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# CLASSIFICATION AND DESCRIPTION OF WORLD FORMATION TYPES

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## *PART I. INTRODUCTION*

*Hierarchy Revisions Working Group  
(Federal Geographic Data Committee)*

*2012*

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This document is being developed for the U.S. National Vegetation Classification, the International Vegetation Classification, and other national and international vegetation classifications.

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## EXECUTIVE SUMMARY

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A vegetation-ecologic classification approach has been developed in which a combination of vegetation attributes (physiognomy, structure, and floristics) and their response to ecological and biogeographic factors are used as the basis for classifying vegetation types (Faber-Langendoen et al. 2012). This approach can help support international, national and subnational classification efforts. Support for many aspects of the development of classification was provided by the U.S. National Vegetation Classification (USNVC) partnership, in conjunction with development of the International Vegetation Classification (IVC) (FGDC 2008, Faber-Langendoen et al. 2009, Jennings et al. 2009). The classification structure was largely developed by the Hierarchy Revisions Working Group (HRWG), which contained members from across the Americas. The group was authorized by the U.S. Federal Geographic Data Committee (FGDC) to develop a revised vegetation classification, global in scope, to replace the earlier versions of the structure that guided the USNVC and IVC, which relied on the UNESCO (1973) global classification (see FGDC 1997, Grossman et al. 1998). In this document, we summarize the development of the upper formation levels.

We first describe the history of the Hierarchy Revisions Working Group and discuss the three main parameters that guide the classification – it focuses on vegetated parts of the globe, on existing vegetation, and includes (but distinguishes) both cultural and natural vegetation, for which parallel hierarchies are provided.

For natural (including semi-natural) vegetation, we define three main physiognomic levels: Formation Class, Formation Subclass, and Formation and describe each of the types for all three levels. For cultural vegetation, we define and describe four main physiognomic levels: Cultural Class, Cultural Subclass, Cultural Formation, and Cultural Subformation. We use a fourth physiognomic level for cultural vegetation because the floristic / biogeographic patterns used for natural vegetation at the fourth level are not nearly as relevant for cultural vegetation. We provide guidance for developing formation type description and nomenclature.

The upper levels were not developed in a strictly top down manner. Rather, members of the HRWG had access to draft mid and lower level units (from Division to association) for the U.S. and parts of Canada and Latin America. A comprehensive master spreadsheet of draft units for these units was organized under the upper levels, and was used to critique the overall “naturalness” of the formation units. The HRWG reevaluated formation concepts where formations introduced undesirable splits in lower units that were otherwise ecologically and floristically similar. Our goal was to make splits between upper level types that had good ecological and vegetation support for them. Still, inevitably, given the multi-dimensional and continuous gradients affecting vegetation, some criteria for upper levels require splitting otherwise closely related floristic and physiognomic types (e.g., open woodland from grassland, floodplain forest from upland forest).

Part I of the report provides an introduction to the overall classification, focusing on the upper formation levels. Appendices provide important information on members of the

working group, a draft set of formation types at all three levels, growth forms used to describe the types, and comparisons with other formation level classifications. One appendix provides a key to Level 1. The final appendix introduces examples of the Division level, the level immediately below formation. A comprehensive set of Divisions for all formations is a key next step in the process of establishing an ecological vegetation classification framework.

Part II provides a description for each type, following a standardized template format. The HRWG had limited time to develop descriptions, and we focused more on developing consistent, meaningful concepts, than extensive descriptive text. Thus, these descriptions are a first preliminary effort at global descriptions for formation types, and are provided to give some guidance to our concepts. Undoubtedly even these preliminary descriptions are biased by our western hemisphere perspective. We look forward to engaging with a broader set of ecologists around the globe to continue improving both the concepts and the descriptions. We hope such collaboration can develop, in part, by identifying vegetation types at the Division level around the globe.

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## INTRODUCTION

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There is currently no established classification framework by which vegetation ecologists can organize, define and describe global vegetation patterns at multiple scales, from broad physiognomic types to narrowly defined floristic types. Some classification publications provide little more than a name, others provide very expansive descriptions but with only some or little consistency to the classification, and others focus solely on either structural or floristic patterns. What is needed is a comprehensive, global vegetation classification approach that is multi-scalar (from broad global types to local fine scale types), committed to a rigorous plot-based approach while building on the accumulated work of vegetation ecologists over the past century, open to ongoing peer review, and able to maintain an authoritative list of types at all times that can be used for description, inventory, monitoring and mapping.

Here, we briefly introduce an ecological vegetation classification approach that addresses these needs, then focus on the development and rationale for the upper formation levels. These formations, both natural and cultural, provide a basic synopsis of the world's vegetation, structured by specific criteria, with sufficient detail to encourage consistent application anywhere in the world **and** within a multi-scale hierarchical structure. Details of the scientific basis for the classification approach, which builds on the integrated “physiognomic-floristic-ecologic” approach to vegetation classification (Rübel 1930-31, in Shimwell 1971, Whittaker 1962, Brown et al. 1998, Devilliers et al. 1991, 1996, Bohn et al. 2000-2003, Rodwell et al. 2002, Davies et al. 2004), are provided in Faber-Langendoen et al. (2012). Appendices to this report contain specific descriptions to each formation and a key to the uppermost formation class level, along with comparisons to other global formation level classifications. The classification has been developed to support the U.S. National Vegetation Classification (FGDC 2008), other partner classifications, such as the Canadian and Bolivian NVC, and constitutes a revision of the International Vegetation Classification (Grossman et al. 1998) that was based on UNESCO (1973).

## BACKGROUND

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### HIERARCHY REVISIONS WORKING GROUP

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The U.S. National Vegetation Classification (USNVC) emerged through a partnership between federal agencies and nongovernmental organizations – NatureServe and the Ecological Society of America's Vegetation Classification Panel (hereafter Panel) – through the auspices of the Federal Geographic Data Committee Vegetation Subcommittee (FGDC 1997). The USNVC adopted the international structure of UNESCO (1973) for its classification, and at the same time NatureServe supported applications of the UNESCO-based structure in other countries through the International Vegetation Classification (IVC) (Grossman et al. 1998). Thus, when the USNVC partners agreed in 2003 to undertake a revision to the USNVC, an international approach was adopted, reflecting the goals to incorporate global classification concepts, to avoid an artificial national perspective on units; that is, we sought to minimize the proliferation of artificial units by concentrating upon the natural structuring of vegetation world-wide and to emphasize the physiognomic-structural,

floristic and ecological components of vegetation without a particular emphasis on any single human construct such as height, woodiness, cover, environmental schema, or other human uses. To this end, the partners agreed to form a Hierarchy Revisions Working Group (HRWG) sponsored by FGDC. The work of the HRWG progressed in two phases.

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## PHASE I

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The Hierarchy Revisions Working Group (HRWG) was formed in November of 2003, co-chaired by representatives of the U.S. Forest Service (USFS) and NatureServe. Members were drawn from state and federal agencies and organizations in the U.S, Canada and Latin America. All were chosen based on either their familiarity with the USNVC and related classifications or for their expertise in vegetation classification. Members were also encouraged to have their own “teams” with which to consult, including the U.S. Forest Service Vegetation Technical Guide team who developed an existing vegetation classification and mapping manual (Tart et al. 2005), NatureServe staff who developed mesoscale classification units called “terrestrial ecological systems” (Comer et al. 2003, Josse et al. 2003, Comer and Schulz 2007), and California vegetation ecologists who tested the hierarchy above the alliance level on California’s vegetation (see Sawyer et al. 2009, Appendix 3). The HRWG interacted regularly with the ESA Panel, federal agencies, and NatureServe staff.

The HRWG process was somewhat formal, consisting of more or less bimonthly phone calls between November 2003 and November 2007, and three face-to-face meetings (May 3-6, 2004 in Denver, Colorado; May 22-25, 2005 in Washington DC; March 8-10 2007 in Mojave, California). The result was a suggested 8-level hierarchy to replace the 7-level hierarchy then in use (FGDC 1997). The lower two floristic levels, alliance and association, were retained as is, and the top five formation levels were compressed into three, to make way for three new physiognomic-floristic mid levels. In 2006, FGDC began the formal process for the USNVC revision, incorporating both the HRWG suggestions on the full hierarchy and the ESA Panel’s work on standards for the lower floristic levels. The HRWG continued to advise the USNVC partners through 2007 and 2008, leading to a formal revised FGDC Standard (2008). This Standard established the hierarchical framework of the USNVC and the processes for establishing and revising USNVC types. At that time, a formal report was drafted by the HRWG but never completed (Faber-Langendoen et al. 2007). That report, containing a summary of HRWG members over this period, was recently revised and is now under review (Faber-Langendoen et al. 2012p). Lower floristic level guidelines were published by Jennings et al. (2009).

The revised standard was a substantial overhaul of the 1997 standard and the classification, as summarized by FGDC (2008):

- a) uses vegetation criteria to define all types (de-emphasizing abiotic criteria, such as hydrologic regimes in wetland types),*
- b) provides a clear distinction between natural (including semi-natural) vegetation and cultural vegetation wherever these can be observed from broad growth form patterns (rather than combining natural and cultural vegetation initially and separating them at lower levels),*
- c) for natural vegetation, defines the upper levels of the hierarchy based on broad growth form patterns that reflect ecological relationships (rather than detailed structural criteria, which are more effectively used in combination with floristic criteria in lower levels of the hierarchy),*

*d) provides a new set of mid levels for natural vegetation units that bridge the large conceptual gap between alliance and formation,*

*e) integrates the physiognomic and floristic hierarchy levels based on ecologic vegetation patterns, rather than developing the physiognomic and floristic levels independently and then forcing them into a hierarchy,*

*f) provides detailed standards for plot data collection, type description and classification, data management and peer review of natural vegetation,*

*g) provides a dynamic content standard for the USNVC that allows the FGDC partner agencies and organizations to revise the classification and its component vegetation types through a peer review process, and*

*h) for cultural vegetation, provides an independent set of levels that addresses the particular needs of cultural vegetation.*

The structure of the revised hierarchy is also a substantial revision of the 1997 hierarchy, which relied heavily on the UNESCO (1973) physiognomic hierarchy for all levels above the alliance. The newly adopted national vegetation hierarchy consists of eight levels, organized into three upper levels, three middle levels, and two lower levels (Table 1).

Table 1. Comparison of original 1997 USNVC vegetation hierarchy and the 2008 revisions to that hierarchy. See also Table 2, which provides the details on both the natural and cultural 2008 hierarchies. The 1997 hierarchy was largely derived from UNESCO (1973, see also Mueller-Dombois and Ellenberg 1974, Appendix B).

| 1997 FGDC Hierarchy                             | 2008 Revised Hierarchy (for Natural Vegetation) |                              |
|-------------------------------------------------|-------------------------------------------------|------------------------------|
| Division — Vegetation vs. Non-vegetation        | <b>Upper Levels</b>                             |                              |
| Order — Tree, Shrub, Herb, Nonvascular          |                                                 |                              |
| Level 1 — Formation Class                       |                                                 | Level 1 — Formation Class    |
| Level 2 — Formation Subclass                    |                                                 |                              |
| Level 3 — Formation Group                       |                                                 | Level 2 — Formation Subclass |
| Level 4 — Formation Subgroup — Natural/Cultural |                                                 |                              |
| Level 5 — Formation                             | <b>Middle Levels</b>                            | Level 3 — Formation          |
|                                                 |                                                 | Level 4 — Division           |
|                                                 |                                                 | Level 5 — Macrogroup         |
|                                                 |                                                 | Level 6 — Group              |
| Level 6 — Alliance                              | <b>Lower Levels</b>                             | Level 7 — Alliance           |
| Level 7 — Association                           |                                                 | Level 8 — Association        |

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## PHASE II

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With the completion of the FGDC standard, USNVC partners began implementing revisions to the classification system. But two important issues remained to be resolved. First, the 2008 FGDC standard called for a screening/peer review process to induct proposed types into the revised USNVC. Thus, in June of 2010, FGDC requested the HRWG to take on the task of reviewing, revising

and describing the pilot upper level units (L1 – L3) provided in the FGDC 2008 standard (Appendix G). Fortunately, most of the members of the original HRWG stayed with the project and new members were added (Appendix A).

During this phase of development, the HRWG was able to draw on extensive testing of the upper level units, which were being used as mid and lower level units in the USNVC ([usnvc.org](http://usnvc.org)) and in Canada ([cnvc-cnvc.ca](http://cnvc-cnvc.ca)). NatureServe and partners also began applying the same approach to revisions to the International Vegetation Classification (IVC) through projects in South America (Josse 2011, Navarro 2011) and Africa. Testing of the hierarchy in Africa led to one major proposed change: move all wetland formations under an expanded Class V – Hydromorphic and Hydrophytic Vegetation. A draft of world grassland types from Formation Class to Division was also published (Faber-Langendoen and Josse 2010).

The HRWG completed the initial review of the units in October of 2010, having found that, by-and-large, information from proposed new mid-levels provided good support to the upper levels (see Division examples in Appendix J). The decision was also made to not adopt the suggested revision to Class V (to move all wetlands under a single large class), but to leave wetlands as in the 2008 scheme (see “Wetlands” section below). The HRWG made a few modest changes to the 2008 version (e.g., adding a Tropical Thorn Woodland formation, modifying various formation names), and, in consultation with the Ecological Society of America Vegetation Classification Panel (hereafter “ESA Panel”), submitted a request to FGDC that the USNVC partners adopt the 2008 pilot units. FGDC approved the request. The “official” draft set of units, as approved by FGDC (with a few name changes only) is provided in Appendix B.

The HRWG then began writing detailed descriptions of each of the L1 – L3 units. The descriptions follow the standard description template. After a year of effort, these descriptions are now complete and ready for peer review (Faber-Langendoen et al, Part II, attached separately). In addition, a key to Level 1 was produced (Appendix H, attached separately).

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## CONTEXT FOR THE HIERARCHY

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Several primary categories are helpful in describing the scope of the classification and placing it within a broader land cover context: vegetated –non-vegetated, existing vegetation, and natural – cultural vegetation.

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### VEGETATED – NON-VEGETATED

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The classification includes all vegetated areas. That is, all areas with 1% or more of their surface area covered by live vegetation are classified. This includes vegetation found on both strictly upland environments and in wetlands (rooted emergent and floating vegetation). The classification excludes non-vegetated (i.e. < 1% vegetation cover) natural lands (e.g., rock, glaciers, some deserts) and waters (e.g., lakes and rivers) and non-vegetated cultural lands (e.g., roads, buildings, mines) and waters (e.g., reservoirs, canals), though it can easily be linked to land cover classifications that do include these lands to provide a full terrestrial coverage (see “Natural and Cultural Vegetation” section below).

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## EXISTING VEGETATION

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The classification includes only existing vegetation types, as described by FGDC (2008): “Existing vegetation is the plant cover, or floristic composition and vegetation structure, documented to occur at a specific location and time, preferably at the optimal time during the growing season.” (see also Tart et al. 2005, Jennings et al. 2009). Abiotic factors, geographic and successional relationships are used to help interpret the types. Existing vegetation can provide the basis for describing potential vegetation types.

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## NATURAL AND CULTURAL VEGETATION

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The classification provides separate categories for natural and cultural vegetation, a distinction that is consistent with other vegetation and land cover classifications (e.g. Küchler 1969, Anderson et al. 1976, Di Gregorio and Jansen 1996). Although cultural and natural vegetation are distinguished in the classification, both are subsequently classified in a hierarchical framework that emphasizes primarily floristics at the lower levels, both physiognomic and floristics at mid levels, and primarily physiognomy at upper levels.

**Natural (including semi-natural) vegetation** is defined as vegetation where ecological processes primarily determine species composition and stand structure; that is, the vegetation is comprised of a set of plant species growing spontaneously (i.e., with little human influence) and is shaped by both abiotic and biotic processes (Küchler 1969, Westhoff and van der Maarel 1973). **Cultural vegetation** is defined as vegetation with a distinctive structure, composition, and development determined by regular human activity (cultural vegetation *sensu stricto* of Küchler 1969). The distinctive physiognomy, floristics, and dependence on human activity for its persistence set cultural vegetation apart from natural and semi-natural vegetation. These distinctive attributes typically include one or more of the following:

- Dominant herbaceous vegetation is regularly-spaced and/or growing in rows, often in areas with substantial cover of bare soil for significant periods of the year, usually determined by tillage or chemical treatment.
- Dominant vegetation has highly-manipulated growth forms. Structure is rarely the result of natural plant development, but is usually determined by mechanical pruning, mowing, clipping, etc.
- Dominant vegetation is comprised of species not native to the site or area that have been intentionally introduced by humans and that would not persist without active management by humans.

Recognition of cultural or “anthromorphic” vegetation classes parallels recent calls for recognition of an “Anthrosol” order for soils because of intrinsic properties of the soil caused by farming, fertilizing, irrigation and tillage (Bryant and Galbraith 2003, Gong et al. 2003).

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## SUMMARY

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We identify these fundamental aspects of vegetation using two categorical levels (Table 1a). These categories provide the organizing framework for the classification, beginning with Level 1. The framework allows the vegetation-ecologic approach to be easily extended to a full terrestrial approach by linking these categories to existing land cover classification systems, such as FAO Land Cover Classification System (Di Gregorio and Jansen 1996) (Table 1b). Further examples of this approach are provided for the USNVC by FGDC (2008, Appendix B - Relationships to the U.S. National Land Cover Database (NLCD) (USGS 2001).

