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A System of Vegetation Classification Applied to Hawaii

Michael G. Buck

Timothy E. Paysen



The Authors:

MICHAEL G. BUCK is a resource forester with the Hawaii Division of Forestry and Wildlife. He joined the Division in 1977, and currently works in its resource inventory, research, and remote sensing programs. He holds a bachelor's degree in resource management from State University of New York, Syracuse (1976). **TIMOTHY E. PAYSEN**, a research forester, is assigned to the Station's chaparral and related ecosystems research unit, with headquarters at Riverside, California. He earned a bachelor's degree in forest management at Humboldt State College (1969), and a doctorate in applied statistics at the University of California, Riverside (1978).

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In Hawaii, the growing interdisciplinary responsibilities in resource management have resulted in a diversity of languages used to describe vegetation. Organizational and discipline oriented biases have given rise to unique systems for classifying vegetation—a reflection of the distinct information requirements of the various resource management and other technical groups. Through a variety of programs, the Hawaii Division of Forestry and Wildlife has management and protection responsibilities for more than half of the land area in the State (*fig. 1*). There is a need for a classification system that names vegetative communities in terminology acceptable to the various disciplines it represents that can be used as a basic language among them.

This need was brought prominently into focus as the Division began work on a statewide multiresource forest inventory. The existing classification systems available in Hawaii were oriented either to a single function or extremely detailed with no hierarchy to a management level. Using a framework from the Vegetation Classification System for Southern California (Paysen and others 1980, 1982), criteria and nomenclature were adapted to develop the Hawaii Vegetation Classification System.

Representatives of these agencies participated in the development of the System: Hawaii Division of Forestry and Wildlife; Forest Service, U.S. Department of Agriculture; and Fish and Wildlife Service, U.S. Department of the Interior.

