for soil sampling). Plot size in forest stands is usually 400-500 m\(^2\); plot shape is variable but usually square or rectangular. Plot size is reduced for grassland, wetland, or alpine sampling. At each site, the standardized provincial site, soil, humus form, vegetation, and mensuration data sheets are completed according to the procedures in Luttmerding et al. (1990).

Analysis

The information collected from the sample plots must be analysed and integrated into a usable classification. To do this, we code vegetation and selected soil, physical, and mensurational data for tabulation by a computer program.

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developed by Klinka and Phelps\textsuperscript{6} and expanded by Meidinger et al. (1987) and Emanuel\textsuperscript{7,8}. The program sorts, organizes, and presents these data; it does not perform any classification. This procedure aids in the traditional Braun-Blanquet method of classification by tabular analysis (see Mueller-Dombois and Ellenberg 1974), mainly by reducing manual procedures and transcription errors.

The program produces environment, vegetation, and vegetation summary tables. The classifier specifies the tentative ecosystem units, relying largely on personal knowledge and judgement. The program summarizes environment and vegetation data according to the specified units. The summary vegetation table then presents species presence (frequency of occurrence in sample plots) and mean cover or species significance (an estimate of both cover and abundance) for all plant species in all differentiated units. Successive working tables can be rapidly produced; additions, corrections, and rearrangements can be easily made.

The classifier generally groups plots by tentative biogeoclimatic unit and by estimated moisture/nutrient regime. The vegetation tables list species by stratum or layer (trees, shrubs, herbs, etc.) in order of presence and mean percent cover for each ecosystem unit. Plots or groups of plots that are floristically different may be separated or moved to another group. Plots that appear similar in moisture and nutrient regime are experimentally merged. Similar groupings from other biogeoclimatic units are compared and then fit into the vegetation hierarchy. Through this process of computer-assisted, experimental grouping, rearrangement, and refining of groups, the plant and site associations are defined (Poore 1962). Site associations may then be subdivided into site series, types, or phases, often on the basis of edaphic factors as summarized by the environment tables.

**Mapping**

Biogeoclimatic mapping begins with a review of available ecosystem classifications within or near the mapping area. Biogeoclimatic units are characterized and summarized in synopsis form. A draft map, based on physiography and the extrapolation of elevational limits, may be prepared. Field mapping is done along selected transects by ground and air survey. The ground survey includes brief descriptions (rapid reconnaissance) of vegetation and soils; special attention is paid to zonal ecosystems. Boundaries drawn in the field are based on the type and occurrence of zonal ecosystems, floristic combinations, and the distribution of azonal, edaphic climax ecosystems. Final boundaries are drawn after fieldwork and data analysis have been completed. Boundaries outside transects are extrapolated on the basis of elevation and physiography.

A revision (at 1:2000000) of Krajina's maps of the biogeoclimatic zones of British Columbia has been prepared by the B.C. Ministry of Forests (1988). Colour biogeoclimatic unit maps, including zones, subzones, and variants, of the Coast and

\textsuperscript{6} Ibid.
\textsuperscript{7} Emanuel, J. 1985. A vegetation classification program. Univ. B.C., Faculty of Forestry, Vancouver, B.C. Unpublished manuscript.
\textsuperscript{8} Emanuel, J. 1990. VTAB-PC Version 1.1. Software and documentation for personal computer version of VTAB. B.C. Min. For., Victoria, B.C.
northern Interior have been mapped at scales of 1:500 000 to 1:600 000 (Nuszdorfer et al. 1984; McLeod and Meidinger 1986; Pojar et al. 1988). Maps in draft form at scales of 1:100 000 to 1:500 000 are available for the rest of the province through the Forest Service regional offices.

Ecosystem mapping assists area-specific land management by providing managers with information on the location and distribution of site units. Mitchell et al. (1989) outline the methods for ecosystem mapping, using the Ministry's experience to date (e.g., Klinka et al. 1980b; Inselberg et al. 1982; Lindeburgh and Trowbridge 1984; Banner et al. 1985; Mitchell and Eremko 1987).

Ecosystem mapping follows sampling and classification. A key to site units may be prepared, using readily identifiable features of the vegetation and physical environment. Mapping is based on a combination of ground and air surveys and interpretation of available air photographs (usually black and white at 1:15840 or 1:20000). Photo-interpretation relies on characteristics of the tree layer and identifiable environmental characteristics such as elevation, topographic position, and slope gradient. Map delineations are tentatively labelled as to their component site units and are then field-checked to verify boundaries and labels. Map units vary according to the intensity and scale of mapping. Some map units are site series, types, or phases; others are complexes of site units.

Uses

A multifactor, integrative, hierarchical classification can be put to many uses, depending on the parameters incorporated in the classification and the needs and objectives of its users. As a natural taxonomic classification (i.e., one based on the characteristics of ecosystems themselves), ecosystem classification provides an ideal framework for other scientific research, including plant autecology and synecology, soil investigations, climatology, and biogeography. The classification also forms the basis for the selection and establishment of a system of natural areas or ecological reserves in British Columbia (Krajina et al. 1978; B.C. Ministry of Parks 1989). With its strong climatic foundations, the classification can provide useful information to agrologists and horticulturists. Through its interpretive and predictive powers, however, the ecosystem classification in British Columbia has made its most valuable contributions to the field of natural resource management.