**Table 1a. Conceptual Categories and Level One of the Hierarchy (from FGDC 2008, Table 2.1).**

| CATEGORY 1   | CATEGORY 2                         | Level 1                                                              |
|--------------|------------------------------------|----------------------------------------------------------------------|
| VEGETATED    | (SEMI) NATURAL VEGETATION          | Forest to Open Woodland (Mesomorphic Tree Vegetation)                |
|              |                                    | Shrubland & Grassland (Mesomorphic Shrub & Herb Vegetation)          |
|              |                                    | Desert & Semi-Desert (Xeromorphic Woodland, Scrub & Herb Vegetation) |
|              |                                    | Polar & High Montane Scrub & Grassland (Cryomorphic Vegetation)      |
|              |                                    | Aquatic Vegetation (Hydromorphic Vegetation)                         |
|              |                                    | Rock Vegetation (Lithomorphic Vegetation)                            |
|              | CULTURAL VEGETATION                | Agricultural & Developed Vegetation (Anthromorphic Vegetation)       |
| NONVEGETATED | Not included (see Table 1b below). |                                                                      |

**Table 1b. Optional non-vegetated categories from land cover classifications (FAO Land Cover Classification System).**

| CATEGORY 1    | CATEGORY 2 | Level 1 FAO (1996)                                  |
|---------------|------------|-----------------------------------------------------|
| NON-VEGETATED | NATURAL    | TERRESTRIAL: Bare Areas                             |
|               |            | AQUATIC: Natural Waterbodies, Snow and Ice          |
|               | CULTURAL   | TERRESTRIAL: Artificial Surfaces & Associated Areas |
|               |            | AQUATIC: Artificial Surfaces and Associated Areas   |

## THE HIERARCHY

The eight levels of the hierarchy for both cultural and natural vegetation are provided in Table 2. The vegetation-ecologic approach treats natural vegetation distinct from cultural vegetation; thus, each has similar but differently defined hierarchical levels. This allows for a dynamic portrait of all existing vegetation in a way that reflects ongoing changes driven by land use, climate change, invasive species and natural processes. Table 3 provides examples of natural (3a) and cultural (3b) types across all levels of the two hierarchies.

Table 2. The levels of the hierarchy, showing parallels for natural and cultural types.

| Natural Hierarchy Level | Cultural Hierarchy Level   |
|-------------------------|----------------------------|
| L1 – Formation Class    | L1 – Cultural Class        |
| L2 – Formation Subclass | L2 – Cultural Subclass     |
| L3 – Formation          | L3 – Cultural Formation    |
| L4 – Division           | L4 – Cultural Subformation |
| L5 – Macrogroup         | L5 – Cultural Group        |
| L6 – Group              | L6 – Cultural Subgroup     |
| L7 – Alliance           | L7 – Cultural Type         |
| L8 – Association        | L8 – Cultural Subtype      |

Table 3a. Hierarchical classification for natural vegetation, with examples.

| Natural Vegetation     | Example                                                                                                                                                                                                  |
|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Upper Levels</b>    |                                                                                                                                                                                                          |
| 1 – Formation Class    | <b>Scientific Name:</b> Mesomorphic Shrub & Herb Vegetation<br><b>Colloquial Name:</b> Shrubland & Grassland                                                                                             |
| 2 – Formation Subclass | <b>Scientific Name:</b> Temperate & Boreal Shrub & Herb Vegetation<br><b>Colloquial Name:</b> Temperate & Boreal Grassland & Shrubland                                                                   |
| 3 - Formation          | <b>Scientific Name:</b> Temperate Shrub & Herb Vegetation<br><b>Colloquial Name:</b> Temperate Grassland & Shrubland                                                                                     |
| <b>Mid Levels</b>      |                                                                                                                                                                                                          |
| 4 – Division           | <b>Scientific Name:</b> <i>Andropogon – Stipa – Bouteloua</i> Grassland & Shrubland Division<br><b>Colloquial Name:</b> Great Plains Grassland & Shrubland                                               |
| 5 – Macrogroup         | <b>Scientific Name:</b> <i>Andropogon gerardii – Schizachyrium scoparium – Sorghastrum nutans</i> Grassland & Shrubland Macrogroup<br><b>Colloquial Name:</b> Great Plains Tallgrass Prairie & Shrubland |
| 6 - Group              | <b>Scientific Name:</b> <i>Andropogon gerardii – Sporobolus heterolepis</i> Grassland Group<br><b>Colloquial Name:</b> Northern & Central Great Plains Tallgrass Prairie                                 |
| <b>Lower Levels</b>    |                                                                                                                                                                                                          |

|                 |                                                                                                                                                                                                                 |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7 – Alliance    | <b>Scientific Name:</b> <i>Andropogon gerardii</i> – ( <i>Calamagrostis canadensis</i> – <i>Panicum virgatum</i> ) Grassland Alliance<br><b>Colloquial Name:</b> Northern & Central Wet-mesic Tallgrass Prairie |
| 8 – Association | <b>Scientific Name:</b> <i>Andropogon gerardii</i> – <i>Panicum virgatum</i> – <i>Helianthus grosseserratus</i> Grassland<br><b>Colloquial Name:</b> Central Wet-mesic Tallgrass Prairie                        |

Table 3b. Hierarchical classification for cultural vegetation, with examples.

| Cultural Vegetation             | Example                            | Example                           |
|---------------------------------|------------------------------------|-----------------------------------|
| <b>Upper Levels</b>             |                                    |                                   |
| 1 – Cultural Class              | Anthromorphic Vegetation           | Anthromorphic Vegetation          |
| 2 – Cultural Subclass           | Herbaceous Agricultural Vegetation | Woody Agricultural Vegetation     |
| 3 – Cultural Formation          | Row & Close Grain Crop             | Woody Horticultural Crop          |
| 4 – Cultural Subformation       | Graminoid Row Crop                 | Orchard                           |
| <b>Mid Levels</b>               |                                    |                                   |
| 5 – Cultural Group [optional]   | Tropical & Temperate Corn Crop     | Tropical & Temperate Tree Orchard |
| 6 – Cultural Subgroup           | Corn Crop                          | Fruit Orchard                     |
| <b>Lower Levels</b>             |                                    |                                   |
| 7 – Cultural Type               | Maize Corn                         | Apple                             |
| 8 – Cultural Subtype [optional] | Corn for silage                    |                                   |

## DEVELOPMENT OF THE UPPER LEVELS

The upper levels of the classification were based on the formation concept, a prominent concept in the history of vegetation classification (Appendix E). The definition provided by Whittaker (1962 p 150) is typical: “a community type defined by dominance of a given growth form in the uppermost stratum (or the uppermost closed stratum) of the community or by a combination of dominant growth forms.” The UNESCO (1973) definition guided much of the earlier work on the vegetation-ecologic approach and defined the formation as “basically physiognomic-structural in character with supplementary ecological information integrated into its various categories and applicable to natural and semi-natural vegetation.” Physiognomy can be defined as “the visible structure or outward appearance of a plant community as expressed by the dominant growth forms, such as their leaf appearance or deciduousness” (Fosberg 1961). Structure is the horizontal and vertical spatial pattern of growth forms in a plant community, especially with regard to their height, abundance, coverage or biomass within the individual layers (Gabriel and Talbot 1984).

We define growth form<sup>1</sup> as the shape or appearance of a plant reflecting growing conditions and genetics (see Appendix B1 for a glossary of terms). Growth form is usually consistent within a

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<sup>1</sup> A similar term, life form, is defined as the ecological strategy that a plant uses to complete its life cycle, e.g., Raunkiaer life forms are defined on the position of the bud or organs from which new shoots or foliage

species, but may vary under extremes of environment (Mueller-Dombois and Ellenberg 1974). A list of growth forms is provided in Appendix C as a first approximation for defining upper level types<sup>2</sup>. This list is structured into two levels – general growth forms and specific growth forms. These lists were adapted from Whittaker (1975, pg 359) and Box (1981). The lists may reflect a western hemisphere perspective, but the intent is to provide a method for characterizing the growth form composition of all formations. For comparison, an extended list of “ecophysiognomic” growth form types developed by Box and Fujiwara (2005) is presented in Appendix D. This extended list could provide a stronger basis for the approach proposed here but needs further review. Introducing a combination of morphological, anatomical and physiological adaptations could allow for finer classification distinctions. Instead, however, we proposed adding diagnostic species at the mid-levels of the classification, in addition to growth form descriptors.

By characterizing the growth forms as part of a vegetation plot, it becomes possible to empirically describe the growth form components of a vegetation type and relate them to ecological factors. Thus, combinations of growth forms can define xeromorphic (desert) vegetation or hydromorphic (aquatic) vegetation. Some growth forms, however, such as “flowering forb” do not show particular strong ecological relationships, at least not as currently defined. They may be constant growth forms rather than diagnostic ones.

As with species in lower level units, a growth form is rarely restricted to one upper level formation type. Too often, a single physiognomic criteria has been used alone to define a formation (e.g., defining a formation by 25-60% tree canopy cover). Although such criteria may be helpful in a diagnostic key or for particular mapping applications, we suggest that in an integrated classification, the use of differential growth forms is more helpful. The same growth forms may appear in multiple units, but it is the relative abundance of that growth form, in combination with ecological processes and consideration of broad floristic-biogeographic patterns at lower levels, that define formation types (Table 4). Thus, tree covered lawns are separated from natural forests because of differences in the combination of shrub, herb and tree growth forms and in ecological processes, though both may have 25-60% tree canopy. That said, just as a specified presence and abundance of one or more differential species are primary criteria for defining vegetation types at lower levels, the presence and abundance levels of one or more growth forms are primary criteria for defining vegetation types at upper levels.

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develop after an unfavorable season. Different life forms may not always exhibit clear outward structural differences (e.g., hemicryptophytes and geophytes).

<sup>2</sup> The growth form list in the FGDC standard is published as a “normative list” which may require a formal approval process for amending it. In the mean-time, all additions or changes could be treated as optional.

Table 4. Characters used to distinguish Tropical Lowland Humid Forest from Tropical Montane Humid Forest (after Whitmore 1984, Table 18.1).

| Formation Criteria                         | FORMATION                              |                                       |
|--------------------------------------------|----------------------------------------|---------------------------------------|
|                                            | Tropical Lowland Humid Forest          | Tropical Montane Humid Forest         |
| Canopy height                              | 25-45 m                                | 1.5-33 m                              |
| Emergent trees                             | Characteristic, to 60 (80) m tall      | Often to usually absent, to 37 m tall |
| Pinnate leaves                             | Frequent                               | Rare to very rare                     |
| Principle leaf size class of woody plants* | Mesophyll or Macrophyll (or Megaphyll) | Mesophyll or microphyll               |
| Buttresses                                 | Usually frequent and large             | Uncommon, small or absent             |
| Cauliflory                                 | Frequent                               | Rare to absent                        |
| Big woody climbers                         | Abundant                               | Usually none                          |
| Bole climbers                              | Often abundant                         | Very few, frequent to abundant        |
| Vascular epiphytes                         | Frequent                               | Frequent to abundant                  |
| Nonvascular epiphytes                      | Occasional                             | Occasional to abundant                |

\*for definition of leaf-sizes see Mueller-Dombois and Ellenberg (1974, pg 453)

Finally, growth forms are closely related to plant functional types (PFTs) – a grouping of organisms that respond in a similar way to a suite of environmental factors (Gitay and Noble 1997). A comparison of PFTs used for broad scale assessments show a very close relationship to the growth forms presented here, and leads to aggregations of functional types that are similar to formations (Leemans 1997). This opens up the possibility of modeling responses of formations to disturbances and to climate change (Cramer 1997), as earlier developed by Box (1981), who formulated climatic envelopes for each of his growth form/plant functional types (Appendix D).

The upper levels were not developed in a strictly top down manner. Rather, members of the HRWG had access to draft mid and lower level units (from Division to association) for the U.S. and parts of Canada and Latin America. In addition, comparisons were made with other classifications in which physiognomic or formation types were used to organize floristic types, such as the European vegetation types published in Rodwell et al. 2002 (see other examples in Appendix E). To test relationships between upper and lower levels, a comprehensive master spreadsheet of draft units for these units was organized under the upper levels, and was used to critique the overall “naturalness” of the formation units. The HRWG reevaluated formation concepts where formations introduced undesirable splits in lower units that were otherwise ecologically and floristically similar. Our goal was to make splits between types that had good ecological and vegetation support for them. Still, inevitably, given the multi-dimensional and continuous gradients affecting vegetation, some criteria for upper levels require splitting otherwise closely related floristic types (e.g., open woodland from grassland, floodplain forest from upland forest).

In summary, the upper levels of the hierarchy are based on dominant and diagnostic growth forms that reflect ecological and anthropogenic drivers at global and continental scales, and their concepts are influenced by consideration of vegetation patterns at lower levels. The comprehensive set of formation types, for all 3 levels (L1-L3), are provided in Appendix B. Next, we detail the processes and logic by which the HRWG arrived at the various natural formation units, including detailed classification comments for each description (See Appendix H).

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## FORMATION CLASS

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**Formation Class:** A vegetation classification unit of high rank (1<sup>st</sup> level) defined by broad combinations of dominant general growth forms adapted to basic ranges of moisture, temperature, and/or substrate or aquatic conditions (FGDC 2008, cf. Beard 1973, cf. “major physiognomic types” of Whittaker 1975).

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## ECOLOGICAL APPROACH TO ORGANIZING FORMATION CLASS TYPES

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A primary concern of the HRWG was to consider the ecological relationships among vegetation types rather than simply growth forms alone. We asked ourselves what fundamental ecological/environmental and anthropogenic processes order vegetation globally? Can we identify the characteristics of vegetation that reflect those processes? Our concern is a familiar one to those seeking an ecological basis for developing vegetation classifications. For example, Warming (1909, p. 143) wrote:

*“Why not use each growth form [lichen, moss, herb, dwarf-shrub, shrub, tree] as a foundation upon which to build a special class? The following classes could then be distinguished: that of forest formations, of bush-formations of shrub-formations, of dwarf-shrub formations, or perennial-herb formations, of moss-formations, and of alga-formations...From a morphological standpoint this would possess a certain interest, but from a phytogeographical one it must be dismissed, because it would involve the separation of formations that are ecologically closely allied.”*

He goes on to state that formations can be based on a single or compound growth forms – where many growth-forms are combined to form a single whole. This approach has been echoed by others over the years (Whittaker 1962, 1975, Box and Fujiwara 2005) and was adopted by the HRWG. Here we rely strongly on multiple growth forms to define formations types, e.g., including needle-leaved and cold deciduous broad-leaved trees together within a temperate and boreal forest subformation, aseasonal or drought deciduous herbaceous growth forms with evergreen or drought-deciduous shrubs to define topical grassland, savanna & shrubland subformation, etc., wherever these combination of growth forms reflected a more natural vegetation unit with respect to macro-ecological gradients.

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## TERMINOLOGY FOR FORMATION NAMES

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Because our growth forms emphasize primarily morphological adaptations we use the term “morphic” to name formation types – as in hydromorphic, mesomorphic, xeromorphic (see also Ellenberg 1988, Table 4). Other researchers have used terms such as hydrophyte, mesophyte, xerophytes (e.g. Warming 1909). But these terms are often applied to species, where the

combination of morphology, anatomy, physiology, and even life history strategy define the forms. These terms may be better applied in the mid and lower levels of the classification where species are part of the criteria. Compounding the issue in North America is use of the term “hydrophyte” species that depend to varying degrees on wet habitats, irrespective of any obvious morphologic or anatomical adaptations (another term for this type of vegetation is “helophyte”). For example, Tiner (1998) defines hydrophytes as “plants growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content.” Hydrophytic vegetation is defined as, “the sum total of macrophytic plant life that occurs in areas where the frequency and duration of inundation or soil saturation produce permanently or periodically saturated soils of sufficient duration to exert a controlling influence on the plant species present” (U.S. Army Corps of Engineers 1987). By contrast, hydromorphic vegetation in our approach is defined by types where rooted and floating aquatic growth forms are dominant (i.e., aquatic vegetation).

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## ZONAL AND AZONAL VEGETATION

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Zonal vegetation refers to vegetation that reflects a close relation to the current climatic conditions of a region and that develop without significant human interference on soils with non-extreme properties (Mueller-Dombois and Ellenberg 1974). For example, mesic mixed beech-maple forests with *Fagus grandifolia* (American beech) and *Acer saccharum* (sugar maple) in northeastern United States and southeast Canada. Azonal vegetation is found on sites subject to “excessive” moisture or drought within that climatic region or strong anthropogenic influence; for example, sedge meadows, forested swamps and rocky woodlands, as well as corn fields, orchards, etc.. From the perspective of existing vegetation, we treat zonal and azonal vegetation together as part of extended environmental gradients. Thus, although climate is a strong contributor to global environmental gradients, other factors are also notable, including substrate (rock, water). The combinations of factors are used when assessing the ecological relationships among formations.

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## THE SIX NATURAL FORMATION CLASSES

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The formation class is the top level at which users enter the classification: thus, a small set of clearly defined types is helpful. The six types are defined by broad combinations of dominant general growth forms associated with basic moisture, temperature, and/or substrate or aquatic conditions, often spanning multiple climatic regions (See Appendix B1 for a glossary of terms).

In addition, practical applications of the classification suggest that we be as clear as possible on specifying criteria for what constitutes forest and woodlands versus various grassland and shrubland types. Indeed, concerns over the precise boundaries of these classes require careful attention and are noted in the description.

### 1. “Forest to Open Woodland” (Mesomorphic Tree Vegetation).

**Type Concept Sentence:** Tropical, temperate and boreal forests, woodlands and tree savannas characterized by broadly mesomorphic (including scleromorphic) tree growth forms (including *broad-leaved*, *needle-leaved*, *sclerophyllous*, *palm*, *bamboo trees*, and *tree ferns*), with at least 10% cover, irregular horizontal spacing of vegetation structure, and spanning humid to seasonally dry tropical to boreal and subalpine climates and wet to dry substrate conditions. Includes native forests as well as managed and some plantation forests where human management is infrequent.

This class contains all mesomorphic tree-dominated vegetation (including scleromorphic tree vegetation) down to 10% canopy cover. The HRWG followed the FAO recommendations (FAO 2001), which are satisfactory for ecological and floristic application in many treed biomes, in both upland and wetland formations. The appropriate boundaries for distinguishing forest and woodland vegetation have been defined in many ways. This is further complicated by use of the term savanna (see below). However, it is also common to define Forest & Woodlands as having >25% tree cover, whereas tree savannas, commonly found in grassland regions of the world, have 10-25% tree cover (see UNESCO 1973, FGDC 1997, Grossman et al. 1998). But savanna definitions vary widely, from 5-30% to 10-50% (Curtis 1959), 10-60% cover, or even higher, thus spanning the same range as used by others for woodlands. Given the commonality of a lower threshold of 10% tree cover, we felt it best to place tree savannas and woodlands together, then separate them at lower levels. The HRWG recognizes that this is not entirely satisfactory from some rangeland perspectives.

The term “savanna” (let alone its spelling, with or with the “h”) has often engendered confusion and debate. In our work, the term is restricted to two broad vegetation patterns. For temperate regions, it is applied to grasslands or shrublands with scattered trees (typically 10-30%) and primarily limited to fire-maintained upland types. Temperate grasslands without scattered trees are referred to either as grasslands or prairies. For tropical vegetation, it is applied in the classical sense as interchangeable with tropical grasslands, with or without scattered trees, but sometimes separating out the treed tropical savanna distinct from non-treed tropical savanna (tropical grasslands *sensu stricto*).