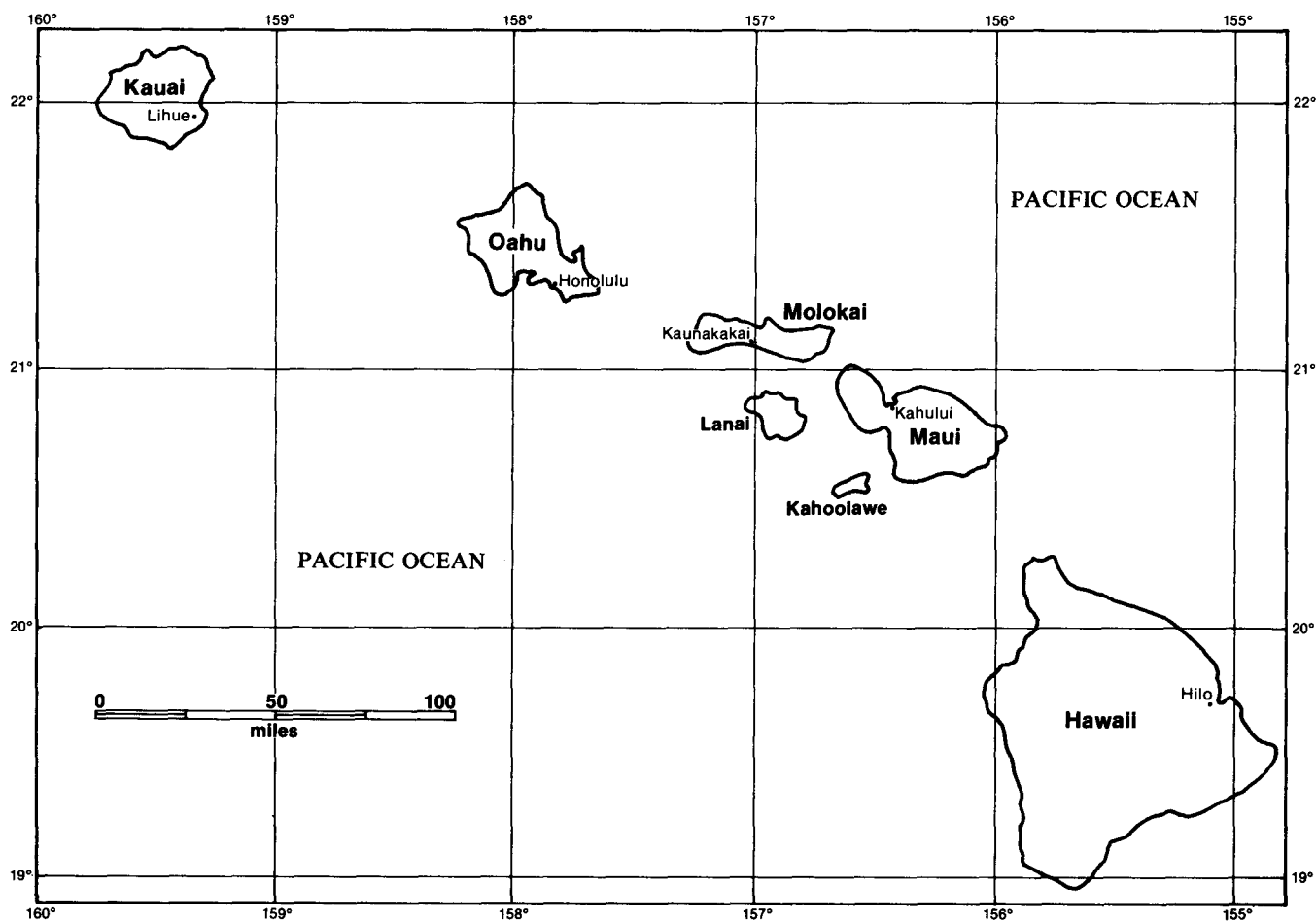


Figure 1--The State of Hawaii comprises 132 islands, reefs, and shoals stretching 2452 km southeast to northwest across the Tropic of Cancer. The eight main islands make up over 99 percent of the total land area of 1,670,500 ha.

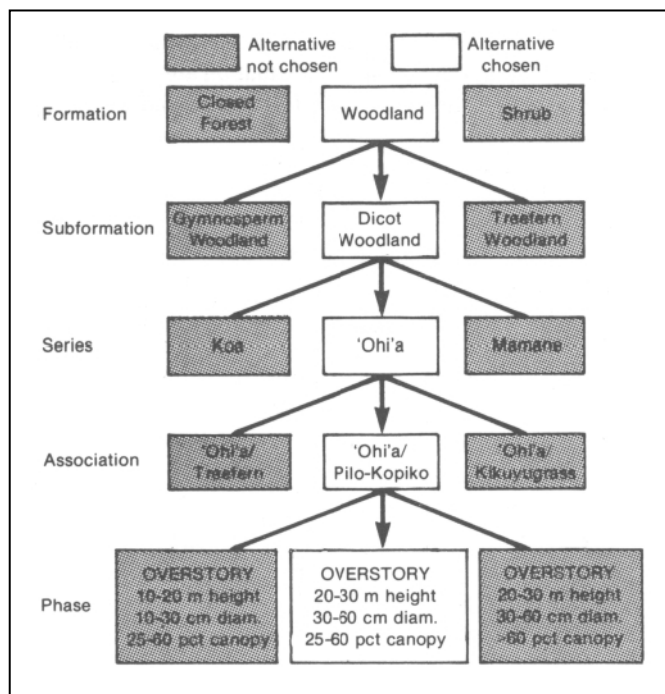


Figure 2--The hierarchy of the Hawaii vegetation classification system is shown here. The classification becomes progressively more precise as it moves through the five levels of the system.

The disciplines and resource management functions represented included research, inventory, wildlife, planning, management, and threatened and endangered species.

The System of Classification for use in Hawaii addresses a basic plant community unit with five levels of descriptive detail, the first four hierarchical (*fig. 2*). The System is compatible with a proposed national land classification system (Driscoll and others 1982), and is also compatible with the International System of Vegetation Classification (UNESCO 1973).

The Hawaii System can be put to a variety of uses, but its chief function is to be a basic language. To fulfill this function, inherent in it are unique properties that make it flexible, functionally neutral, and applicable to both current and potential vegetation. The System provides a framework to identify missing gaps in our knowledge of the vegetative communities in Hawaii as well as a logical format to display and communicate this knowledge.