Sound management of natural resources requires knowledge and understanding of large amounts of information about diverse yet inter-related physical and biological resources, including water, soil, timber, range, wildlife, and recreation. Traditionally, resource managers have carried out separate inventories of each resource of importance in an area, then attempted to analyse the different factors and weigh the consequences of various combinations of uses.

An ecosystem classification organizes knowledge about various resources, at both generalized and detailed levels. It provides a framework for the presentation of information, interpretations, and predictions about ecosystems. It serves as a common
denominator for developing, comparing, and evaluating management strategies, and predicting the consequences of management decisions on complex systems. Hence, ecosystem classification is well suited to helping us achieve the objectives of integrated resource management — objectives that have long been pursued but difficult to reach.

To date, most ecosystem classification in British Columbia has been applied to the management of timber, range and wildlife resources. Management interpretations and recommendations have dealt with: tree or forage species selection for logged-over or grazed areas; residue management (especially slashburning); site preparation; seedling stock type; stocking standards; and silvicultural systems. The classification also provides an ideal framework for growth and yield studies, a systematic basis for seed zone and seed orchard establishment; a site-specific guide to thinning, fertilization, and prescribed burning; and a broad regional base for forest planning and land use allocation. Some examples of the practical applications and interpretive value of BEC can be found in Klinka and Carter (1980), Klinka et al. (1980 a,b, 1984), Pojar et al. (1984), Green et al. (1984), Utzig et al. (1986), Cariboo Forest Region (1987), Meldinger et al. (1988), DeLong (1988), and Lloyd et al. (1990).

ECOREGION CLASSIFICATION

An ecoregion classification has been developed and mapped for British Columbia to provide a systematic view of the broad geographic relationships of the province (Demarchi 1988; Demarchi et al. 1990). This classification is based on the interaction of macroclimatic processes (Marsh 1988) and physiography (Holland 1976; Mathews 1986). The major practical difference between the ecoregion classification and the biogeoclimatic ecosystem classification (BEC) is that, in mountainous terrain, ecoregion classification stratifies the landscape into geographical units that circumscribe all elevations, whereas BEC delineates altitudinal belts of ecological zones within geographical units.

The ecoregion classification of British Columbia is a hierarchical system (Figure 7) whose levels have been defined as follows:

1. **Ecodomain** - an area of broad climatic uniformity (4 units in B.C.)
2. **Ecodivision** - an area of broad climatic and physiographic uniformity (7 units in B.C.)
3. **Ecoprovince** - an area with consistent climate or oceanography, relief and plate tectonics (10 units in B.C.)
4. **Ecoregion** - an area with major physiographic and minor macroclimatic or oceanographic variation (33 units in B.C.)
5. **Ecosection** - an area with minor physiographic and macroclimatic or oceanographic variation (72 units in B.C. + 11 ecoregions with no subdivisions)

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9 Contributed by D.A. Demarchi.
The ecodomains and ecodivisions are very broad and place British Columbia in a global context. Ecoprovinces, ecoregions, and eosections are progressively more detailed and narrow in scope and relate the province to other parts of North America and the Pacific Ocean, or segments of the province to each other. The lower three classes describe areas of similar climate, physiography, zonation, and wildlife potential.

This mountainous province has another level of complexity, that of topo-climatic zonation. Within each terrestrial ecoregion are climatic zones that are reflected by the plant and animal communities present (see Figure 8). These zones are best dealt with through BEC (Figure 7) (Krajina 1965; Pojar et al. 1987; B.C. Ministry of Forests 1988).

Ecoregions have been mapped for the entire province at two scales: 1:2000000 (Demarchi 1988) and 1:500000 (Pojar et al. 1988; Wildlife Branch 1989). As well, they have been described in terms of characteristic climate, physiography, vegetation or ocean currents, and fauna (Demarchi et al. 1990).
The climax concept applied to vegetation implies that in the course of time and in the absence of disturbance, the same types of plant communities will develop and perpetuate themselves through reproduction on ecologically equivalent sites. Such plant communities are called climax communities and they represent the final stage of succession on a given site.

The zonal concept implies that the influence of regional climate is most strongly expressed in the vegetation and soils of those ecosystems least influenced by variations in local topography and soil physical and chemical properties. Such ecosystems are called zonal and other ecosystems azonal. The climax zonal ecosystems are considered to be characteristic marks of a regional climate.

The regional ecosystem concept implies the delineation of large units of land with similar climates, physiographies, and zonal sequences.

FIGURE 7. Relationship between ecoregion and biogeoclimatic classification. Modified from Pojar et al. (1988).
FIGURE 8. Relationship of biogeoclimatic units to ecossection units in the Fraser Plateau Ecoregion.
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