Scleromorphic tree vegetation is treated here as broadly mesomorphic and is the growth form distinctive to the warm-temperate formation (level 3).

## 2. Shrubland & Grassland (Mesomorphic Shrub & Herb Vegetation).

**Type Concept Sentence:** Grasslands, shrublands, open tree savannas, marshes, bogs and fens dominated by broadly mesomorphic (including scleromorphic) shrub and herb growth forms (including *broad-leaved*, *needle-leaved*, and *sclerophyllous shrubs*, and *forb* and *graminoid herbs*) with an irregular horizontal canopy structure, mesomorphic trees typically <10% cover, and tropical to boreal and subalpine climates and wet to dry substrate conditions.

Shrublands and grasslands are combined here because in many non-forested vegetation types, these two growth forms may occupy the same upper strata, or in some cases, grasses may even overtop shrubs (tallgrass prairie, emergent marshes). This can lead to strong floristic overlap between shrub and grass types, supporting combining them at the upper levels and separating them at lower levels.

The primary issue with this class is incorporating both upland and wetland types. See discussion on “Wetlands” below.

## 3. Polar and High Montane Scrub & Grassland (Cryomorphic Vegetation)

**Type Concept Sentence:** Cool and warm semi-deserts dominated by xeromorphic growth forms, including *succulent* (e.g., cacti, euphorbias) and *small-leaved shrubs* and *trees*, desert grasses and other xeromorphic growth forms, with an irregular horizontal canopy spacing that is often open to very sparse.

The name of this formation class emphasizes the cryomorphic nature of the vegetation. But in many tropical montane regions that are roughly equivalent with the temperate “alpine” zone, the vegetation is not truly cryomorphic. That is, the soils do not experience cryoturbation and the vegetation doesn’t experience frost, strong winds, and short growing seasons. This is true for parts of the paramo and puna, so the HRWG placed them under Shrubland & Grassland (class 2) in Tropical Montane Grassland & Shrubland. However, all temperate alpine vegetation is placed in cryomorphic.

#### 4. Desert & Semi-Desert (Xeromorphic Woodland, Scrub & Grassland Vegetation)

**Type Concept Sentence:** Tundra, alpine and tropical high montane habitats dominated by cryomorphic growth forms (including *dwarf-shrubs*, associated *herbs*, *lichens* and *mosses*) with low height and open to closed canopy.

Inclusion of Tropical Thorn Woodland with other warm-desert scrub was a late addition to the hierarchy. The decision was based on the similarity of xeromorphic trees to other desert vegetation, although some will prefer that thorn woodland be placed next to Tropical Seasonally Dry Forest (indeed some authors include thorn woodlands in that concept [Pennington et al. 2006]). Our logic for the placement of Tropical Thorn Woodland is based on explicitly defined xeromorphic growth forms (e.g. succulents, leafless thorn trees, etc).

Distinguishing non-vegetated and vegetated areas in deserts will also be difficult, given that on a site where vegetation is around 1% cover, there may be patches that vary between < 1 and > 1%, and unbiased plot sampling of the site could have some plots with no cover. The few plants occurring at such low percentages may also be generalists and not particularly strong diagnostic species.

#### 5. Aquatic Vegetation (Hydromorphic Vegetation)

**Type Concept Sentence:** Open freshwater and saltwater wetlands dominated by aquatic vegetation, either rooted with leaves rising up to or near the surface, or floating freely on the water surface. Stands typically have surface water, generally up to 2 m in depth, along ocean, lake, pond, and river margins in non-tidal, tidal and intertidal habitats.

We include rooted and submerged vegetation in this formation class but treat all other emergent wetlands under mesomorphic vegetation classes 1 and 2, as many emergent wetlands share growth forms with upland vegetation. We expect that this aquatic vegetation class will be most useful in wetland situations such as ponds (i.e. bodies of water smaller than 8 ha and less than 2 m deep with no wave action – Cowardin et al. 1979). Where aquatic vegetation forms a component of lakes, rivers and oceans, other classification schemes can provide a more holistic set of types, within which various levels of aquatic vegetation types can be included. Nonetheless, it is possible to include all vegetated habitats, even seagrasses, in this classification (e.g. Den Hartog (2003) developed comprehensive marine seagrass formations and lower level floristic units for the globe). Thus, although from a terrestrial perspective, wetlands may seem to be distinctive enough from classes 1 and 2 to place them here, when viewed from the larger aquatic vegetation perspective that includes floating and submerged freshwater and marine vegetation, they are more closely related to those classes.

#### 6. Rock Vegetation (Lithomorphic Vegetation)

**Type Concept Sentence:** *Lichen, bryophyte, alga or fern-dominated rocky habitats such as cliffs, talus, scree, pavement, cobble, lava or boulderfields.*

This formation class is restricted to vegetation found on consolidate and unconsolidated rocks where vascular plant cover is < 10% (though there is discussion as to whether non-seed plants such as ferns or *Selaginella* spp should be excluded from the 10% vascular cover limit), and the nonvascular vegetation is present to abundant. The typical habitat is cliff, scree, talus or rock outcrops, but lava flows, some desert vegetation, alpine scree and cobble beaches fit here as well. There are questions to be resolved regarding placement of sparsely vegetated boulder or cobble drainages in dry creeks, river beds, or rocky shorelines, where nonvascular vegetation may be a minor component. Scree vegetation may have more direct contact with soil with higher levels of vascular plant cover. The lack of information on rock vegetation makes classification and descriptions difficult.

Overall, this class may be ecologically disparate and some types might better be assigned to the formation class with best-matching growth form features, as these rock types often take on characteristics of the vegetation in the surrounding landscape. The formations (L3 units) in this class often have parallels to other formations, so it will be possible to track these relationships over time.

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## WETLANDS

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Wetlands have international significance due to the variety of human and ecological values they provide. However, placing wetlands in the hierarchy has been challenging. Wetlands are handled in various ways by ecological and vegetation classifications. In various global schemes, they are sometimes only noted incidentally, next to the main climatically driven types (e.g. Whittaker 1975, Box and Fujiwara 2005). Others recognized them as wholly distinct from other vegetation (NWWG 1997). The HRWG integrated them more directly into the hierarchical levels, although we struggled with their placement, as described below.

**Current version:** Wetlands are dispersed among the various classes but are segregated out at Level 3, as recommended by the HRWG, and included as a pilot example in the FGDC standard (2008).

**Alternate version:** Wetlands are grouped together into a single large hydromorphic and hydrophytic (or helomorphic) vegetation group. This version comes from options previously considered by the HRWG. It is also the product of reviews of the current version provided by a team of African ecologists, experience with wetland projects in the U.S., in conjunction with EPA, who use the National Wetlands Inventory / Cowardin wetland classification (Cowardin et al. 1979), and from review of the Canadian wetland classification (NWWG 1997), which recognizes wetlands as a separate class at the outset.

*Rationale for Current Version (wetlands initially dispersed among other classes, then individual wetland types recognized at formation level)*

1. Relies more strongly on dominant growth forms rather than diagnostic ones.
2. More strongly separates out the most distinctive vegetation classes ("more orthogonal vegetation criteria"). That is, it is difficult to class all wetlands together globally due to their "relative wetness," because that depends on the context of surrounding regional climatic and vegetation patterns.

3. Wetland distinctions vary even at the species level, because many widespread species may be considered wetland in some regions but not in other regions; e.g., definitions of Facultative and Obligate wetlands differ in US wetland regions.
4. Less dependent on ecological considerations in defining the class (i.e, a wetland/non-wetland distinction).

Rationale for Alternative Version (*wetlands grouped with aquatic vegetation as a single class, then individual wetland types recognized at formation level*)

1. Identifies the wetland criteria up front, overall, rather than repeatedly across subclasses.
2. Groups closely related wetland types together.
3. Provides a set of wetland subclasses that are clearly identified in many wetland classifications (e.g., swamp, bog & fen, marsh).
4. More strongly integrates ecologically related growth forms, even if not the dominant ones.

Rationale for either Version

1. Both do a good job of grouping vegetation patterns.
2. Both are equally amenable to mapping approaches.
3. Both provide useful categories for vegetation management.
4. Both recognize the same major wetland types at formation level (level 3).

The HRWG decided to retain the current version because it was more faithful to the criteria required for Level 1. Forested wetlands are placed in the “Forest to Open Woodland” class and shrub and herb wetlands are placed in the “Shrubland & Grassland” class. As all major wetland types are separated out at Level 3, most users will find few disadvantages to the current approach, and they can choose to aggregate all wetlands into their own category if so desired. Our approach is a classification of all vegetation, not a classification of wetland and non-wetland, which is more concerned with legal conservation and water law issues.

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## FORMATION SUBCLASS

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**Formation Subclass:** A vegetation classification unit of high rank (2<sup>nd</sup> level) defined by combinations of general dominant and diagnostic growth forms that reflect global macroclimatic factors driven primarily by latitude and continental position, or that reflect overriding substrate or aquatic conditions. (FGDC 2008, cf. Whittaker 1975, Walter 1985, Box and Fujiwara 2005).

Macroclimatic factors have a strong influence on the development of the formation subclass, even among substrate-based classes. Few issues arose in developing these subclasses. The HRWG worked with vegetation patterns that often correspond to broad bioclimatic classes. The work of Rivas-Martinez and others (Rivas-Martinez et al. 1999, Rivas-Martinez and Rivas-Sáens 1996-2009) was helpful for global scale distinctions, particularly the division of bioclimates into Tropical, Temperate, Mediterranean, Boreal, and Polar (Figure 1). Here we review a few of the subclasses, where some problems in definition were encountered. In all cases, see additional “classification comments” in the type descriptions in part II.

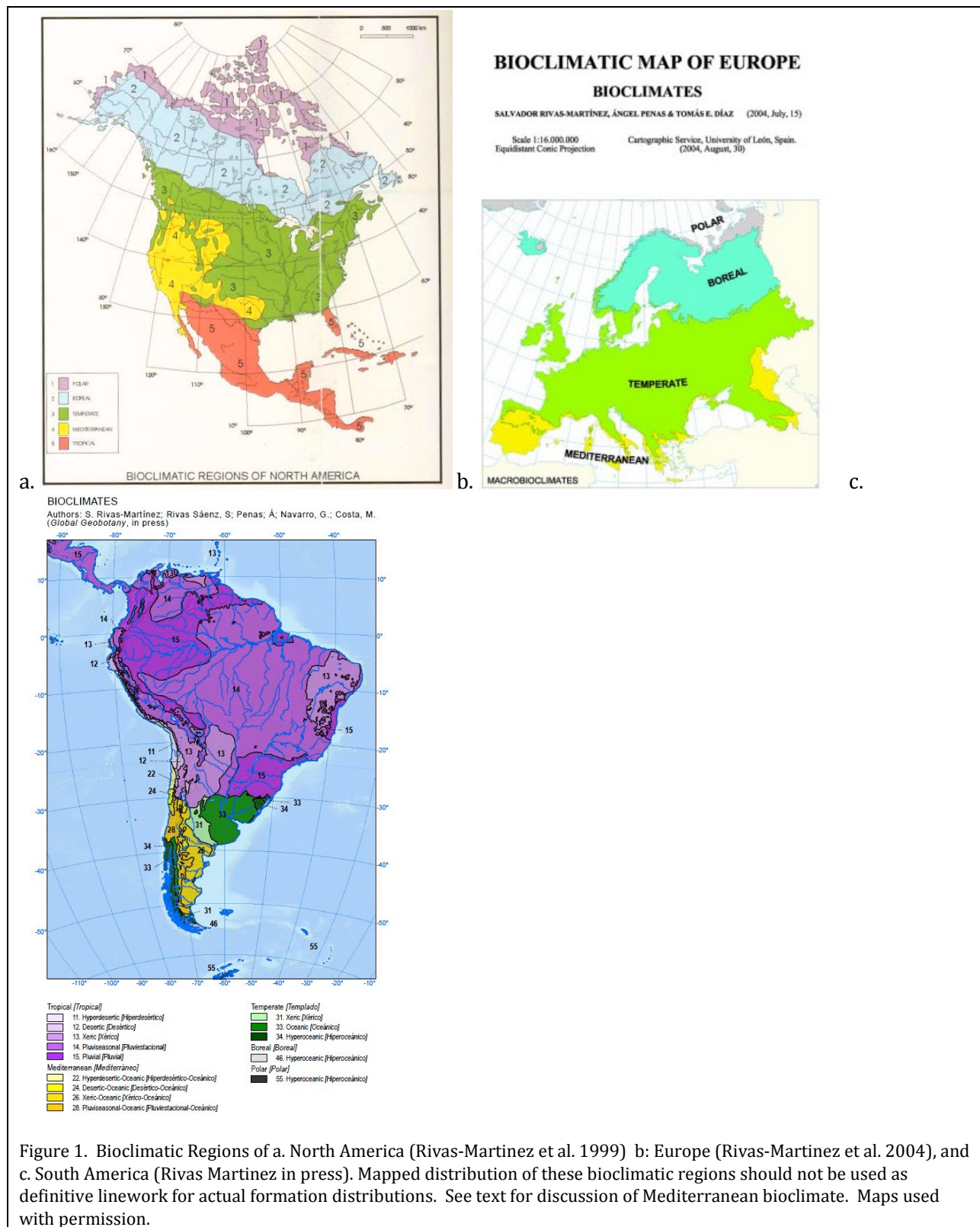
### Temperate, Boreal and Montane Vegetation

Temperate & Boreal vegetation are combined at the subclass level, because they share many of the same broad growth forms. They are recognized as distinct at the formation (L3) level based on the simplified set of growth forms and distinctive climate found in the boreal forests. Montane forests, shrublands and grasslands in the temperate and boreal regions do not contain distinctive growth forms from lower elevation vegetation, until one reaches the alpine zone. Alpine vegetation shares strong growth form similarities with polar vegetation, and they are treated together at the subclass level (4.B. Temperate, Boreal & Polar Alpine - Tundra Vegetation)

### Temperate and Mediterranean Vegetation

The one bioclimate of Rivas-Martinez and Rivas-Sáens (1996-2009) that does not correspond as closely to our approach is the Mediterranean bioclimate. They define this bioclimate to include not only Mediterranean scrub vegetation but also vegetation that we place in Cool Semi-Desert, e.g. in North America, the Great Basin vegetation, in South America the Patagonian vegetation, and in Europe the Eastern European steppe. (Figures 1, 2). In addition, we only use the term “Mediterranean” in reference to “Mediterranean Scrub & Grassland” (an L3 formation unit), thus restricting the vegetation concept to sclerophyllous and other Mediterranean type scrub growth forms, within a broadly temperate and boreal subclass. The distinctive Mediterranean vegetation around the world has been variously treated either narrowly or broadly; here, we use the term narrowly based on growth forms. The sclerophyllous and mixed evergreen – deciduous tree growth forms of the European Mediterranean region are also found in other warm-temperate climates, and so are included in the Warm-Temperate Forest class. Thus, that formation includes: in Europe, the European Mediterranean cork-oak forests (*Quercus suber*) of Spain and Portugal, fir forests (*Abies maroccana*) and cedar forests (*Cedrus atlantica*) in high-mountain areas in Morocco; oak woodlands broadly distributed throughout the Mediterranean Basin countries; in South America, the warm temperate forests of *Nothofagus macrocarpa*, *N. glauca*, *N. alessandrii*, *Austrocedrus chilensis* forests, etc.; in Australia, the many Eucalypt forests; in North America, both the Mediterranean California forests and woodlands and the Southeast U.S. Coastal Plain forests.

Our approach here, as throughout, is to emphasize the vegetation patterns, and to assess their significance through correlations with broad ecological and biogeographic processes. For example, at the level of formation subclass, we typically combine temperate and boreal units, despite the differences in macroclimate, because of their fairly strong overlap in dominant and diagnostic growth forms, whereas tropical types are much more distinctive from either temperate or boreal. Separate temperate and boreal types are recognized at the formation level.



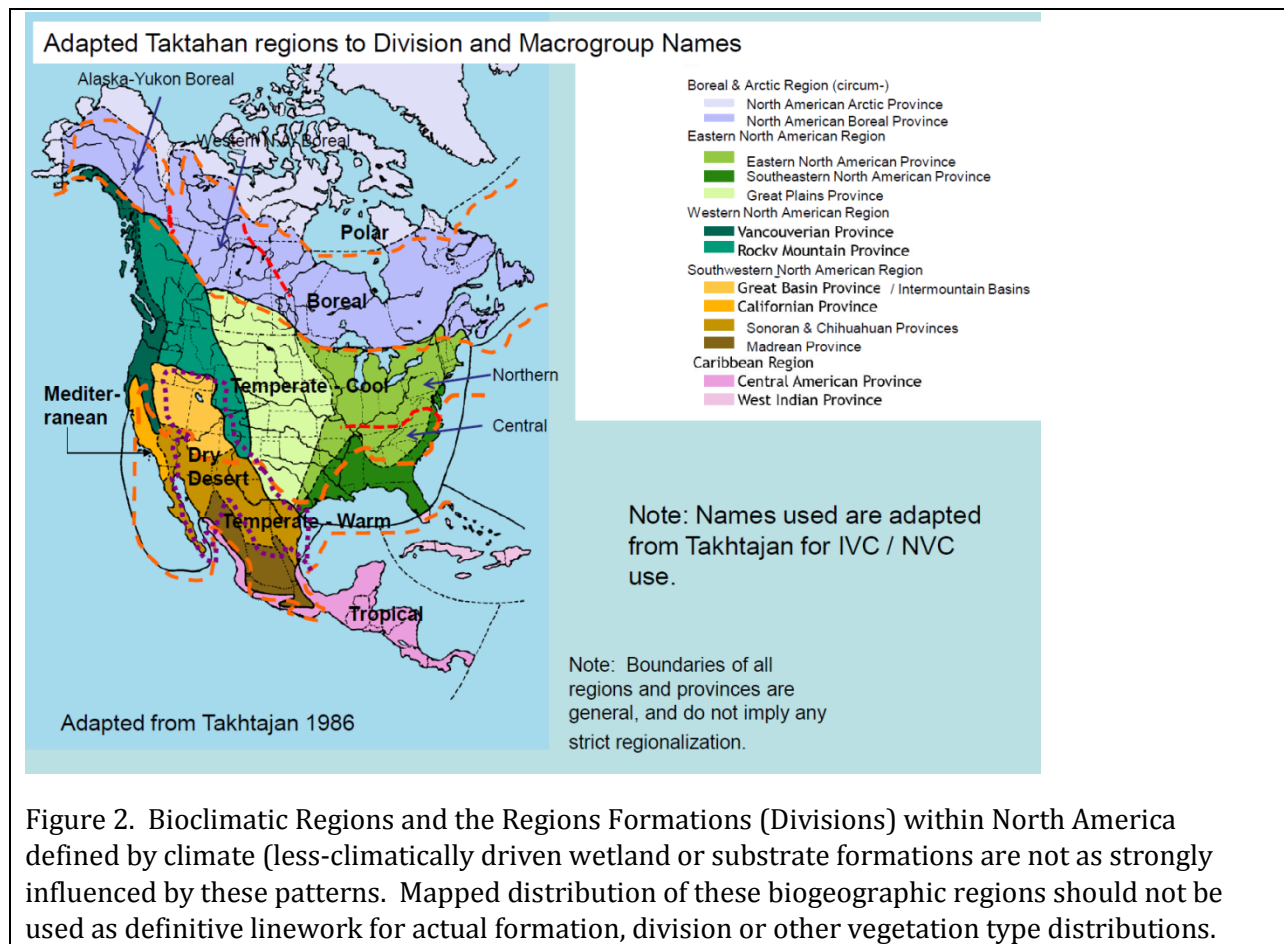


Figure 2. Bioclimatic Regions and the Regions Formations (Divisions) within North America defined by climate (less-climatically driven wetland or substrate formations are not as strongly influenced by these patterns). Mapped distribution of these biogeographic regions should not be used as definitive linework for actual formation, division or other vegetation type distributions.