EARLIER CLASSIFICATIONS

Vegetation classification systems have been a necessary byproduct of inventory, mapping, land classification, or ecosystem classification. Vegetation classification schemes have been developed for use in local areas, such as the island of Oahu (Egler 1939), and for mapping vegetation on a global

scale (Fosberg 1967, UNESCO 1973). Some systems were developed to provide a framework for describing the structure and dynamics of vegetation (Braun-Blanquet 1932), while others are used to place vegetation growing sites into categories defined by functional resource management criteria.

In Hawaii, although early explorers gave accounts of vegetation observed on the Islands, Hillebrand (1888) was the first to classify vegetation, recognizing five zones largely on the basis of elevation. A strand vegetation zone was added to this classification as well as moist windward and dry leeward subzones (Rock 1913).

In his ecological and floristic studies in Kipapa Gulch, Oahu, Hosaka (1937) recognized six plant zones on the basis of climate and flora. Elaborating on Hosaka's classification, Egler (1939) proposed for Oahu a series of vegetation zones that are correlated with differences in precipitation and insolation.

In their ecological work on the island of Hawaii, Robyns and Lamb (1939) used a vegetation classification based on assumed climax formations and physiognomic types of forest, parkland, shrub, moss-lichen, and bog. They also set up a new general classification of altitudinal zones for the island of Hawaii.

A zonal vegetation classification was applied to all the major islands on the basis of characteristics of the vegetation itself, as correlated with rainfall at the lower elevations and temperature at the higher elevations (Ripperton and Hosaka 1942).

Three recent vegetation mapping projects have added to classification efforts in Hawaii. Forest type maps of the State identified vegetation units by cover type, growth productivity, density, and stand size (Nelson 1967). A vegetation map of Hawaii Volcanoes National Park identified 31 major vegetation units by cover type, canopy height, and crown cover in six different macroclimates (Mueller-Dombois and Fosberg 1974). Statewide vegetation mapping of native Hawaiian vegetation separated vegetation units by tree crown cover and height, species composition and dominance, general habitat type, and understory species composition (Jacobi 1978).

CLASSIFICATION SYSTEM

The five levels of descriptive detail in the Hawaii System are Formation, Subformation, Series, Association, and Phase (*fig. 2*). Of these, the first four levels are explicit members of a formal hierarchy.

Each level in the hierarchy is a more generalized version of the level below it and can also be characterized by criteria established for that level (floristic, physiognomic, or morphological).

The easiest way to understand the relationship between the various levels of the system is to start with its basic unit, the Association, and work up the hierarchy. In this aggregating system, the classes at a given level in the hierarchy are grouped according to prescribed similarities to form classes of the next higher hierarchical level.

Association

A plant Association is an assemblage of plants with a characteristic floristic composition that grows under a uniform set of environmental conditions. A plant Association is recognized by its several characteristic dominant species within defined vegetation layers.

The term "Association" has been used elsewhere to describe only those plant communities that are at climax or ultimate site potential. As Paysen and others (1982) have indicated, however, other authors have used Association to identify communities that are not necessarily at climax. Association in this report refers to plant communities that are relatively stable in terms of their persistence in a given vegetation system. A vegetation system comprises the plant communities and community dynamics that characterize a distinctive vegetation, and lend identity to an extensive ecosystem or floristic zone (Paysen and others 1982). The persistence of an Association may be attributed to its long-term occupancy on a given site or to its consistent occurrence over space or time in a given vegetation system. An Association, therefore, may be

frequently observed on a landscape or may be a consistent invader after disturbances.

Associations have no community size (areal extent) limitations; yet areal limits in a given situation are imposed by the class boundary criteria for each formation, and by the cover dominance criteria applied to each layer when naming the Association.

In field testing the system, we found many Associations in Hawaii having distinct vertical layers. One plant, however, does not constitute a layer. A completely expressed layer, or a change of composition within a layer, must comprise more than a few random individuals on a landscape. Certain areas in the rain forest, for example, consisted of five layers: two overstory tree layers (5-30 m), a midstory treefern layer (3-5 m), an understory fern layer (0.5-2 m), and a ground cover layer (fig. 3). Within each layer two or more species were present.