## FORMATION

**Formation:** A vegetation classification unit of high rank (3<sup>rd</sup> level) defined by combinations of dominant and diagnostic growth forms that reflect global macroclimatic conditions as modified by altitude, seasonality of precipitation, substrates, and hydrologic conditions. (FGDC 2008, cf. “formation-type” and “biome-type” of Whittaker 1975, Walter 1985, Box and Fujiwara 2005).

The formation describes vegetation patterns that reflect the combination of macroclimates and/or substrate and topography. There is no strict parallelism among criteria in identifying formations; thus, in a few cases, a subclass is not split any further, because no major patterns of variation are evident with respect to the vegetation or ecological processes as compared to other types at that level. In addition, bottom-up information may also be considered, from the Division level. For example, a formation split was avoided if it creates two Divisions with overlapping floristics within

broadly similar growth forms (though tradeoffs are inevitable; e.g., wetland and upland forest formations may overlap in floristics and dominants)

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## FORMATION ISSUES

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### Tropical humid forest (1.A.2, 1.A.3).

Commonly called tropical rain forests, we chose this term to ensure that users understand that both moist and wet, or seasonal evergreen and aseasonal evergreen, rain forests are included in the concept.

### Temperate and boreal forest formations (1.B.1 – 1.B.5.)

The distinctive growth forms and climate relations of major forest formations draw from a variety of works, including Walter (1985), who separated boreal, cool-temperate and warm-temperate forests. See the Formation subclass discussion under “Temperate and Mediterranean vegetation” for a discussion of warm temperate and Mediterranean forest vegetation.

Placement of subalpine forests is problematic, as to whether they are more boreal-like or temperate-like in their growth forms and floristics, and corresponding climate. At this time, we treat subalpine forests within the temperate, as they often take on some of the characteristics of lower elevation forests, and we restrict boreal forests to the high latitude regions of the globe.

### Mediterranean scrub and grassland formation (2B.1)

See discussion of this vegetation under the Formation Subclass – Warm Temperate and Mediterranean vegetation.”

### Coastal upland scrub and herb formations (2.A.3., 2.B.4)

Distinctive ecology and substrate of beaches and dunes ,somewhat reflected in vegetation, are separated out into their own formations. This is one of the weaker formation distinctions. Note that coastal salt marshes are treated separately as a wetland formation.

### Salt marsh (2.B.7)

The vast majority of salt marshes are temperate, and so the formation is treated under 2.B (Temperate & Boreal Grassland & Shrubland). However, this makes placement of tropical salt marshes within this formation problematic. We may, for practicality, need to create a “tropical salt marsh” formation, particularly as both inland and coastal salt marshes are included in the formation (this itself is in need of further review).

### Polar tundra formations (4.C).

Wet Tundra includes peaty wet tundra (bogs and poor fens) and tundra meadows and marshes, blf Thus a separate “Wet Tundra” is not recognized.

### Tropical high montane and temperate alpine (4.A.1)

The Tropical Montane Shrubland, Grassland & Savanna (i.e. *paramo* and *puna*) is placed under the Mesomorphic class (2.A.2), differentiating it from the Tropical High Montane Scrub & Grassland Formation that has been placed within the Cryomorphic Scrub & Herb Vegetation Class. This split is owed to key physiognomic distinctions such as the ground cover of the formation, which is continuous for ??? as compared to the low, semi-open coverage of the tropical cryomorphic formations, and the predominance of mesomorphic growth forms (predominantly tussock grasses, large rosette plants, shrubs with evergreen coriaceous and sclerophyllous – *ericoid* leaves, and cushion plants). As for environmental drivers, seasonality is related to rainfall rather than temperature. The main difference of this formation with its temperate counterpart is the diurnal fluctuation of temperature, which can be 20°C or more in tropical high mountains (i.e. Andes, Africa) with no growth limiting season.

#### Cliff, scree and rock formations (6.A.1-6.D.2)

Climate and substrate combinations are used for these formations, but there is little literature available to guide us. Vascular components of these rock formations are often helpful. That is, one might find bromeliads on tropical cliffs, deciduous broadleaf shrubs on temperate cliffs, and sclerophyllous evergreen shrubs on Mediterranean cliffs. We are not aware of how the nonvascular growth forms might differ among these formations.

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### WETLAND FORMATIONS

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Our approach to defining wetland formations follows a widely used set of physiognomic-ecological types and terms that provide a set of wetland units corresponding to broad climatic and edaphic factors. We drew in particular on the Canadian Wetland Classification system for types and definitions (National Wetlands Working Group 1997, see also Mackenzie and Moran 2004) and from Mitsch and Gosselink (2000) for ecological processes and functions. The major wetland types that inform our formation distinctions are described in Table 5. Most of the wetland types are divided into tropical versus temperate wetlands based on the different kinds of dominant growth forms (e.g., broad-leaved evergreen trees and palms in tropical swamps) (see Appendix B).

Table 5. Major wetland types used to guide formation distinctions. Types, definitions, environmental features and growth forms are adapted from the Canadian National Wetlands Working Group (1997) and Mackenzie and Moran (2004), with linkage to major wetland types described by Mitsch and Gosselink (2000).

| Wetland Type | Definition                                                                                                                                                                                                                                                                                      | Environmental features                                       | Growth forms                                                              | Mitsch & Gosselink (2000) type |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------|
| <b>Bog</b>   | Bogs are shrubby, nutrient-poor peatlands with distinctive communities of ericaceous shrubs and hummock-forming <i>Sphagnum</i> species, sometimes with sedges, adapted to high acid and oxygen-poor soil conditions. Trees >2 m have <10% cover (rarely, raised bogs may contain some forested | +/- ombrotrophic<br>pH < 5.5<br><br>>40 cm fibric/mesic peat | Stunted needle-leaved tree, low shrub, dwarf shrub (ericaceous), sphagnum | Peatland                       |

|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                         |                                                                                                              |                                                                                                               |
|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
|                                                                                  | stands).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                         |                                                                                                              |                                                                                                               |
| <b>Fen</b>                                                                       | Fens are peatlands where groundwater or stream inflow maintains relatively moderate to high mineral content within the rooting zone. Sites are characterized by non-ericaceous shrubs, sedges, grasses, reeds, and brown mosses. Trees >2 m have <10% cover. Forested fen is included under Swamp Forest.                                                                                                                                                                                        | Groundwater-fed<br><br>pH > 5.0<br><br>>40 cm fibric/mesic peat                                                                                                         | Low shrub (often non-ericaceous), sedge (often fine), grass, reed, and brown moss, with or without sphagnum. | Peatland                                                                                                      |
| <b>Freshwater Marsh, Wet Meadow &amp; Shrubland (<i>non-tidal and tidal</i>)</b> | A marsh-wet meadow is a shallowly flooded or saturated wetland dominated by emergent grass-like vegetation. A fluctuating water table is typical in marshes and wet meadows, with early season high water tables and some flooding dropping through the growing (or dry) season, and exposure of the substrate or drying of the profile possible in late (or high of dry) season or drought years. Shrub wetlands (shrub carrs) occupy similar sites to wet meadows. Trees >2 m have <10% cover. | Mineral soils or well-humified peat. Protracted shallow flooding (0.1 to 2.0 m) or prolonged soil profile saturation, or freshwater or oligohaline tidal inundation.    | Grass, sedge (often coarse), forb, low shrub, tall shrub                                                     | Freshwater marshes - emergent<br><br>Tidal freshwater marshes<br><br>Riparian ecosystem (wetland, herb/shrub) |
| <b>Saltwater Marsh</b>                                                           | Saltwater marshes are intertidal to supratidal ecosystems that are flooded diurnally (or less), sometimes with freshwater inputs, and are dominated by salt-tolerant emergent graminoids and succulents. Trees >2 m have <10% cover.                                                                                                                                                                                                                                                             | Intertidal and supratidal zones, semi-diurnal to diurnal, flooding by brackish or saltwater [ <i>n.b. inland non-tidal saline wet meadows may also be placed here</i> ] | Grass, sedge, forb, halophytic (succulent) forb, halophytic shrub                                            | Tidal salt marshes                                                                                            |
| <b>Flooded &amp; Swamp Forest</b>                                                | A swamp is a forested tree mineral wetland (we place shrub swamps in marsh and wet meadow) on sites with a flowing/flooded or fluctuating semipermanent, near surface water table. Forested swamps have trees occurring on elevated microsites. Flooded forests occur on sites where flooding varies from temporary (<7 days) to semi-permanent (>180 days). Trees >2 m have ≥10% cover.                                                                                                         | Mineral soils or well-humified peat. Temporary to semi-permanent flooding (0.1 to 2 m deep), or freshwater or oligohaline tidal inundation.                             | Tall shrub, broad-leaved tree, needle-leaved tree, forb, graminoid, hydromorphic herb (rarely),              | Freshwater swamps<br><br>Riparian ecosystems (wetland, tree)                                                  |
| <b>Mangrove</b>                                                                  | Mangroves occur in the inter-tidal and brackish backwater of estuarine areas in tropical regions. Mangroves include tree and shrub                                                                                                                                                                                                                                                                                                                                                               | Intertidal and supratidal zones, semi-diurnal to diurnal, flooding by                                                                                                   | Mangrove, halophytic shrub, halophytic (succulent) forb,                                                     | Mangrove swamps                                                                                               |

|                                                           |                                                                                                                                                                                                                                                                                                                                                                     |                                                                                               |                                                    |                              |
|-----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|----------------------------------------------------|------------------------------|
|                                                           | forms of mangrove of all heights.                                                                                                                                                                                                                                                                                                                                   | brackish or saltwater                                                                         | graminoids.                                        |                              |
| <b>Aquatic Vegetation</b><br><i>(non-tidal and tidal)</i> | Aquatic wetlands are shallow waters dominated by rooted, submerged and floating aquatic plants. They are associated with permanent still or slow-moving waters, such as shallow potholes, ponds, rivers and lakes. Aquatic plants may occur in mineral or in well-humified sedimentary peat. Emergent growth forms <10% cover, hydromorphic growth forms >1% cover. | +/-Permanent deep flooding (0.5 – 2 m), substrate can be muck, sand, marl or rocky substrates | Hydromorphic (aquatic) herb, Emergents < 10% cover | Freshwater marshes - aquatic |

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### SUMMARY OF CRITERIA FOR NATURAL FORMATIONS

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We summarize the criteria for these three levels and compare them with the Division level in Table 6 to guide the transition to mid-levels.

**TABLE 6. BRIEF SUMMARY OF CRITERIA FOR FORMATION UNITS AND DIVISION**

| Criteria                    | Formation Class                                                                                                                           | Formation Subclass                                                                                                                                                                | Formation                                                                                                                                                               | Division                                                                                                                                                                                  |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Diagnostic species</b>   | --                                                                                                                                        | --                                                                                                                                                                                | --                                                                                                                                                                      | Very large set                                                                                                                                                                            |
| <b>Differential species</b> | -                                                                                                                                         | --                                                                                                                                                                                | --                                                                                                                                                                      | Many strong differentials* (character spp), often endemic to the division.                                                                                                                |
| <b>Dominant species</b>     | --                                                                                                                                        | --                                                                                                                                                                                | Sometimes informative                                                                                                                                                   | At least some of the strong differentials are dominant in parts of the range of the type.                                                                                                 |
| <b>Growth Forms</b>         | Broad combinations of dominant general growth forms and specific growth forms                                                             | Combinations of general and specific dominant and diagnostic growth forms                                                                                                         | Combinations of dominant and diagnostic growth forms, sometimes based on Individual diagnostic growth forms (e.g. mangrove)                                             | The same combination of growth forms as at the formation level                                                                                                                            |
| <b>Range of Variation</b>   | Overlapping general growth forms (tree, shrub), but combinations of diagnostic growth forms generally non-overlapping (e.g., xeromorphic) | Combinations of diagnostic growth forms partially non-overlapping (e.g., warm temperate forests and tropical forests                                                              | Combinations of diagnostic growth forms more strongly overlapping (e.g., temperate and boreal forests), relative abundances more important                              | Essentially non-overlapping floristics                                                                                                                                                    |
| <b>Ecological Gradients</b> | Basic moisture, temperature, and/or substrate or aquatic conditions                                                                       | Global macroclimatic factors driven primarily by latitude and continental position, or that reflect overriding substrate (rock vegetation) or water salinity (aquatic vegetation) | Global macroclimatic conditions in combination with landmass and edaphic factors, such as altitude, seasonality of precipitation, substrates, and hydrologic conditions | Continental scale biogeographic differences in composition, reflecting macroclimate patterns modified by the continents. Divisions within a formation are often geographically separated. |

\*a strong differential is a species BOTH primarily restricted to a type (rarely in other types) AND of sufficient constancy (draft guidance: >10% (20%?) of plots/stands at Division level) (Chytrý, M. and Tichý, L., 2003).

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## DEVELOPMENT OF CULTURAL FORMATIONS

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As with the natural vegetation, physiognomic criteria represent the primary properties of cultural vegetation at the upper levels, but are assessed in light of human activities that govern these properties. Thus, the arrangement and organizing criteria for these units is quite different from natural units, being largely constructed from physiognomic and structural considerations driven by human management activities. Excluded from these criteria are properties from outside the current vegetation, such as explicit habitat factors (e.g., climate, soil type) or land use activities (e.g., grazed pasture versus ungrazed pasture), except as these are expressed in the vegetation growth forms and structures. Some types are difficult to classify as natural or cultural vegetation (e.g., forest plantation, pastures), and the user may need to compare both parts of the hierarchy to determine the type's location.

The upper levels of the hierarchy are based on dominant and diagnostic growth forms that reflect anthropogenic drivers at global to continental scales. A comprehensive set of cultural vegetation units are available in pilot form for most levels of the hierarchy, based on the U.S. Natural Resources Conservation Service's National Resources Inventory (NRI) (FGDC 2008, Appendix I); thus, we deferred to that classification for most of the units but organized them into a hierarchical structure consistent with the overall framework.

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### CULTURAL CLASS

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**Cultural Class:** A vegetation classification unit of high rank (1<sup>st</sup> level) defined by broad combinations of dominant general growth forms determined by global scale human activities

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### CULTURAL SUBCLASS

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**Cultural Subclass:** A vegetation classification unit of high rank (2<sup>nd</sup> level) defined by combinations of general dominant and diagnostic growth forms that reflect global human activities.

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### CULTURAL FORMATION

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**Cultural Formation:** A vegetation classification unit of high rank (3<sup>rd</sup> level) defined by combinations of dominant and diagnostic growth forms that reflect global scale human activities.

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## TYPE DESCRIPTION

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Many details of type description are already provided in FGDC (2008) and Jennings et al. (2009), including from plot data preparation and data collection, data analysis, interpretation, documentation and archiving, and type description, nomenclature and peer review. That work, however, was focused on the lower floristic levels, alliances and associations. Additional guidance

is needed for application across all levels of the hierarchy. Here we summarize our approach to type description of the formations.

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## UPPER LEVEL NOMENCLATURAL RULES

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The HRWG has adopted and advocated for the approach taken in FGDC (2008) and Jennings et al. (2009), whereby a scientific name, a translated scientific name (from the vernacular plant names available from widely accepted standard taxonomic references), and a colloquial name are all provided. Translated names and colloquial names are provided in English and a variety of other common languages. The names can include both physiognomic terms (forest, grassland, bog, tundra) and species names, and may also include a biogeographic term. The HRWG recommends development of a glossary of nomenclatural terms to guide ongoing naming of types.

Formation types at Levels 1 -3 are named, defined and organized by vegetation structure and physiognomy, as these are reflected in broad climatic and site factors. A convenient aid for naming the formations, and consistent with the goal of using common terminology (FGDC 2008), is to use terms based on the habitats that they occupy (though it should be re-emphasized that habitat factors are not typically used in defining formations, Whitmore 1984, pg. 155). To avoid tendencies towards making the name too descriptive, we also provide a one-sentence descriptive summary of the type. The result is a set of easily recognized formations with memorable colloquial names that communicate the most distinctive vegetation and ecological characteristics of the formation. Currently, we apply only English terms to the three formation levels, and distinguish scientific and common names only for Level 1.<sup>3</sup>

### Level 1 (Formation class)

Class names are based on the very broad growth forms that correspond to global moisture/temperature regimes. The single name helps identify the broad grouping of growth forms that correspond to particular moisture/temperature conditions. A parenthetical set of names is included to guide general users to the main kind of vegetation included in the class. The class level is organized by decreasing complexity and cover of the vegetation, reflecting increasingly stressful site factors. Given the wide overlap in use of the terms “Forest” and “Woodland” we use both terms to indicate that the class definition encompasses all mesomorphic (i.e. broad-leaved or needle-leaved) trees of varying height and canopy spacing.

Examples:

- Mesomorphic Tree Vegetation (Forest to Open Woodland)
- Mesomorphic Shrub & Herb Vegetation (Shrubland & Grassland)
- Xeromorphic Woodland, Scrub & Herb Vegetation (Desert & Semi-Desert)
- Hydromorphic Vegetation (Aquatic Vegetation)

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<sup>3</sup> These approaches to nomenclature do not rule out the option of adding a formal Latinized name for types at these three levels, as done by Rübél (1930-31, in Shimwell 1971, Appendix B). For example, following Rübél, the scientific names for the Desert and Semi-Desert class could be “Deserta”, the Warm Semi-Desert subclass could be named “Siccadeserta” and the Cool Semi-Desert subclass named “Frigorideserta”.

## Level 2 (Formation subclass)

The subclass name reflects the structure, physiognomy and environmental factors that characterize the subclass. The primary environmental factor is macroclimate. Physiognomic terms are sometimes more specific than the class name (e.g., scrub versus shrubland where the vegetation may include tall xeromorphic tree-like plants such as tall cacti). All such terms, if used, should be defined.

Examples:

- Tropical Forest
- Temperate & Boreal Grassland & Shrubland
- Cool Semi-Desert Scrub and Grassland
- Saltwater Aquatic Vegetation

## Level 3 (Formation)

The formation name reflects the structure, physiognomy and environmental factors that characterize the formation. The primary environmental factors are macroclimate in combination with soil moisture conditions, elevation and substrate. Physiognomic terms are sometimes more specific than the class or subclass name. All physiognomic terms should be defined in the vegetation type description.

Examples:

- Tropical Lowland Humid Forest
- Mediterranean Scrub & Grassland
- Cool Semi-Desert Scrub & Grassland
- Marine & Estuarine Saltwater Aquatic Vegetation

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## DESCRIPTION TEMPLATE

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The official template for describing types is provided in FGDC (2008) and Jennings et al (2009), and is appropriate to all levels of the hierarchy (see also FGDC 2008, Section 3.2.3). An expanded set of instructions on completing the template is available on request from the authors. A few general observations on the format of these descriptions:

- A standard template is used, supplemented with a few additional fields.
- Level 1 types are fairly unique with concepts essentially taken from the expertise of the HRWG members. Other levels are more commonly used by other classifications and appropriate citations and synonyms are provided.
- A standard set of growth forms is used (see Appendix C) as provided in FGDC (2008, Appendix E). Please consult these definitions to clarify concepts. Growth forms types are placed in *italics* to remind the reader that the terms have specific meanings. The HRWG is discovering the need for additional growth forms and will propose some amendments as we

proceed. Additional growth forms that may be useful to add to the list and that are included in the descriptions can also be placed in italics, with an asterisk.

- The descriptions are provisional until formally reviewed and approved through the peer review process, after which they will be made available on the [usnvc.org](http://usnvc.org) and NatureServe explorer websites ([natureserve.org/explorer](http://natureserve.org/explorer)).

The HRWG had limited time to develop descriptions, and we focused more on developing consistent, meaningful concepts, than extensive descriptive text. Thus, these descriptions are a first preliminary effort at global descriptions for formation types, and are provided to give some guidance to our concepts. Undoubtedly even these preliminary descriptions are biased by our western hemisphere perspective. We look forward to engaging with a broader set of ecologists around the globe to continue improving both the concepts and the descriptions. We hope such collaboration can develop, in part, by identifying vegetation types at the Division level around the globe.

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## PEER REVIEW

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We follow the approach of FGDC (2008) and Jennings et al. (2009) for peer review. Those documents outline a process based on a dynamic classification standard (such as the guidelines provided here), whereby peer review is an open process conducted by professional organizations in collaboration with other interested parties. It is administered by a peer review board under the aegis of an institution capable of providing independent reviewers of appropriate experience in vegetation classification. In this case, the ESA Vegetation Classification Panel will solicit review of the current set of formations. National and international review will be solicited, and reviews back to the HRWG for response and resubmission of a final draft to the USNVC partners, and for use with the IVC and other classifications. It is desirable to have a panel of international vegetation ecologists oversee the ongoing peer review of these global formation types.

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## A KEY TO THE FORMATIONS

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An introduction and key to the Formation Class (Level 1) is provided in Appendix I.

A word is in order about how ecologists might use such a formation-level key. We note in the introduction to the key, that keying out formations requires attention to vegetation strata and growth forms. But in many cases, detailed recording of specific growth forms may not be needed if a species list and vegetation strata or general growth forms are part of the plot description (e.g., Peet et al. 1998, Mucina et al. 2000, Tart et al. 2005). This is because many species only have a single or primary growth form. If a flora or species list for a state, province, or nation also identifies the species growth form(s), then a rollup of species to growth forms will simplify the standard field methods. The user need only be aware of those species which have multiple growth forms, and which one or more growth forms is present on the plot. In the U.S., the United States Department of Agriculture (USDA) PLANTS database (2002 version; see <http://plants.usda.gov>) identifies the general growth form (“growth habit”) of all plant species in the U.S. This list could be supplemented with the specific growth forms (Appendix C) of each species.

We note the above issue with respect to keys, because it also suggests an efficient way in which descriptions at upper levels of the hierarchy can be integrated with descriptions at other levels; namely that descriptions of sites include both growth forms/strata and species (along with environment and site information).

## SYNOPSIS

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We have introduced an ecological vegetation classification framework by which vegetation ecologists can organize global vegetation patterns at multiple scales, and we provide a rationale and detailed descriptions for each of the upper level units. We believe this framework is an important contribution to what is currently available. Some classification publications provide little more than a name, others provide very expansive descriptions, but with only some or little consistency to the classification. Many global classifications only deal with broad structural patterns, others with only floristics. Here, we provide an introduction to formations, along with the descriptions and key, as a basic synopsis of the world's vegetation structured by specific growth form criteria with sufficient detail to encourage consistent application anywhere in the world, **and** within a hierarchical structure that includes both floristic and growth form criteria, ultimately at the levels of alliance and association. The formations descriptions are not detailed; rather, they rely on a large tradition of description and classification for their support, and they seek to provide as concise an overview as possible. They are presented here in draft form, and we are aware that we have not been able to invest as much effort across all of them. More work is needed to reference the many publications that support or improve these concepts. In addition, our work is only one, among many, and so establishing crosswalks to other classification will increase our understanding of how others have defined and described the vegetation.

A real test of these concepts is whether they provide any value in moving to the next step, that of supporting description and classification of Divisions and Macrogroups within the formations. It is these types that force us to specify very clearly which continents and regions these formations are found in and whether the summaries of variability so simply described here can account for the variation observed around the globe. Our expertise has primarily come from Western Hemisphere vegetation ecologists (though we have also considered vegetation in Africa and Europe). We look forward to helping vegetation ecologists achieve consensus on these “mid-level” units (see Appendix I for examples of Cool Temperate Forest and Grassland Divisions). Such collaboration can help us better understand the ecological processes, biogeographic and historical relationships, current threats and conservation status of vegetation types.

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## APPENDICES

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### APPENDIX A. HIERARCHY REVISIONS WORKING GROUP 2010-2012

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#### **CANADA**

|                     |                                                        |
|---------------------|--------------------------------------------------------|
| Del Meidinger       | (British Columbia Ministry of Forests, now consultant) |
| Serguei Ponomarenko | (NatureServe-Canada)                                   |
| Jean-Pierre Saucier | (Ministère des Ressources naturelles, Québec)          |

#### **UNITED STATES**

|                           |                                                               |
|---------------------------|---------------------------------------------------------------|
| Don Faber-Langendoen      | (NatureServe) (chair)                                         |
| Gene Fults                | (Natural Resources Conservation Service)                      |
| Andy Gray                 | (U.S. Forest Service)                                         |
| Eileen Helmer             | (U.S. Forest Service, Puerto Rico)                            |
| Bruce Hoagland            | (University of Oklahoma)                                      |
| Todd Keeler-Wolf          | (California Department of Fish and Game)                      |
| David Tart                | (U.S. Forest Service)                                         |
| Alan Weakley<br>Carolina) | (North Carolina Botanic Garden, University of North Carolina) |

#### **LATIN AMERICA**

|                 |                                               |
|-----------------|-----------------------------------------------|
| Carmen Josse    | (NatureServe, Chile)                          |
| Gonzalo Navarro | (Bolivia & Universidad Complutense de Madrid) |

APPENDIX B. FORMATION LEVEL UNITS, LEVEL 1 TO LEVEL 3.

|  | LEVEL 1– FORMATION CLASS                                                      | LEVEL 2 – FORMATION SUBCLASS                                 | LEVEL 3 – FORMATION<br>Wetland formations marked with *                            |
|--|-------------------------------------------------------------------------------|--------------------------------------------------------------|------------------------------------------------------------------------------------|
|  | <b>1. Mesomorphic Tree Vegetation (Forest to Open Woodland)</b>               | <b>1.A. Tropical Forest</b>                                  | <b>1.A.1. Tropical Seasonally Dry Forest</b>                                       |
|  |                                                                               |                                                              | <b>1.A.2. Tropical Lowland Humid Forest</b>                                        |
|  |                                                                               |                                                              | <b>1.A.3. Tropical Montane Humid Forest</b>                                        |
|  |                                                                               |                                                              | <b>1.A.4. Tropical Flooded &amp; Swamp Forest *</b>                                |
|  |                                                                               |                                                              | <b>1.A.5. Mangrove*</b>                                                            |
|  |                                                                               | <b>1.B. Temperate &amp; Boreal Forest</b>                    | <b>1.B.1. Warm Temperate Forest</b>                                                |
|  |                                                                               |                                                              | <b>1.B.2. Cool Temperate Forest</b>                                                |
|  |                                                                               |                                                              | <b>1.B.3. Temperate Flooded &amp; Swamp Forest *</b>                               |
|  |                                                                               |                                                              | <b>1.B.4. Boreal Forest</b>                                                        |
|  |                                                                               |                                                              | <b>1.B.5. Boreal Flooded &amp; Swamp Forest *</b>                                  |
|  | <b>2. Mesomorphic Shrub &amp; Herb Vegetation (Shrubland &amp; Grassland)</b> | <b>2.A. Tropical Grassland, Savanna &amp; Shrubland</b>      | <b>2.A.1. Tropical Lowland Grassland, Savanna &amp; Shrubland</b>                  |
|  |                                                                               |                                                              | <b>2.A.2. Tropical Montane Grassland &amp; Shrubland</b>                           |
|  |                                                                               |                                                              | <b>2.A.3. Tropical Scrub &amp; Herb Coastal Vegetation</b>                         |
|  |                                                                               |                                                              | <b>2.A.4. Tropical Bog &amp; Fen *</b>                                             |
|  |                                                                               |                                                              | <b>2.A.5. Tropical Freshwater Marsh, Wet Meadow &amp; Shrubland*</b>               |
|  |                                                                               | <b>2.B. Temperate &amp; Boreal Grassland &amp; Shrubland</b> | <b>2.B.1. Mediterranean Scrub &amp; Grassland</b>                                  |
|  |                                                                               |                                                              | <b>2.B.2. Temperate Grassland &amp; Shrubland</b>                                  |
|  |                                                                               |                                                              | <b>2.B.3. Boreal Grassland &amp; Shrubland</b>                                     |
|  |                                                                               |                                                              | <b>2.B.4. Temperate &amp; Boreal Scrub &amp; Herb Coastal Vegetation</b>           |
|  |                                                                               |                                                              | <b>2.B.5. Temperate &amp; Boreal Bog &amp; Fen*</b>                                |
|  |                                                                               |                                                              | <b>2.B.6. Temperate &amp; Boreal Freshwater Marsh, Wet Meadow &amp; Shrubland*</b> |
|  |                                                                               |                                                              | <b>2.B.7. Salt Marsh *</b>                                                         |

|  |                                                                                                    |                                                                           |                                                                                      |
|--|----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  | <b>3. Xeromorphic Woodland, Scrub &amp; Herb Vegetation (Desert &amp; Semi-Desert)</b>             | <b>3.A. Warm Desert &amp; Semi-Desert Woodland, Scrub &amp; Grassland</b> | <b>3.A.1. Tropical Thorn Woodland</b>                                                |
|  |                                                                                                    |                                                                           | <b>3.A.2. Warm Desert &amp; Semi-Desert Scrub &amp; Grassland</b>                    |
|  |                                                                                                    | <b>3.B. Cool Semi-Desert Scrub &amp; Grassland</b>                        | <b>3.B.1. Cool Semi-Desert Scrub &amp; Grassland</b>                                 |
|  | <b>4. Cryomorphic Scrub &amp; Herb Vegetation (Polar &amp; High Montane Scrub &amp; Grassland)</b> | <b>4.A. Tropical High Montane Scrub &amp; Grassland</b>                   | <b>4.A.1. Tropical High Montane Scrub &amp; Grassland</b>                            |
|  |                                                                                                    |                                                                           | <b>4.B.1. Temperate &amp; Boreal Alpine Dwarf-shrub &amp; Grassland</b>              |
|  |                                                                                                    | <b>4.B. Temperate, Boreal &amp; Polar Alpine - Tundra Vegetation</b>      | <b>4.B.2. Polar Tundra Vegetation</b>                                                |
|  | <b>5. Hydromorphic Vegetation (Aquatic Vegetation)</b>                                             | <b>5.A. Saltwater Aquatic Vegetation</b>                                  | <b>5.A.1. Floating &amp; Suspended Macroalgae Saltwater Vegetation</b>               |
|  |                                                                                                    |                                                                           | <b>5.A.2. Benthic Macroalgae Saltwater Vegetation</b>                                |
|  |                                                                                                    |                                                                           | <b>5.A.3. Benthic Aquatic Vascular Saltwater Vegetation</b>                          |
|  |                                                                                                    |                                                                           | <b>5.A.4. Benthic Lichen Saltwater Vegetation</b>                                    |
|  |                                                                                                    | <b>5.B. Freshwater Aquatic Vegetation</b>                                 | <b>5.B.1. Tropical Freshwater Aquatic Vegetation</b>                                 |
|  |                                                                                                    |                                                                           | <b>5.B.2. Temperate &amp; Boreal Freshwater Aquatic Vegetation</b>                   |
|  | <b>6. Lithomorphic Vegetation (Rock Vegetation)</b>                                                | <b>6.A. Tropical Rock Vegetation</b>                                      | <b>6.A.1. Tropical Cliff, Scree &amp; Other Rock Vegetation</b>                      |
|  |                                                                                                    |                                                                           | <b>6.B.1. Mediterranean Cliff, Scree &amp; Other Rock Vegetation</b>                 |
|  |                                                                                                    | <b>6.B. Mediterranean, Temperate &amp; Boreal Rock Vegetation</b>         | <b>6.B.2. Temperate &amp; Boreal Cliff, Scree &amp; Other Rock Vegetation</b>        |
|  |                                                                                                    |                                                                           | <b>6.C.1. Warm Desert &amp; Semi-Desert Cliff, Scree &amp; Other Rock Vegetation</b> |
|  |                                                                                                    | <b>6.C. Desert &amp; Semi-Desert Rock Vegetation</b>                      | <b>6.C.2. Cool Semi-Desert Cliff, Scree &amp; Other Rock Vegetation</b>              |
|  |                                                                                                    |                                                                           | <b>6.D.1. Tropical High Montane Cliff, Scree &amp; Other Rock Vegetation</b>         |
|  |                                                                                                    | <b>6.D. Polar &amp; High Montane Rock Vegetation</b>                      | <b>6.D.2. Polar &amp; Alpine Cliff, Scree &amp; Other Rock Vegetation</b>            |

|  |                                                                                      |                                                                 |                                                                         |
|--|--------------------------------------------------------------------------------------|-----------------------------------------------------------------|-------------------------------------------------------------------------|
|  | <b>7. Anthromorphic Vegetation<br/>(Agricultural &amp; Developed<br/>Vegetation)</b> | <b>7.A. Woody Agricultural<br/>Vegetation</b>                   | <b>7.A.1. Woody Horticultural Crop</b>                                  |
|  |                                                                                      |                                                                 | <b>7.A.2. Intensive Forest Plantation &amp; Agroforestry Vegetation</b> |
|  |                                                                                      |                                                                 | <b>7.A.3. Woody Wetland Horticultural Crop</b>                          |
|  |                                                                                      | <b>7.B. Herbaceous Agricultural<br/>Vegetation</b>              | <b>7.B.1. Row &amp; Close Grain Crop</b>                                |
|  |                                                                                      |                                                                 | <b>7.B.2. Pasture - Hay Field &amp; Crop</b>                            |
|  |                                                                                      |                                                                 | <b>7.B.3. Herbaceous Horticultural Crop</b>                             |
|  |                                                                                      |                                                                 | <b>7.B.4. Fallow Field &amp; Weed Vegetation</b>                        |
|  |                                                                                      |                                                                 | <b>7.B.5. Herbaceous Wetland Agricultural Crop</b>                      |
|  |                                                                                      | <b>7.C Herbaceous &amp; Woody<br/>Developed Vegetation</b>      | <b>7.C.1. Lawn &amp; Recreational Vegetation</b>                        |
|  |                                                                                      |                                                                 | <b>7.C.2. Horticultural Garden Vegetation</b>                           |
|  |                                                                                      |                                                                 | <b>7.C.3. Open Developed Vegetation</b>                                 |
|  |                                                                                      |                                                                 | <b>7.C.4. Developed Wetland Vegetation</b>                              |
|  |                                                                                      | <b>7.D. Agricultural &amp; Developed<br/>Aquatic Vegetation</b> | <b>7.D.1. Agricultural Pond Vegetation</b>                              |
|  |                                                                                      |                                                                 | <b>7.D.2. Urban &amp; Recreational Pond Vegetation</b>                  |
|  |                                                                                      |                                                                 |                                                                         |
|  |                                                                                      | <b>6 natural classes</b>                                        | <b>14 natural subclasses</b>                                            |
|  |                                                                                      | <b>1 cultural subclass</b>                                      | <b>4 cultural subclasses</b>                                            |
|  |                                                                                      |                                                                 | <b>42 natural formations</b>                                            |
|  |                                                                                      |                                                                 | <b>14 cultural formations</b>                                           |

|                                      |                                |                                    |
|--------------------------------------|--------------------------------|------------------------------------|
| Non-vegetated Classes<br>(non - NVC) | Natural Open Water             | Lakes                              |
|                                      |                                | Rivers                             |
|                                      |                                | Estuaries and Oceans               |
|                                      | Cultural Open Water            | Reservoirs, Canals, etc.           |
|                                      | Perennial Snow / Ice           |                                    |
|                                      | Natural Bare Areas             | Consolidated (Rock, etc)           |
|                                      |                                | Unconsolidated (Sand, Gravel, etc) |
|                                      |                                | Subterranean                       |
|                                      | Cultural Bare Areas- Developed | Developed, Low Intensity           |
|                                      |                                | Developed, Medium Intensity        |
|                                      |                                | Developed, High Intensity          |

| Descriptive Modifiers |  | Classes (continous variables may also be used)                            |
|-----------------------|--|---------------------------------------------------------------------------|
| Leaf Phenology        |  | Evergreen (e.g., > 75%)<br>Mixed (e.g., 25-75%)<br>Deciduous (e.g., >75%) |
| Canopy Height         |  | Tall (> 5 m, > 10 m etc.)<br>Medium (2 - 5 m)<br>Short< 2 m)              |
| Canopy Spacing        |  | Closed (e.g. 60-100%)<br>Open (e.g., 25-60%)<br>Sparse(e.g., 10-25%)      |

| Wetland Modifiers? |                   |
|--------------------|-------------------|
| To be determined   | e.g. see NWI plus |

## APPENDIX B.1. GLOSSARY OF TERMS

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The following set of terms are selected from the FGDC (2008) standard.