Adequate field study is essential for identification of Associations. Individual Associations may exist as a result of environmental interactions among stable and unstable biological and physical factors that include human influences. Two adjacent stands of 'ohi'a (*Metrosideros polymorpha*) on different volcanic substrates in the Hilo Forest Reserve, for example, may represent different Associations within the 'Ohi'a Series because of different species composition and dominance in the understory layers. Similarly, logging disturbance may have affected the vegetation composition of adjacent koa (*Acacia koa*) stands on the windward side of the island of Hawaii, and different Associations in the Koa Series might be identified.



Figure 3--An example of the vegetation layers found in many 'Ohi'a (*Metrosideros polymorpha*) / Treefern (*Cibotium* spp.) Associations.



Figure 4—Two commonly found Series of strand vegetation found in coastal areas. The foreground is the Ilima (*Sida* spp.) Series of the Forb Subformation, Herbaceous Formation. The Naupaka-kuahiwi (*Scaevola chamissoniana*) Series of the Shrub Formation is in the background.

Series

The Series can be thought of as generalizations of plant Associations. All plant Associations with given dominant overstory species constitute a Series that is named by that species (*fig. 4*). This category does not imply greater heterogeneity than the Association. It still recognizes the basic plant community, but does so at a general level. It also allows



Figure 5—An 'Ohi'a/a'Ama'uma'u Association of the 'Ohi'a Series found in Haleakala National Park on the island of Maui. This Association is important habitat for many of the rare Hawaii forest birds found in the park.

for reference to an entire set of floristically related communities. A particular plant community may be recognized as an 'Ohi'a/a'Ama'uma'u (*Sadleria cyatheoides*) Association, for example, or it may be recognized as an element of the 'Ohi'a Series (*fig. 5*).

In the use of this system, the identification of any hierarchical level should not be treated with a greater degree of precision than is warranted by current management needs or by requirements for advancing the state of our knowledge. A Series may be recognized, but may be sufficiently described for a given purpose by giving it a Formation level name. A Lantana (*Lantana camara*) Series, for example, may be described as an element of the Shrub Formation if further precision is not warranted (*fig. 6*). Also, a generalized landscape description need not include the enumeration of all Associations that are found on it (*fig. 7*).

Subformation

A Subformation is an aggregation of Series with a given physiognomic character and a particular stem and leaf morphology in the dominant overstory species. The following key may be used to identify the physiognomic and morphologic characteristics of the Subformations of the Hawaii Vegetation Classification System:

<i>Physiognomic or morphologic characteristic:</i>	<i>Go to number</i>
1 Dominant plant species (overstory) woody	2
1 Dominant plant species herbaceous	10
2 Height of dominant species in overstory ≥ 5 m	3
2 Height of dominant species in overstory < 5 m	Shrub
3 Canopy cover of overstory > 60 percent	4
3 Canopy cover of overstory 25 to 60 percent	7
4 Dominant plant of overstory a treefern	Treefern forest
4 Dominant plant of overstory not a treefern	5
5 Dominant plant of overstory with seeds borne on upper side of open scales that are often produced in cones	Gymnosperm forest
5 Dominant plant of overstory with broad leaves bearing flowers	6
6 Dominant plant of overstory a monocot	Monocot forest
6 Dominant plant of overstory a dicot	Dicot forest
7 Dominant plant of overstory a treefern	Treefern woodland
7 Dominant plant of overstory not a treefern	8
8 Dominant plant of overstory with seeds borne on upper side of open scales that are often produced in cones	Gymnosperm woodland
8 Dominant plant of overstory with broad leaves, bearing flowers	9
9 Dominant plant of overstory a monocot	Monocot woodland
9 Dominant plant of overstory a dicot	Dicot woodland
10 Stand requires mechanical support of water to maintain physiognomic integrity	Aquatic
10 Stand does not require the mechanical support of water	11
11 Dominant species grass or grasslike	Graminoid
11 Dominant species not grass or grasslike	12
12 Dominant species cryptogamic (ferns, mosses, lichens)	Cryptogamic
12 Dominant species not cryptogamic	Forb

Figure 6--A valley bottom is choked with Lantana (*Lantana camara*), an aggressive exotic shrub introduced to the Hawaiian Islands as an ornamental.