- Agricultural Vegetation** — a vegetation type that exhibits a) rapid turnover in structure, typically at least on an annual basis, either through comprehensive manipulation of physiognomy and floristics by harvesting and/or planting, or by continual removal of above ground structure (e.g., cutting, haying), or b) showing strong linear (planted) features. The herbaceous layer may be bare at various times of the year.
- Abiotic** — pertaining to the nonliving parts of an ecosystem, such as soil particles, bedrock, air, and water (Helms 1998).
- Abundance** — the total number of individuals of a taxon or taxa in an area, volume, population, or community; often measured as cover in plants (Lincoln et al. 1998).
- Basal Area** — the cross-sectional area of all stems of a species or all stems in a stand measured at breast height (4.5 feet or 1.37 meters above the ground) and expressed per unit of land area (Helms 1998).
- Biome** — major type of natural vegetation that occurs wherever a particular mix of climatic and edaphic conditions is encountered: or we may equate it with a the notion of a major ecosystem type. (Ladle and Whittaker 2011).
- Canopy Cover** — the percentage of ground covered by the vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings in the canopy are included (SRM 1989, USDA NRCS 1997). *cf.* foliar cover.
- Class** — see Formation Class.
- Classification** — the grouping of similar types (in this case – vegetation types) according to criteria (in this case - physiognomic and floristic). The rules for classification shall be clarified prior to delineation of the types within the classification standard. Classification methods should be clear, precise, and based upon objective criteria so that the outcome is theoretically independent of who applies the classification. (UNEP/FAO 1995, FGDC 1997).
- Classification Plot Records** — plot records that contain the data necessary to inform the development or revision of the floristic units within the NVC. Such plots typically contain high quality data on floristic composition and structure, and conform to the standard articulated in Section 3.1.1 (Jennings et al.2006). *cf.* Occurrence Plot Records.
- Close grown crops** — crops that are generally drill-seeded or broadcast, such as wheat, oats, rice, barley, and flax, resulting in very narrow regularly spaced, structure (adapted from NRI 2003).
- Cover** — see canopy cover, foliar cover.
- Cropland** — see Agricultural Vegetation.
- Cross-walk** — to describe and document the relationships between members of one set or series and members of another set or series. These relationships may be one-to-one, one-to-many, or many-to-many.

**Cryomorphic** — pertaining to plants having structural or functional adaptations to survive cold temperatures and resist frost damage (e.g., alpine creeping dwarf-shrubs, krummholz).

**Cultural Vegetation** — vegetation with a distinctive structure, composition, and development determined by regular human activity (Küchler 1969).

**Developed Vegetation** — a vegetation type that typically contains an almost continuous herbaceous (typically grass) layer, with a closely cropped physiognomy, typically through continual removal of above ground structure (e.g. cutting, mowing), and where tree cover is highly variable, or other highly manipulated planted gardens.

**Diagnostic Growth Form** — any growth form or group of growth forms whose relative constancy or abundance differentiates one vegetation type from another. Diagnostic growth forms include Dominant Growth Form and Indicator Growth Form.

**Division** — the fourth level in the natural vegetation hierarchy, in which each vegetation unit is defined by a group of plant communities in a given continental or other broad geographic area exhibiting a common set of dominant growth forms and many diagnostic plant taxa (including character taxa of the dominant growth forms) corresponding to broad climatic and environmental characteristics. (Westhoff and van der Maarel 1973, p 664-665, Whittaker 1975).

**Dominance** — the extent to which a given taxon or growth form has a strong influence in a community because of its size, abundance, or cover. (Lincoln et al. 1998).

**Dominant Growth Form** — growth form with the highest percent of cover, usually in the uppermost dominant layer (in other contexts dominant growth forms can be defined in terms of biomass, density, height, coverage, etc).

**Epiphyte** — a vascular or nonvascular plant that grows by germinating and rooting on other plants or other perched structures, and does not root in the ground (adapted from FGDC 1997).

**Existing Vegetation** — vegetation found at a given location at the time of observation (Jennings et al. 2006). cf. Potential Natural Vegetation.

**Field Stratum** — the layer of vegetation consisting of herbs, regardless of height, as well as woody plants less than 0.5 m in height (Jennings et al. 2006).

**Floating Aquatic Stratum** — the layer of vegetation consisting of rooted or drifting plants that float on the water surface; e.g. duckweed, water-lily (Jennings et al. 2006).

**Foliar Cover** — the percentage of ground covered by the vertical projection of the aerial portion of plants. Small openings in the canopy and intraspecific overlap are excluded (SRM 1989) cf. canopy cover.

**Forb** — a non-aquatic, non-graminoid herb with relatively broad leaves and/or showy flowers. Includes both flowering and spore-bearing, non-graminoid herbs.

**Formation** — the third level in the natural vegetation hierarchy, in which each vegetation unit is defined by a geographically widespread (global) plant communities of similar physiognomy and dominant growth forms, typically related to major topographic and edaphic conditions occurring within major climatic conditions (Whittaker 1975, Lincoln et al. 1998). The formation corresponds to a (cf.) “biome.” **Formation Class** — the first (highest) level in the natural vegetation hierarchy, in which each vegetation unit is

defined by a characteristic combination of dominant growth forms adapted to a very basic set of moisture / temperature regimes.

**Formation Subclass** — the second level in the natural vegetation hierarchy, in which each vegetation unit is defined by geographically widespread (global) plant communities of similar physiognomy and dominant growth forms, typically related to major climatic conditions (Whittaker 1975, Lincoln et al. 1998).

**Graminoid** — a non-aquatic, flowering herb with relatively long, narrow leaves and inconspicuous flowers with parts reduced to bracts. Includes grasses, sedges, rushes, and arrowgrasses.

**Ground Stratum** — *cf.* nonvascular stratum.

**Growth form** — the shape or appearance of a plant reflecting growing conditions and genetics. Growth form is usually consistent within a species, but may vary under extremes of environment (Mueller-Dombois and Ellenberg 1974). Growth forms determine the visible structure or physiognomy of plant communities (Whittaker 1973a).

**Habitat** — a general term referring to the locality, site and particular type of local environment occupied by an organism or community (adapted from Lincoln et al. 1998).

**Herb** — a vascular plant without perennial aboveground woody stems, with perennating buds borne at or below the ground surface (Whittaker 1975, FGDC 1997). Includes forbs (both flowering forbs and spore-bearing ferns), graminoids, and herbaceous vines.

**Herb Stratum** — see Field Stratum.

**Hydromorphic** — pertaining to plants having structural or functional adaptations for living in water-dominated or aquatic habitats (adapted from FGDC 1997 and Lincoln et al. 1998).

**Indicator Growth Form** — a growth form whose presence, abundance, or vigor is considered to indicate certain site conditions.

**Land Cover** — the observed (bio)physical cover of the earth's surface (Di Gregorio and Jansen 1996).

**Land Use** — the arrangements, activities, and inputs people undertake in a certain land cover type to produce, change, or maintain it (Di Gregorio and Jansen 1996).

**Layer (vegetation)** — a structural component of a community consisting of plants of approximately the same height and growth form (e.g., tree overstory, tree regeneration). *cf.* Stratum.

**Liana** — a woody, climbing plant that begins life as terrestrial seedlings but relies on external structural support for height growth during some part of its life (Gerwing 2004), typically exceeding 5 m in height or length at maturity.

**Life form** — plant type defined by the characteristic structural features and method of perennation, generally as defined by Raunkiaer (1934; see Beard 1973).

**Lithomorphic** — pertaining to plants having structural or functional adaptations for living on rock surfaces or in rocky substrates (i.e. particle sizes larger than 2 mm diameter (adapted from Lincoln et al. 1998).

- Macroclimate** — the climate of a major geographical region primarily reflecting latitude and continental position, excluding the effects of landform and vegetation (adapted from Bailey 1988, 1996; Lincoln et al. 1998; Forman and Godron 1986).
- Mesoclimate** — the climate of a geographic area resulting from modification of the macroclimate by the influences of landforms, altitude, aspect, and slope gradient (Bailey 1988, 1996).
- Mesomorphic** — pertaining to plants requiring environmental conditions of moderate moisture and temperature or which are only partially protected against desiccation (adapted from Lincoln et al. 1998).
- Microclimate** — the climate of the immediate surroundings or habitat resulting from modification of the mesoclimate by the influences of local topography, vegetation, and soil (adapted from Lincoln et al. 1998 and Bailey 1988, 1996).
- Moss Stratum** — see Ground Stratum.
- Natural Vegetation** — vegetation where ecological processes primarily determine species and site characteristics; that is, vegetation comprised of a largely spontaneously growing set of plant species that are shaped by both site and biotic processes (Kuchler 1969, Westhoff and Van der Maarel. 1973).
- Nonvascular** — a plant or plant-like organism without specialized water or fluid conductive tissue (xylem and phloem). Includes mosses, liverworts, hornworts, lichens, and algae (adapted from FGDC 1997).
- Nonvascular Stratum** — the layer of vegetation consisting of non-vascular plants growing on soil or rock surfaces. This includes mosses, liverworts, hornworts, lichens, and algae (Jennings et al. 2006). Sometimes called the Ground Stratum.
- Non-vegetated** — A category used to classify lands with limited capacity to support life and typically having less than 1 percent vegetative cover. Vegetation, if present, is widely spaced. Typically, the surface of barren land is sand, rock, exposed subsoil, or salt-affected soils. Subcategories include salt flats; sand dunes; mud flats; beaches; bare exposed rock; quarries, strip mines, gravel pits, and borrow pits; river wash; oil wasteland; mixed barren lands; and other barren land (adapted from NRI 2003). Exceptions include vegetation which exhibits a distinct composition under very sparse conditions (e.g., sea rocket coastal shore vegetation, or amaranth coastal vegetation). These types rarely have greater than 1% cover.
- Physiognomy** — the visible structure or outward appearance of a plant community as expressed by the dominant growth forms, such as their leaf appearance or deciduousness (Fosberg 1961, Jennings et al. 2006) *cf.* structure.
- Planted/Cultivated** — see Cultural Vegetation.
- Plot** — in the context of vegetation classification, an area of defined size and shape that is intended for characterizing a homogenous occurrence of vegetation. *cf.* relevé.
- Potential Natural Vegetation** — the vegetation that would become established if successional sequences were completed without interference by man or natural disturbance under the present climatic and edaphic conditions (Tüxen 1956). *cf.* existing vegetation.
- Range of Variation** — the values of an attribute, such as species composition or environmental parameters, that fall within the upper and lower bounds determined

for that attribute. The range of variation in the floristic composition of a vegetation type may, for example, be expressed in terms of its beta diversity (*cf.* Wilson and Shmida 1984, McCune et al. 2002), either along an environmental gradient or as the amount of compositional change among a group of plots.

**Relevé** — a record of vegetation intended for characterizing a stand of vegetation having uniform habitat and relatively homogeneous plant cover, and which is large enough in area to contain a large proportion of the species typically occurring in the plant community (Mueller-Dombois and Ellenberg 1974) *cf.* plot.

**Reserved** — a section of the FGDC standard that will be addressed or developed in subsequent versions.

**Sampling Strategy** — the means and criteria used to select the locations for plots (based on Tart et al. 2005b, Mueller-Dombois and Ellenberg 1974, and Gauch 1982).

**Seral** — a vegetation type (or component species) that is nonclimax; a species or community demonstrably susceptible to replacement by another species or community (Daubenmire 1978).

**Semi-Natural Vegetation** — vegetation in which past or present human activities significantly influence composition or structure, but do not eliminate or dominate spontaneous ecological processes (Westhoff and Van der Maarel 1973).

**Shrub** — a woody plant that generally has several erect, spreading, or prostrate stems which give it a bushy appearance. In instances where growth form cannot be determined, woody plants less than 5 m in height at maturity shall be considered shrubs. Includes dwarf-shrubs, krummholz, and low or short woody vines (adapted from FGDC 1997 and Box 1981).

**Shrub Stratum** — the layer of vegetation consisting of woody plants more than 0.5 m tall but less than 5 m in height, such as shrubs, tree seedling and saplings, and lianas. Epiphytes may also be included in this stratum. Rooted herbs are excluded even if they are over 0.5 m in height (adapted from Jennings et al. 2006).

**Stand** — a spatially continuous unit of vegetation with uniform composition, structure, and environmental conditions. This term is often used to indicate a particular example of a plant community (Jennings et al. 2006).

**Stratum** — a structural component of a community consisting of plants of approximately the same height; e.g., tree, shrub, or herb strata (Jennings et al. 2006).

**Structure (vegetation)** — (1) the spatial pattern of growth forms in a plant community, especially with regard to their height, abundance, or coverage within the individual layers (Gabriel and Talbot 1984). (2) the spatial arrangement of the components of vegetation resulting from plant size and height, vertical stratification into layers, and horizontal spacing of plants (Lincoln et al. 1998, Mueller-Dombois and Ellenberg 1974). *cf.* physiognomy.

**Subclass** — the level in the NVC classification hierarchy under class (see Figure 1) based on growth form characteristics (Grossman et al. 1998).

**Submerged Aquatic Stratum** — the layer of vegetation consisting of rooted or drifting plants that by-and-large remain submerged in the water column or on the aquatic bottom; e.g. sea grass (Jennings et al. 2006).

**Tree** — a woody plant that generally has a single main stem and a more or less definite crown. In instances where growth form cannot be determined, woody plants equal to or greater than 5 m in height at maturity shall be considered trees (adapted from FGDC 1997). Includes dwarf trees (Tart et al. 2005b) or “treelets” (Box 1981).

**Tree Stratum** — the layer of vegetation consisting of woody plants more than 5 m in height, including mature trees, shrubs over 5 m tall, and lianas. Epiphytes growing on these woody plants are also included in this stratum (Jennings et al. 2006).

**Type** — see Vegetation Type.

**Vegetation** — the collective plant cover of an area (FGDC 1997)

**Vegetation type** — a named category of plant community or vegetation defined on the basis of shared floristic and/or physiognomic characteristics that distinguish it from other kinds of plant communities or vegetation (Tart et al. 2005a). This term can refer to units in any level of the NVC hierarchy.

**Xeromorphic** — pertaining to plants having structural or functional adaptations to prevent water loss by evaporation (Lincoln et al. 1998).

## APPENDIX C. GROWTH FORM NAMES, CODES, AND DEFINITIONS

Names, definitions and codes for general and specific growth forms for use in collecting vegetation plot data (from Table E.1 of FGDC 2008) (see also Whittaker 1975:359, Tart et al. 2005b). Growth forms should not be confused with vegetation layers or strata.