Figure 7--A disturbed lower valley bottom on the island of Maui contains diverse populations of native and introduced plants.





Figure 8--A Hala (*Pandanus tectorius*) Series of the Monocot Subformation commonly found in coastal areas throughout the South Pacific. The leaves (lauhala), because of their toughness and pliability, are used by the natives of the Pacific for their homes, mats, baskets, and clothes.



Figure 9--An Uluhe or Staghorn Fern (*Dicranopteris linearis*) Series of the Cryptogamic Subformation. Uluhe grows in dense thickets at altitudes of 150 to 900 m. It smothers existing vegetation and prevents regeneration of other plants.

The Subformation category is included in the system to provide a set of classes that are more distinct than those at the Formation level; for example, treefern as opposed to monocot forests (fig. 8) or graminoid as opposed to cryptogamic (fig. 9).

Formation

A Formation is an aggregation of Subformations with a given physiognomic character (fig. 10). All Subformations characterized by an overstory of trees with a closed canopy (60-100 pct crown cover), for example, make up the Closed Forest Formation (fig. 11). Four Formations are currently proposed for Hawaii.

Phase

Although Phase is treated as a category of the classification, it is primarily a vehicle to recognize unique demands made by specific disciplines, and for management application of the system. It is a means of addressing variability within a plant community and, therefore, only the general pattern of its use can be prescribed--strict definition of all potentially relevant Phases of plant communities is not practical in this report. The Phase level of description can be applied to any level in the hierarchy.

Phase descriptors are often chosen in relation to specific functional applications. A biologist interested in potential

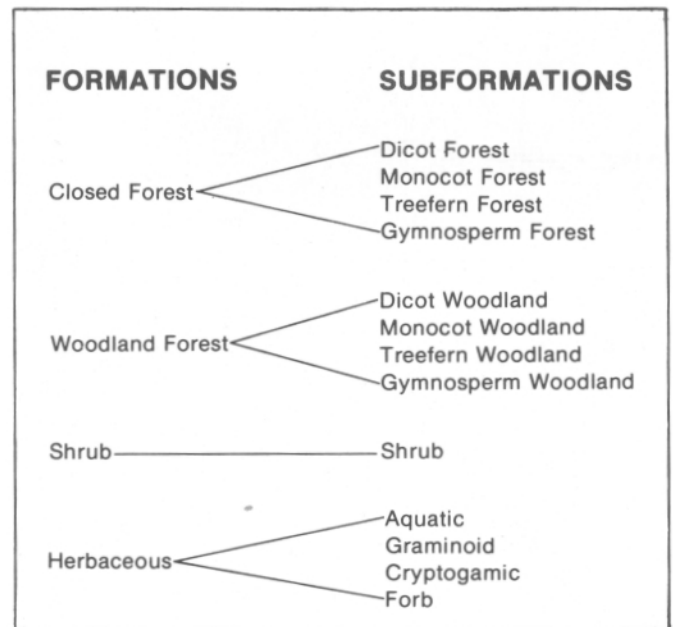


Figure 10--The 4 formations and 13 Subformations of the Hawaii Vegetation Classification System.

habitat for an endangered forest bird may define Phases of the 'Ohi'a/'Olapa (*Cheirodendron trigynum*) Association by the percent cover of nectar and fruit bearing tree species in the overstory layers. A forester who considers the noxious vine banana poka (*Passiflora mollissima*) in any Koa Series as an indicator of potential plant community disruption or developmental trend might use its presence as a phase descriptor

Figure 11--Two closed forest Formations commonly found in the coastal areas of Hawaii. A Coconut (*Cocos nucifera*) Series of the Monocot Subformation is shown on the right and the Kiawe (*Prosopis pallida*) Series of the Dicot Subformation in the upper left.





Figure 12--A Koa/Banana Poka Association found on the windward side of the island of Hawaii. Banana poka is an ornamental vine introduced to the islands in 1930 and has invaded more than 10,100 ha of native forest. It smothers the overstory canopy and successfully prevents regeneration of any other vegetation.



Figure 13--A Robusta Eucalyptus (*Eucalyptus robusta*)/Treefern Association on the island of Hawaii. More than 16,200 ha of eucalyptus plantations have been planted throughout the State.