| Growth Form Code | NAME AND DEFINITION                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| T                | <b>Tree</b> - A woody plant that generally has a single main stem and a more or less definite crown. In instances where growth form cannot be determined, woody plants equal to or greater than 5 m in height at maturity are to be considered trees (adapted from FGDC 1997). Includes krummholz (wind-stunted trees and small trees or “treelets” (Box 1981)                                                                                                              |
| S                | <b>Shrub</b> - A woody plant that generally has several erect, spreading, or prostrate stems which give it a bushy appearance. In instances where growth form cannot be determined, woody plants less than 5 m in height at maturity are to be considered shrubs (adapted from FGDC 1997). Includes dwarf-shrubs (less than 30 cm), low or short woody vines, and arborescents (woody plants that branch at or near ground-level but grow to low tree heights). (Box 1981). |
| H                | <b>Herb</b> - A vascular, non-woody plant without perennial aboveground woody stems, with perennating buds borne at or below the ground surface. (Whittaker 1975, FGDC 1997). Includes forbs (both flowering forbs and spore-bearing vascular plants), graminoids, and herbaceous vines.                                                                                                                                                                                    |
| N                | <b>Nonvascular</b> - A plant or plant-like organism without specialized water or fluid conductive tissue (xylem and phloem). Includes mosses, liverworts, hornworts, lichens, and algae (adapted from FGDC 1997). Also called thallophytes or “nonvascular cryptogams,” (that is, excluding the vascular cryptogams; see Herb) (Box 1981).                                                                                                                                  |
| E                | <b>Epiphyte</b> - A vascular or nonvascular plant that grows by germinating and rooting on other plants or other perched structures, and does not root in the ground (adapted from FGDC 1997).                                                                                                                                                                                                                                                                              |
| L                | <b>Liana</b> - A woody, climbing plant that begins life as terrestrial seedlings but relies on external structural support for height growth during some part of its life (Gerwing 2004), typically exceeding 5 m in height or length at maturity.                                                                                                                                                                                                                          |

| General Growth Form Code | Specific Growth Form Code | NAME AND DEFINITION                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------------------|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| T                        | TBD                       | <b>Broad-leaved deciduous tree</b> - A tree with a branching crown, leaves that have well-defined leaf blades that are generally of at least microphyll size ( $\geq 225 \text{ mm}^2$ , or $0.35 \text{ in}^2$ ) and which seasonally loses all of its leaves and becomes temporarily bare-stemmed. (adapted from FGDC 1997, Box 1981) <i>[n.b. This growth form may need to be further divided into Broad-leaved semi-deciduous tree (TBDS) for the tropics].</i> |
|                          | TBE                       | <b>Broad-leaved evergreen tree</b> - A tree with a branching crown, leaves that have well-defined leaf blades that are generally of at least microphyll sized ( $\geq 225 \text{ mm}^2$ or $0.35 \text{ in}^2$ ) and which has green leaves all year round. (FGDC 1997, Box 1981)                                                                                                                                                                                   |

|   |      |                                                                                                                                                                                                                                                                                                                                             |
|---|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   | TBES | <b>Sclerophyllous tree</b> - A type of broad-leaved evergreen tree with leaves that are stiff and firm, and retain their stiffness even when wilted. The leaves are typically relatively small (microphyll to small mesophyll in size), and sometimes rather linear (FGDC 1997, Whittaker 1975, Box 1981)                                   |
|   | TN   | <b>Needle-leaved tree</b> - A tree with slender, elongated leaves or with small overlapping leaves that usually lie flat on the stem. Includes scale-leaved and needle-leaved trees, deciduous and evergreen, needle-leaved trees. (FGDC 1997, Box 1981)                                                                                    |
|   | TU   | <b>Succulent tree</b> – A tree or arborescent plant with fleshy stems or leaves with specialized tissue for the conservation of water (FGDC 1997). Includes cacti, Joshua trees, euphorbias, and others over 5 meters in height at maturity. An “arborescent stem-succulent” (Box 1981)                                                     |
|   | TM   | <b>Small-leaved tree</b> - A tree with very small leaves ( $<225 \text{ mm}^2$ , or $0.35 \text{ in}^2$ ), or even leafless, sometimes armed with spines. Includes both evergreen and deciduous small-leaved trees, such as <i>Acacia greggii</i> , <i>Mimosa</i> (adapted from “thorn tree” by Whittaker 1975).                            |
|   | TP   | <b>Palm tree</b> - An evergreen, broad-leaved, flowering tree with a simple, unbranched stem and terminal, rosulate crown of large, pinnate or fan-shaped leaves. A type of rosette tree. Palms are the primary taxa (but see Draceanaceae, some Pandanaceae, etc.; Box 1981)                                                               |
|   | TF   | <b>Tree fern</b> - An evergreen, broad-leaved, spore-bearing tree (or arborescent fern) with a simple, unbranched stem and terminal, rosulate crown of large fronds. A type of rosette tree, including taxa from Cyatheaceae and some Velloziaceae (Box 1981).                                                                              |
|   | TG   | <b>Bamboo tree</b> - A woody-stemmed, arborescent grass that is equal to or greater than 5 m in height at maturity. Only applies to woody-stemmed bamboos. Includes the “Arborescent grasses” (Box 1981). Other more typically woody grasses, such as <i>Arundo</i> , <i>Saccharum</i> , currently excluded, and treated as Herb-graminoid. |
| S | SD   | <b>Dwarf-shrub</b> - A caespitose, creeping, matted, or cushion-forming shrub that is generally small-leaved and is typically less than 30 cm tall at maturity due to genetic and/or environmental constraints. Does not include woody plants less than 30 cm tall due to young age. (adapted from Mueller-Dombois and Ellenberg 1974)      |
|   | SBD  | <b>Broad-leaved deciduous shrub</b> - A shrub that is typically more than 30 cm tall at maturity with leaves that have well-defined leaf blades that are generally of at least microphyll size ( $\geq 225 \text{ mm}^2$ , or $0.35 \text{ in}^2$ and seasonally loses all of its leaves and becomes temporarily bare-stemmed (FGDC 1997).  |
|   | SBE  | <b>Broad-leaved evergreen shrub</b> - A shrub that is typically more than 30 cm tall at maturity with leaves that are generally of at least microphyll sized ( $\geq 225 \text{ mm}^2$ , or $0.35 \text{ in}^2$ and has green leaves all year round (adapted from FGDC 1997, Box 1981).                                                     |
|   | SBES | <b>Sclerophyllous shrub</b> - A type of broad-leaved evergreen shrub with relatively small, leaves that are stiff and firm, and retain their stiffness even when wilted (FGDC 1997, Whittaker 1975).                                                                                                                                        |
|   | SN   | <b>Needle-leaved shrub</b> - A shrub that is typically more than 30 cm tall at maturity with slender, elongated leaves or with small overlapping leaves that usually lie flat on the stem (FGDC 1997). Includes scale-leaved as well as needle-leaved shrubs,                                                                               |

|   |     |                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   |     | and deciduous as well as evergreen.                                                                                                                                                                                                                                                                                                                                                                                      |
|   | SU  | <b>Succulent shrub</b> – A juicy or leathery shrub that is typically more than 30 cm tall at maturity with specialized tissue for the conservation of water (adapted from FGDC 1997 and the Thorn shrub of Whittaker 1975). Includes cacti less than 5 meters in height at maturity. Includes both the “Typical Stem succulents” and “Bush succulents” (Box 1981). Includes Aloe, Agave.                                 |
|   | SM  | <b>Small-leaved shrub</b> - A shrub that is typically more than 30 cm tall at maturity with very small leaves (<225 mm <sup>2</sup> , or 0.35 in <sup>2</sup> ), or even leafless, sometimes armed with spines, usually having compound, deciduous leaves that are often reduced in size. Includes Larrea tridentata, Prosopis glandulosa, Acacia neovernicosa, Senna, Calliandra (Jennings et al. 2006, Whittaker 1975) |
|   | SP  | <b>Palm shrub</b> - An evergreen, broad-leaved, unbranched shrub that is typically more than 30 cm tall at maturity with a simple stem and terminal, rosulate crown of large, pinnate or fan-shaped leaves. Includes palms, espelettia, etc.                                                                                                                                                                             |
| H | HA  | <b>Aquatic herb</b> - A flowering or non-flowering herb structurally adapted to live floating or submerged in an aquatic environment. Does not include emergent plants such as cattails and sedges. (FGDC 1997, Jennings et al. 2006)                                                                                                                                                                                    |
|   | HF  | <b>Forb</b> - A non-aquatic, flowering or spore-bearing, non-graminoid herb..                                                                                                                                                                                                                                                                                                                                            |
|   | HFF | <b>Flowering forb</b> - A forb with relatively broad leaves and showy flowers. Does not include graminoids, ferns, or fern-allies.                                                                                                                                                                                                                                                                                       |
|   | HFE | <b>Spore-bearing forb</b> - A non-flowering, spore-bearing forb. Includes non-aquatic, non-woody ferns, clubmosses, spikemosses, horsetails, and quillworts.                                                                                                                                                                                                                                                             |
|   | HFS | <b>Succulent forb</b> - A flowering forb with a fleshy stem and often with reduced leaves. Includes Salicornia and others.                                                                                                                                                                                                                                                                                               |
|   | HG  | <b>Graminoid</b> - A non-aquatic, flowering herb with relatively long, narrow leaves and inconspicuous, reduced flowers. Includes grasses, sedges, rushes, and arrow-grasses.                                                                                                                                                                                                                                            |
| N | NB  | <b>Bryophyte</b> - A nonvascular, non-flowering, photosynthetic plant that bears leaf-like appendages or lobes and attaches to substrates by rhizoids. Includes mosses, liverworts, and hornworts (Abercrombie et al. 1966).                                                                                                                                                                                             |
|   | NA  | <b>Alga</b> - A nonvascular, photosynthetic plant with a simple form ranging from single- or multi-celled to a filamentous or ribbon-like thallus with relatively complex internal organization (Abercrombie et al. 1966).                                                                                                                                                                                               |
|   | NL  | <b>Lichen</b> - An organism generally recognized as a single plant that consists of a fungus and an alga or cyanobacterium living in symbiotic association (FGDC 1997).                                                                                                                                                                                                                                                  |
| E | E   | <b>Epiphyte</b> - A vascular or nonvascular plant that grows by germinating and rooting on other plants or other perched structures, and does not root in the ground                                                                                                                                                                                                                                                     |

|   |   |                                                                                                                                                                                                                                                    |
|---|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| L |   | (adapted from FGDC 1997). This growth form may be used as a modifier of other growth forms. E.g. HFF-E                                                                                                                                             |
|   | L | <b>Liana</b> - A woody, climbing plant that begins life as terrestrial seedlings but relies on external structural support for height growth during some part of its life (Gerwing 2004), typically exceeding 5 m in height or length at maturity. |

## APPENDIX D. GROWTH FORMS FROM BOX AND FUJIWARA (2005)

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**Table 4.2. Main Terrestrial Plant Life Forms.** This classification from Box and Fujiwara (2005) represents an expanded version of the original model of 90 plant ‘ecophysiognomic’ types and their worldwide climatic envelopes (Box 1981). Physiognomic groupings are shown on the left, numbers of types and short descriptions of the 114 actual types are shown on the left.

|                                  |               |   |                                                                                                       |
|----------------------------------|---------------|---|-------------------------------------------------------------------------------------------------------|
| <b>Trees (broad-leaved)</b>      |               |   |                                                                                                       |
| Evergreen                        | Laurophyll    | 4 | tropical, tropical-montane, subtropical/warm-temperate, cool-maritime                                 |
|                                  | Gymnosperm    | 1 | (sub)tropical broad/linear-leaved                                                                     |
|                                  | Microphyll    | 1 | (sub)tropical coriaceous                                                                              |
|                                  | Sclerophyll   | 4 | (sub)tropical, warm-temp., mediterranean, tall-temperate                                              |
| Deciduous                        | Raingreen     | 3 | monsoon-mesomorphic, montane, xero-microphyll                                                         |
|                                  | Bottle Trees  | 1 | tropical (raingreen)                                                                                  |
|                                  | Summergreen   | 2 | nemoral, short-summer                                                                                 |
| Needle-leaved                    | (evergreen)   | 6 | tropical-xeric, heliophilic long-needed, submediterranean, temperate, cool-laurophyll, boreal/montane |
| <b>Small Trees</b>               |               |   |                                                                                                       |
| Evergreen                        | Laurophyll    | 4 | tropical, cloud-forest, subtropical/warm-temperate, cool-maritime                                     |
|                                  | Sclerophyll   | 1 | tropical macro-sclerophyll                                                                            |
| Deciduous                        |               | 2 | raingreen, summergreen                                                                                |
| Needle-leaved                    |               | 1 | dwarf-needle/scale-leaved                                                                             |
| <b>Tuft-Trees and Treelets</b>   |               | 3 | palm trees, bottle palms, palm treelets                                                               |
| <b>Arborescents</b>              |               |   |                                                                                                       |
| Evergreen                        | Laurophyll    | 2 | tropical, extra-tropical                                                                              |
|                                  | Sclerophyll   | 1 | tropical/subtropical                                                                                  |
| Deciduous                        |               | 2 | raingreen, summergreen                                                                                |
| Stemgreen                        |               | 2 | mesic-microphyll, xeric/leafless                                                                      |
| <b>Tuft-Arborescents</b>         |               | 4 | tree-ferns, tropical-alpine, coriaceous, sclerophyll/succulent                                        |
| <b>Krummholz (needle-leaved)</b> |               | 2 | evergreen, summergreen                                                                                |
| <b>Shrubs</b>                    |               |   |                                                                                                       |
| Evergreen                        | Laurophyll    | 2 | tropical, subtropical/warm-temperate                                                                  |
|                                  | Sclerophyll   | 2 | mediterranean, hot-desert                                                                             |
|                                  | Succulent     | 1 |                                                                                                       |
|                                  | Needle-Leaved | 1 |                                                                                                       |
| Semi-evergreen xeric             |               | 1 | temperate                                                                                             |
| Summergreen                      |               | 2 | nemoral-mesomorphic, xeromorphic                                                                      |

|                        |                |   |                                                              |
|------------------------|----------------|---|--------------------------------------------------------------|
| <b>Dwarf-Shrubs</b>    |                |   |                                                              |
| Evergreen              |                | 4 | mediterranean, temperate, maritime-heath, boreal/tundra      |
| Summergreen            |                | 1 | boreal/tundra                                                |
| Xeromorphic            |                | 1 | leptophyll/leafless                                          |
| Cushion-form           |                | 2 | mesic-evergreen, xeromorphic                                 |
| <b>Rosette-Shrubs</b>  |                |   |                                                              |
|                        |                | 2 | trunkless palms, xeric leaf-succulent                        |
| <b>Stem-Succulents</b> |                |   |                                                              |
|                        |                | 5 | columnar, branched-arborescent, typical, frutescent, cryptic |
| <b>Semi-Shrubs</b>     |                |   |                                                              |
|                        |                | 3 | mesomorphic, xeromorphic, xylopodial-xeromorphic             |
| <b>Graminoids</b>      |                |   |                                                              |
| Broad-leaved (bamboos) |                | 2 | arborescent, dwarf                                           |
| Tall                   |                | 3 | cane-graminoids, typical-tall, tall-tussock                  |
| Short                  |                | 5 | spreading, bunch, short-tussock, sclerophyll, desert-grasses |
| <b>Forbs</b>           |                |   |                                                              |
| Evergreen              |                | 3 | tropical-arborescent, tropical, temperate                    |
| Deciduous              | Raingreen      | 2 | typical, cold-desert                                         |
|                        | Summergreen    | 3 | tall, typical, spring-ephemeral                              |
| Xeromorphic            |                | 2 | succulent, cushion-form                                      |
| Ephemeral              |                | 2 | desert-ephemeral, cold-desert                                |
| <b>Ferns</b>           |                |   |                                                              |
|                        |                | 3 | evergreen, raingreen, summergreen                            |
| <b>Vines</b>           |                |   |                                                              |
|                        | Lianas         | 1 | tropical-evergreen                                           |
|                        | Vines          | 3 | evergreen, raingreen, summergreen                            |
|                        | Epiphytic      | 1 |                                                              |
| <b>Epiphytes</b>       |                |   |                                                              |
|                        | Rosette        | 2 | large-tropical, stenophyll                                   |
|                        | Stem-Succulent | 1 |                                                              |
|                        | Shrublet       | 1 | wintergreen-shrublet                                         |
|                        | Herbs          | 3 | tropical-forb, fern, small-fern                              |
| <b>Cryptogams</b>      |                |   |                                                              |
|                        |                | 2 | mat-forming, xeromorphic                                     |

## APPENDIX E. COMPARISONS TO OTHER FORMATION-LEVEL CLASSIFICATIONS

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### MAIN WORLD TERRESTRIAL BIOME TYPES (BOX AND FUJIWARA 2005)

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(These biomes types are recognized by most modern treatments of world vegetation).

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Tropical rain forest (including montane and cloud forests)

Tropical deciduous forest, woodland, and thorn scrub

Tropical savanna [i.e. grassland]

Deserts

    Warm deserts (subtropical)

    Cold-winter deserts (continental)

Mediterranean forest, scrub, and shrublands

Temperate forests

    Deciduous broad-leaved forest

    Evergreen broad-leaved forest (incl. laurel forest, warm-temperate mixed forest)

    Temperate rain forest

Conifer forests

    Boreal (including deciduous)

    Montane conifer forest (temperate montane and subalpine)

Grasslands (temperate)

Tundra and alpine vegetation

    Polar and temperate-alpine tundra

    Tropical alpine vegetation

Terrestrial wetlands (swamp, marsh, bog, fen)

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From. Box, E.O. and K. Fujiwara. 2005. Vegetation types and their broad-scale distribution. Pp. 106-128 *In* van der Maarel, E. Vegetation ecology. Blackwell Publishing. Malden, MA

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## WORLD WILDLIFE FUND MAJOR HABITAT TYPES (OLSON 2001)

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### MAJOR HABITAT TYPES

**Tropical & Subtropical Moist Broadleaf Forests**

**Tropical & Subtropical Dry Broadleaf Forests**

**Tropical & Subtropical Coniferous Forests**

**Temperate Broadleaf & Mixed Forests**

**Temperate Coniferous Forests**

**Boreal Forests/Taiga**

**Tropical & Subtropical Grasslands, Savannas, & Shrublands**

**Temperate Grasslands, Savannas, & Shrublands**

**Flooded Grassland and Savannas [temperate and tropical]**

**Montane Grassland and Savannas [temperate and tropical]**

**Polar**

**Mediterranean Forests, Woodlands, & Shrub**

**Deserts & Xeric Shrublands**

**Mangroves**

**Lake**

**Rock and Ice**

David M. Olson, Eric Dinerstein, Eric D. Wikramanayake, et al. 2001. Terrestrial ecoregions of the world: a new map of life on earth. *BioScience* 51(11): 933-938.

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## FORMATIONS (BIOMES) - (WHITTAKER 1975)

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### FORESTS AND WOODLANDS

1. Tropical rain forest
2. Tropical seasonal forest
3. Temperate rain forest
4. Temperate deciduous forest
- 5a. Temperate evergreen forest --broadleaf
- 5b. Temp. evergreen forest--needleleaf
- 5c. Temperate evergreen forest--sclerophyll [Mediterranean]
6. Taiga & subarctic-subalpine needle-leaved forest
7. Elfin woodland
8. Tropical broadleaf woodland
- 9a. Thornwood--woodland
- 9b. Thornwood--scrub
- 10a. Temperate woodland --needleleaf
- 10b. Temperate woodland--sclerophyll
- 10c. Temperate woodland--deciduous broadleaf

### SHRUBLANDS

- 11a. Temperate shrubland--deciduous
- 11b. Temperate shrubland--heath
- 11c. Temperate shrubland--sclerophyll [Mediterranean]
- 11d. Temperate shrubland--subalpine, needleleaf
- 11e. Temperate shrubland--subalpine, broadleaf

### GRASSLANDS AND ALPINE VEGETATION

12. Savanna [tropical grassland]
13. Temperate grassland
14. Alpine shrubland
15. Alpine grassland

### COLD AND WARM DESERTS and TUNDRA

16. Tundra
17. Warm semidesert scrub
- 18a. Cool semidesert--open scrub
- 18b. Cool semidesert--dry grassland
19. Arctic-alpine semidesert
20. True desert
21. Arctic-alpine desert

### SWAMPS, MARSHES AND BOGS

22. Cool temperate bog
23. Tropical freshwater swamp forest
24. Temperate freshwater swamp forest
25. Mangrove swamp
25. Saltmarsh

### MARINE AND AQUATIC

[26-29 are aquatic]

29. Marine rocky shores
30. Marine sandy beaches
31. Marine mudflats

Whittaker, R.H. 1975. Communities and ecosystems. 2<sup>nd</sup> edition. MacMillan, New York. (pp. 135-161).