(fig. 12). For a similar reason, signs of pig rooting and trails could provide the basis for a phase descriptor for the Koa Series.

The Phase category is also a logical means for relating developmental phases of different communities to one another across stages of community succession. A recently-burned koa woodland, for example, bears little resemblance to a woodland. The burned site is often dominated by elements of the Herbaceous Formation. But if koa seedlings and sprouts are present, the recent burn is a potential koa woodland in a pioneer stage (even though we classify it as a community in the Herbaceous Formation) and contains a particular Phase of a potential Koa Association. This knowledge allows us to describe the site in terms of its current and potential vegetation, and to incorporate short-term succession into our management planning.



Figure 14--A Bamboo (*Bambusa* spp.) Series found in Akaka Falls State Park on the island of Hawaii. Bamboo is used in Hawaii for crafts, Hawaiian dance implements, and fishing poles.

In using the Phase category to describe ecological stages, we are viewing the site in the context of what we know will probably happen to classify it more usefully for our needs. The system itself does not tell us anything about succession; it allows us to take ecological development and succession into consideration in applying the system for different purposes.

To describe Phase categories, a Phase code or index can be derived for specified purposes. Useful information that can be coded includes size, stature, and density information for desired vegetative layers. The use of a Phase code is not mandatory, but it can be useful for recording data.

NOMENCLATURE

The name given to an Association indicates the dominant and codominant species in each layer (*fig 13*). The combination of dominant and codominant species reflects the entire character of the Association--to the degree possible when only a few species names are used (*table 1*).

APPLICATION

Field classification of plant communities is the most obvious direct use of the system. The result of a field classification effort can serve as a basis for resource management planning, mapping, and environmental description. Many of the system's classification criteria correspond directly with the latest statewide native vegetation mapping project (Jacobi 1978).

The system can also serve as the common link between functional and technical classification systems, thereby facilitating communication between disciplines. An 'Ohi'a-Koa/Pilo (*Coprosma* spp.)-Kolea (*Myrsine lessertiana*) / Treefern/Lo'ulu Association should mean the same thing to every agency or group using the system. Results of classifying a plant community to one or all of the hierarchical levels of the system should be similar--within an acceptable degree of tolerance--no matter who is doing the classifying.

Although classification to the Series level and above is useful for many purposes (*fig. 14*), the system will become most meaningful to land managers when Associations are

Table 1--Rules for naming plant Association and Series for the Hawaii Vegetation Classification System

Situation	Nomenclature rule	Examples
	Associations	
Single-layered Association	Name by dominant species.	'Ohi'a; Koa
Multilayered Association	Dominant species in each layer will name the Association; start with overstory and end with herb layer, if one exists. Separate layer names with a slash (/). A maximum of five layers will be used.	'Ohi'a/Hapu'u pulu/Asplenium Association
Single species dominance in a given layer	Dominant species in the layer will supply the appropriate portion of the Association name.	'Ohi'a/Hapu'u pulu Association (overstory dominated by 'Ohi'a understory layer dominated by Hapu'u pulu)
Mixed species dominance in a layer (crown cover of each codominant species within 10 percent of other codominants)	Layer portion of Association name will be occupied by codominant species names--separated by hyphens. Where distinct synusia within a layer <i>characterize</i> an Association, they should be dealt with as codominants. A maximum of three codominants will be used for any layer.	'Ohi'a-Koa/Hapu'u pulu Association Pukiawe-A'alii Association
Sparse overstory layer-ecologically significant, but insufficient cover to define a Formation (10-25 pct cover) ¹	Include sparse layer parenthetically after the Association name.	Guava/Kikuyu Grass (Koa) Association
	Latin as against common name	
Local usage	Use common names if available for Associations and Series.	Guava/Kikuyu Grass (Koa) Association Kiawe Series
Official correspondence outside of administrative region, community documentation, scientific reports, or other	Use Latin or scientific names for Associations and Series.	<i>Psidium guajava</i> / <i>Pennisetum clandestinum</i> (<i>Acacia koa</i>) Association <i>Prosopis pallida</i> Series

¹For overstory layers, these situations will carry over to the Series level. Series names should be developed accordingly; for example, Guava (Koa) Series.

identified. These can be identified only after plant distribution patterns and their associated environmental settings are carefully evaluated. Resource managers and researchers should work together in this process.