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FORMATIONS OF AUSTRALIA (SPECHT AND SPECHT 2001)

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| AUSTRALIAN TYPES <sup>1,2</sup>                                         |
|-------------------------------------------------------------------------|
| Closed forests (rainforests) - tropical north-eastern Australia         |
| Closed forests (rainforests) - subtropical eastern Australia            |
| Closed forests (rainforests) - temperate south-eastern Australia        |
| Semi-deciduous closed forests - monsoonal northern Australia            |
| Semi-deciduous closed forests - subtropical eastern Australia           |
| Eucalypt open forests and woodlands - monsoonal northern Australia      |
| Eucalypt open forests and woodlands - subtropical eastern Australia     |
| Eucalypt open forests and woodlands - temperate south-eastern Australia |
| Eucalypt open forests and woodlands - montane south-eastern Australia   |
| Eucalypt open forests and woodlands - temperate south-western Australia |
| Eucalypt open forests and woodlands - Australia wetland forests         |
| Mallee eucalypt open-scrubs - monsoonal northern Australia              |
| Mallee eucalypt open-scrubs - subtropical eastern Australia             |
| Mallee eucalypt open-scrubs - temperate south-eastern Australia         |
| Mallee eucalypt open-scrubs - temperate south-western Australia         |
| Heathlands and related shrublands - monsoonal northern Australia        |
| Heathlands and related shrublands - subtropical eastern Australia       |
| Heathlands and related shrublands - temperate south-eastern Australia   |
| Heathlands and related shrublands - montane south-eastern Australia     |
| Heathlands and related shrublands - temperate south-western Australia   |

|                                                                                                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Tussock grasslands                                                                                                                                                    |
| <i>Acacia</i> vegetation - subhumid, subtropical eastern Australia                                                                                                    |
| <i>Acacia</i> vegetation - Australian Arid Zone                                                                                                                       |
| Hummock grasslands - Australian Arid Zone                                                                                                                             |
| Chenopod low shrublands - southern Australia Arid Zone                                                                                                                |
|                                                                                                                                                                       |
| Aquatic vegetation - tropical and subtropical northern Australia                                                                                                      |
| Aquatic vegetation - temperate southern Australia                                                                                                                     |
|                                                                                                                                                                       |
| Coastal dune vegetation                                                                                                                                               |
| Coastal wetland vegetation (mangroves, salt marshes, and brackish wetlands)                                                                                           |
|                                                                                                                                                                       |
| 1. Specht, R.L. and A. Specht. 2001. Australia, ecosystems of. Pp. 307 - 324,<br>In S.A. Levin (ed.). Encyclopedia of Biodiversity, Vol. 1. Academic Press, New York. |
| 2. Floristic groups are also provided for each formation.                                                                                                             |

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## AUSTRALIAN NATIVE VEGETATION (NWLRA 2001)

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Vegetation profile fact sheets were developed for each type listed below:

[http://audit.ea.gov.au/ANRA/vegetation/docs/Native\\_vegetation/nat\\_veg\\_factsheet.cfm](http://audit.ea.gov.au/ANRA/vegetation/docs/Native_vegetation/nat_veg_factsheet.cfm)

|                                                                                                                        |
|------------------------------------------------------------------------------------------------------------------------|
| • <a href="#">Rain forest and vine thickets</a>                                                                        |
| • <a href="#">Eucalypt and tall open forests</a>                                                                       |
| • <a href="#">Eucalypt open forests</a>                                                                                |
| • <a href="#">Eucalypt low open forests</a>                                                                            |
| • <a href="#">Eucalypt woodlands</a>                                                                                   |
| • <a href="#">Acacia forests and woodlands</a>                                                                         |
| • <a href="#">Callitris forests and woodlands</a>                                                                      |
| • <a href="#">Casuarina forests and woodlands</a>                                                                      |
| • <a href="#">Melaleuca forests and woodlands</a>                                                                      |
| • <a href="#">Other forests and woodlands</a>                                                                          |
| • <a href="#">Eucalypt open woodlands</a>                                                                              |
| • <a href="#">Tropical Eucalypt woodlands/grasslands</a>                                                               |
| • <a href="#">Acacia open woodlands</a>                                                                                |
| • <a href="#">Mallee woodlands and shrublands</a>                                                                      |
| • <a href="#">Low closed forests and closed shrublands</a>                                                             |
| • <a href="#">Acacia shrublands</a>                                                                                    |
| • <a href="#">Other shrublands</a>                                                                                     |
| • <a href="#">Heath</a>                                                                                                |
| • <a href="#">Tussock grasslands</a>                                                                                   |
| • <a href="#">Hummock grasslands</a>                                                                                   |
| • <a href="#">Other grasslands, herblands, sedgelands and rushlands</a>                                                |
| • <a href="#">Chenopod shrublands, samphire shrubs and forblands</a>                                                   |
| • <a href="#">Mangroves, tidal mudflats, samphires, claypans, sand, rock, salt lakes, lagoons and freshwater lakes</a> |

| <u>EUROPEAN VEGETATION SURVEY (2002)</u>                           |
|--------------------------------------------------------------------|
| A. Coastal mud-flats and brackish waters                           |
| B. Saltmarsh, sand-dune and sea-cliff vegetation                   |
| C. Rock crevice, scree and boulderfield vegetation                 |
| D. Freshwater aquatic vegetation                                   |
| E. Springs, shoreline, and swamp [marsh] vegetation                |
| F. Bogs and fens                                                   |
| G. Temperate grasslands, heaths, and fringe vegetation             |
| H. Dry grasslands and semi-deserts                                 |
| I. Oromediterranean grasslands and scrub                           |
| J. Montane tall-herb, grassland, fell-field and snowbed vegetation |
| K. Mediterranean garrigue, maquis, mattoral, tomillar and phrygna  |
| L. Temperate broadleaved forests and scrub                         |
| M. Montane heaths and coniferous forests                           |
| N. Weed communities                                                |

Rodwell, J.S., J.H.J. Schamineé, L. Mucian, S. Pignatti, J. Dring and D. Moss. 2002. The diversity of European vegetation. An overview of phytosociological alliances and their relationships to EUNIS habitats. Wageningen, NL. EC-LNV. Report EC-LNV nr. 2002/054. 168 p.

## APPENDIX F. EXAMPLE OF DESCRIPTIVE METHODS FOR DESCRIBING PHYSIOGNOMY - STRUCTURE

**Table 1.** Küchler's method for structural description of vegetation (after Küchler 1967), an example of the Descriptive-Mapping Physiognomic Approach (I). See also footnotes below for variations based on Dansereau (1951) and Beard (1981). These tables do not represent classifications, as such; rather, classifications are produced by combining the categories, sometimes *a priori* (e.g., Specht 1974), but more often, *a posteriori*, based on the process of mapping (e.g., Beard 1981).

| LIFE-FORM CATEGORIES     |   |                                      |   |
|--------------------------|---|--------------------------------------|---|
| BASIC LIFE FORMS         |   | SPECIAL LIFE FORMS                   |   |
| <i>Woody Plants</i>      |   | Climbers (lianas)                    | C |
| Broadleaf evergreen      | B | Stem succulents                      | K |
| Broadleaf deciduous      | D | Tuft plants                          | T |
| Needleleaf evergreen     | E | Bamboos                              | V |
| Needleleaf deciduous     | N | Epiphytes                            | X |
| Aphyllous                | O |                                      |   |
| Semi-deciduous (B+D)     | S | LEAF CHARACTERISTICS                 |   |
| Mixed (D+E)              | M | hard (sclerophyll)                   | h |
| <i>Herbaceous Plants</i> |   | soft                                 | w |
| Graminoids               | G | succulent                            | k |
| Forbs                    | H | large (>400 cm <sup>2</sup> )        | l |
| Lichens, mosses          | L | small (<4 cm <sup>2</sup> )          | s |
| STRUCTURAL CATEGORIES    |   |                                      |   |
| HEIGHT (STRATIFICATION)  |   | COVERAGE                             |   |
| > 35 m                   | 8 | continuous (>75 %)                   | c |
| 20-35 m                  | 7 | interrupted (50-75%)                 | i |
| 10-20 m                  | 6 | parklike, in patches (25-50%)        | p |
| 5-10 m                   | 5 | rare (6-25%)                         | r |
| 2-5 m                    | 4 | barely present, sporadic (1-5%)      | b |
| 0.5-2                    | 3 | almost absent, extremely scarce(<1%) | a |
| 0.1-0.5                  | 2 |                                      |   |
| <0.1                     | 1 |                                      |   |

Dansereau (1951) has 6 categories, instead of 4. Basic Life Forms is separated into two parts: Basic Life-forms (trees, shrubs, herbs, bryophytes, epiphytes, lianas) and Function (deciduous, semi-deciduous, evergreen, evergreen-succulent or leafless); Leaf Characteristics is separated into Leaf Shape and Size (needle, graminoid, small, large-broad, compound, thalloid) and Leaf Texture (filmy, membranous, sclerophyll, succulent-fungoid). Height and Coverage categories are similar to Küchler.

Beard (1981) provides an example amended specifically for Australia. He has 3 categories 1. Physiognomy of Dominant Stratum (Tall Trees > 25 m tall, Medium Trees 10-25 m tall, Low Trees < 10 m tall, Shrubs > 1 m tall, Dwarf shrubs < 1 m tall, Bunch Grasses, Hummock grass, Forbs, Lichens&Mosses, Succulents), 2. Floristics (Eucalyptus, Acacia, Triodea, Heterogenous), and, 3. Density (Dense canopy, Mid-dense canopy, Incomplete Canopy, Rare but Conspicuous, Barren-vegetation largely absent, Scattered).

Beard, J.S. 1981. Classification in relation to vegetation mapping. Pp. 97-106 In A.N. Gillison and D.J. Anderson. Vegetation classification in Australia. CSIRO and Australian National University Press, Canberra, Australia 229 pp.

## APPENDIX G. KEY TO BIOCLIMATIC MAPS OF THE WORLD - RIVAS MARTINEZ & RIVAS-SAENZ

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|   |                                                                                                                                                                                                                                                                                                                                                                               |               |
|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
|   | In territories with a northern latitude of $> 72^\circ$ or a southern latitude of $> 56^\circ$ . In territories outside this latitude and with an altitude of less than 200 m (1): annual positive temperature $T_p < 380$                                                                                                                                                    | POLAR         |
|   | In territories with an altitude of less than 200 m (1): annual positive temperature $T_p > 380$                                                                                                                                                                                                                                                                               | 2             |
| 2 | In territories with an altitude of less than 200 m (1), continentality index $I_c < 11$ , positive temperature of the summer quarter $T_{ps} > 320$ , mean annual temperature $< 6^\circ$ , annual positive temperature 320 – 720                                                                                                                                             | BOREAL        |
|   | Does not meet the conditions                                                                                                                                                                                                                                                                                                                                                  | 3             |
| 3 | In territories with an altitude of less than 200 m (1), depending on the continentality index $I_c$ , the values of the mean annual temperature $T$ and the annual positive temperature $T_p$ must be as follows: for $I_c < 21$ : $T < 5.3^\circ$ and $T_p < 720$ ; for $I_c = 21 - 28$ : $T < 4.8^\circ$ and $T_p < 740$ ; for $I_c > 28$ : $T < 3.8^\circ$ and $T_p < 800$ | BOREAL        |
|   | Does not meet the conditions                                                                                                                                                                                                                                                                                                                                                  | 4             |
| 4 | Summer with no water deficit; ombrothermic index of the hottest two months in the summer quarter $I_{os2} > 2$ or the summer ombrothermic index resulting from the compensation $I_{osc4} > 2$                                                                                                                                                                                | TEMPERATE     |
|   | Does not meet the conditions                                                                                                                                                                                                                                                                                                                                                  | MEDITERRANEAN |

(1) If the location is situated at an altitude of over 200 m, the temperature values need to be calculated theoretically, increasing  $T$  by  $0.6^\circ$ ,  $M$  by  $0.5^\circ$ , and  $I_t$  or  $I_{tc}$  by 13 units for every 100 m over that altitude; if it is situated to the north of parallel  $48^\circ$  N or to the south of parallel  $51^\circ$  S, the values of the mean annual temperature and the annual positive temperature  $T_p$  must also be calculated by increasing  $T$  by  $0.4^\circ$  and  $T_p$  by 12 units for every 100 m over this altitude. When  $I_c \geq 21$  (continental) or when  $I_t$  or  $I_{tc} < 120$  the thermotype is calculated based on the annual positive temperature, and the theoretical values of  $T_p$  at 200 m, increasing 55 units every 100 m over this altitude.

Abbreviations: See Rivas Martinez et al. (1999)

$T_p$  = Yearly positive temperature. In tenths of degrees C, sum of the monthly average temperature of those months whose average temperature is above  $0^\circ\text{C}$ .

$T_{ps}$  = Summer positive temperature. Positive temperature of the summer quarter.

$I_c$  = Continentality Index (year thermic interval).  $I_c = T_{\max} - T_{\min}$ . In degrees C, the number expresses the range between the average temperatures of the warmest month ( $T_{\max}$ ) and the coldest ( $T_{\min}$ ) months of the year. (Hyeroceanic  $I_c = 0-11$ , Oceanic =  $11-21$ , Continental =  $21=65$ ).

$I_{osc}$  = Summer compensated ombrothermic Index.



## APPENDIX H. KEY TO FORMATION CLASS (LEVEL 1)

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See attached document.

Grassland and Shrubland divisions taken from Faber-Langendoen and Josse (2010)

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### 1.B.2. Cool Temperate Forest

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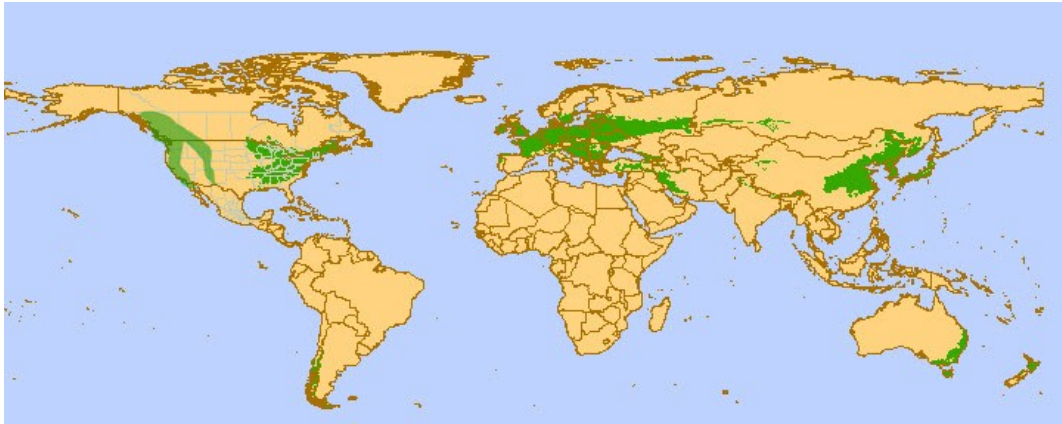


Figure 1. Distribution of the Cool Temperate Forest formation, based on ecoregions where *Cool Temperate Forest* is or was the dominant vegetation. Map is based on Olson et al. (2001), and modified from a map by M. Jennings.

#### **DIVISIONS [draft]:**

- Eastern North America Cool Temperate Forest
- Rocky Mountain Cool Temperate Forest
- Vancouverian Cool Temperate Forest
- Western Eurasia Cool Temperate Forest
- Central Eurasia Cool Temperate Forest
- Eastern Asia Cool Temperate Forest
- Southern New Zealand-Tasmania Cool Temperate Forest?
- Southeast Australia Cool Temperate Forest
- South America (Chilean) Cool Temperate Forest

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## **2.A.1. Tropical Lowland Grassland, Savanna & Shrubland**

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### **DIVISIONS [draft]:**

- 2.A.1.Ea. Caribbean & Central American Lowland Shrubland, Grassland & Savanna (D094)
- 2.A.1.Eb. Amazonian Shrubland & Savanna (D124)
- 2.A.1.Ec. Guyanan Shrubland & Savanna (D125)
- 2.A.1.Ed. Parana Brazilian Shrubland & Savanna (D126)
- 2.A.1.Ee. Chacoan Shrubland & Savanna (D127)
- 2.A.1.Ff. West-Central African Mesic Woodland & Savanna (D128)
- 2.A.1.Fg. Eastern & Southern African Dry Savanna & Woodland (D129)
- 2.A.1.Fh. Mopane Savanna (D130)
- 2.A.1.Fi. Sudano Sahelian Dry Savanna (D131)
- 2.A.1.Ij. Indo-Malayan Mesic Savanna & Grassland (D132)
- 2.A.1.Lk. Australian Tropical Savanna (D133)
- 2.A.1.Ol. Polynesian Lowland Shrubland, Grassland & Savanna (D074)
- 2.A.1.Om. Eastern Melanesian Lowland Shrubland, Grassland & Savanna (D075)

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## **2.B.1. Mediterranean Scrub & Grassland**

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### **DIVISIONS [draft]:**

- 2.B.1.Eb. Chilean Mediterranean Scrub (D106)
- 2.B.1.Fd. South African Cape Mediterranean Scrub (D107)
- 2.B.1.Le. Australian Mediterranean Scrub (D108)
- 2.B.1.Na. California Grassland & Meadow (D021)
- 2.B.1.Na. California Scrub (D020)
- 2.B.1.Pb. Mediterranean Basin Dry Grassland (D104)
- 2.B.1.Pc. Mediterranean Basin Montane Grassland & Scrub (D105)
- 2.B.1.Pc. Mediterranean Basin Scrub (D103)

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## **2.B.2. Temperate Grassland & Shrubland**

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### **DIVISIONS [draft]:**

- 2.B.2.Ek. Pampas Grassland & Shrubland (D141)
- 2.B.2.El. Southern Andean Shrubland & Grassland (D142)
- 2.B.2.Fm. Southern African Montane Grassland (D143)
- 2.B.2.Li. Australian Grassland & Shrubland (D112)
- 2.B.2.Lj. New Zealand Grassland & Shrubland (D113)
- 2.B.2.Na. Western North American Grassland & Shrubland (D022)

- 2.B.2.Nb. Great Plains Grassland & Shrubland (D023)
- 2.B.2.Nc. Eastern North American Grassland, Meadow & Shrubland (D024)
- 2.B.2.Nd. Western North American Interior Sclerophyllous Chaparral Shrubland (D061)
- 2.B.2.Ne. Southeastern North American Grassland & Shrubland (D102)
- 2.B.2.Pf. European Grassland & Heath (D109)
- 2.B.2.Pg. Western Eurasian Grassland & Shrubland (D110)
- 2.B.2.Ph. Eastern Eurasian Grassland & Shrubland (D111)