Direct application of the system carries no ecological connotations, nevertheless ecological science can be applied to identify and name plant communities.

The best way to develop an understanding of vegetation resource status and potential in Hawaii is to start with an accurate description of the vegetation that currently exists. This description should be at a level of precision that is sensitive to development trends and successional events. From this level, the interrelationships between vegetation and environmental controls can be evaluated for an understanding of vegetation dynamics as related to site development. This system of classification provides a means for developing such a

description and for translating the picture of vegetation dynamics into resource management terms.

When Associations are identified, for example, their successional status should eventually be determined. Knowledge of the potential of a site has practical applications in local resource management and land-use decisionmaking. This system of classification provides a plant community framework that can be used to describe the successional pathway or set of alternative pathways that a site can follow. Such a description can help a manager to make reasonable decisions for allocating use of the site. An increased emphasis on managing koa for wildlife and wood products, for example, may bring about a response to increase production of koa in Hawaii. Knowledge of sites that have high potential for koa productivity will help to avoid fruitless attempts to force koa growth on marginal sites.

GLOSSARY

Broadleaf--Refers to all angiosperms with leaves that are *not* needlelike or scalelike. For this vegetation classification system, trees and shrubs that are *not* gymnosperms will be considered broad-leaved.

Canopy--The aggregate of tree and shrub crowns that provide a layer of cover; most often used in reference to tree crowns that provide an "overhead" canopy.

Closed forest--Generally, a unit of vegetation with overstory trees whose crowns are mostly touching. Plant communities with trees having a crown cover of 60 percent or more are considered closed forests.

Codominance-- Refers to a combination of two or more species that share dominance in the same vegetation layer (see Dominance). These species must contribute to a crown cover within plus or minus 10 percent of each other.

Crown cover--The vertical projection of a tree or shrub crown perimeter to the ground.

Cryptogam--A group of primitive plants such as mosses, club mosses, lichens, and ferns that do not produce true flowers or seeds.

D.b.h.--Diameter-at-breast-height. The diameter of a tree trunk at 1.3 m above the ground.

Dicotyledon --Trees of the class Angiospermae whose seeds contain two cotyledons.

Dominance-- Refers to the plant species providing the greatest crown cover in any vegetative layer.

Forb--A broad-leaved herbaceous plant.

Graminoid--Narrow leaved monocotyledonous plants of the families Graminaeae, Cyperaceae, and Juncaceae (excluding bamboos); grass-like plants.

Gymnosperm--Trees with seeds usually borne on the upper side of open scales that are often produced in cones. Includes all trees in the class Gymnospermae.

Herbaceous--Herblike or composed of herbs-plants with soft green leaves and no woody tissue.

Monocotyledon-- Trees of the class Angiospermae whose seeds contain a single cotyledon.

Overstory--The taller plants within a vegetation type, forming the upper layer of canopy cover.

Physiognomy--The characteristic structure of vegetation, apart from land form.

Shrub--A low-branching woody perennial, usually less than 5 m tall, and often having several main stems arising from a central point in the root system.

Synusia--A structural vegetative unit often made up of several species, characterized by relative uniformity of life form. It may be a layer within the physiognomic profile of a community, or it may be a life form type within a layer (for example, epiphytes growing within an overstory layer).

Tree-- A woody plant that usually has an erect perennial stem or trunk at least 7.5 cm d.b.h. and a total height of at least 5 m.

Woodland--A unit of vegetation dominated by trees whose crowns generally are not touching. Plant communities with trees having a crown cover of 25 to 60 percent are considered woodlands.

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A classification system for use in describing vegetation has been developed for Hawaii. Physiognomic and taxonomic criteria are used for a hierarchical stratification of vegetation in which the system categories are Formation, Subformation, Series, Association, and Phase. The System applies to local resource management activities and serves as a framework for resource assessment reporting as it relates to vegetation. Although developed for Hawaii, the system can be applied to other Pacific islands.

Retrieval Terms: vegetation types, plant communities, classification, Hawaii, vegetation classification, tropical forestry, island forestry